Infectious Disease Outbreaks Related to Drinking Water in Canada, 1974-2001

Corinne J. Schuster, PhD[1]
Andrea G. Ellis, MSc[2]
William J. Robertson, MSc[3]
Dominique F. Charron, PhD[2]
Jeff J. Aramini, PhD[2]
Barbara J. Marshall, BASc[4]
Diane T. Medeiros, MSc[3]

ABSTRACT

Background: Recent public attention on drinking water supplies in the aftermath of waterborne infection outbreaks in Walkerton and North Battleford raises questions about safety. We analyzed information on waterborne outbreaks occurring between 1974 and 2001 in order to identify apparent trends, review the current status of monitoring and reporting, and gain a better understanding of the impact of drinking water quality on public health and disease burden.

Methods: Data from outbreak investigations, published and unpublished, were categorized by the type of drinking water provider and were assessed to be definitely, probably or possibly waterborne in nature.

Results: The final data set consisted of 288 outbreaks of disease linked to a drinking water source. There were 99 outbreaks in public water systems, 138 outbreaks in semi-public systems and 51 outbreaks in private systems. The main known causative agents of waterborne disease outbreaks were (in descending frequency of occurrence) *Giardia, Campylobacter, Cryptosporidium,* Norwalk-like viruses, *Salmonella* and hepatitis A virus.

Summary: We found that severe weather, close proximity to animal populations, treatment system malfunctions, poor maintenance and treatment practices were associated with the reported disease outbreaks resulting from drinking water supplies. However, issues related to the accuracy, co-ordination, compatibility and detail of data exist. A systematic and coordinated national surveillance system for comparison purposes, trend identification and policy development is needed so that future waterborne disease outbreaks can be avoided.

MeSH terms: Pathogens; disease outbreaks; drinking water; surveillance

La traduction du résumé se trouve à la fin de l'article.

1. Consultant, HPRP Project 045032, University of Guelph, Guelph, ON
2. Public Health Agency of Canada, Foodborne, Waterborne, and Zoonotic Infections
3. Health Canada, Water Quality and Health Bureau
4. Public Health Agency of Canada, Laboratory for Foodborne Zoonoses

Correspondence: Corinne Schuster, 323 Oprington Place, Kitchener, ON N2N 3P3, Tel: 519-568-8070, E-mail: ac.wallace@sympatico.ca

Reprint requests: Dominique Charron, Foodborne, Waterborne, and Zoonotic Infections Division, Health Canada, 160 Research Lane, Suite 206, Guelph, ON N1G 5B2, Tel: 519-826-2173, E-mail: Dominique_Charron@phac-aspc.gc.ca

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The objective of this study is to present data on Canadian waterborne disease outbreaks in order to gain a better understanding of the impact of drinking water quality on public health and disease burden. In this report, we summarize currently available data on waterborne outbreaks in Canada from 1974-2001 in order to identify the contributing factors associated with waterborne disease outbreaks. The summary includes information on outbreaks related to public and private water supplies that occurred during this period, for which we were able to locate sufficient information for the analysis.

Surveillance of outbreaks of disease related to drinking water in Canada is not conducted in a nationally standardized manner. Laboratory-confirmed cases of most waterborne pathogens are notifiable on a provincial/territorial and national level, but reporting on the source of the infection is not mandatory. Many outbreaks of disease are linked epidemiologically to a drinking water source without laboratory confirmation of infection in the affected people.[1] As a result, data on infectious disease outbreaks related to drinking water in Canada are erratic, not easily accessible and kept in diverse locations and formats in local health units or in the health departments of the provinces/territories. Many outbreak reports are not disseminated or reported beyond the regional authority. Methods for the reporting of outbreaks and for drinking water management vary across the provinces and territories. Additionally, drinking water-related disease outbreak data may not easily be comparable between jurisdictions due to variations in detection methods, diagnostic test specificity and sensitivity, and reporting issues.

Enteric diseases are widely under-reported because of the frequency of generally mild symptoms, illnesses of short duration, reasons of squeamishness or modesty, self-medication using non-prescription products for mild symptoms rather than attending a physician, and the absence of laboratory diagnosis even when attending a physician. Assessing the true scope of the problem is further hindered by the occurrence of asymptomatic infections (e.g., many infections of giardiasis[2]). A Canadian study estimates over 300 cases of infectious acute gastrointestinal illness occur in the

community for every laboratory-confirmed case reported to provincial public health authorities.[3]

METHODS

This paper is based upon a summary of available data on waterborne disease outbreaks in Canada between 1974 and 2001. The data consist of outbreaks from two main sources: Health Canada's summary reports[4] and the Québec health reports.[5] This was augmented by an extensive review of the literature. The quality of data derived from documents from other sources found in the public domain and pertaining to outbreaks that were not already included in the data set were verified by contacting individuals such as members of the Federal-Provincial-Territorial Committee on Drinking Water and local public health officers.

For the purposes of this study, an *outbreak* was defined as an incident in which more than two cases of illness occur after the ingestion of water from the same potable source;[4] and a *case* of waterborne disease was considered to be a person with symptoms of disease linked epidemiologically, by laboratory analysis, or through a hazard in the water, to a contaminated drinking water source. An outbreak of disease was included in the dataset providing that there was enough information to determine that the illness was not associated with recreational water activities and that it was not a result of individuals knowingly consuming non-potable water, e.g., camping away from access to treated water. Further, information on the number of cases was required in order to define it as an outbreak. The remaining outbreaks were categorized based on available epidemiological and microbiological information as definitely, probably or possibly waterborne in nature (Table I).

Data were categorized by water supply type: public (municipal), semi-public (privately owned systems providing drinking water to the visiting general public), and private (systems providing drinking water to the individuals owning the system and their guests). The data did not allow for classification based on type of treatment, ground versus surface source water, or other perhaps more useful categories. Data on the water system or the location of the outbreak were generally provided, whereas population served by the system and treatment information were not always given.

Information on the agent responsible for the outbreak was extracted from the original documentation, which did not always include a laboratory-confirmed pathogen. In other cases, the investigation identified multiple pathogens.

Outbreaks occurring between March and May were defined as spring outbreaks; between June and August as summer outbreaks; between September and November as fall outbreaks and between December and February as winter outbreaks. For a few outbreaks, season rather than date of onset was the only temporal data provided.

Causative factors and barrier failures were extracted, where available, from the outbreak documentation. Most documentation did not contain any information on antecedent causes or predisposing circumstances of an outbreak. We provide a description of the data extracted from what was available, while recognizing that some of the terminology in these documents is vague.

TABLE I

Basis for Categorizing the Waterborne Nature of Outbreaks[6,7]

Definitely waterborne	Adequate epidemiological evidence of a contaminated drinking water source with or without microbiological proof.
Probably waterborne	Disease in the presence of infectious hazard in drinking water (see below), without adequate epidemiological evidence nor microbiological proof. Infectious hazards included: • confirmed potable water contamination • suboptimal potable water microbiological, physical or chemical parameters • treatment or compliance failures • high levels of contamination in raw water.
Possibly waterborne	A pathogen that is sometimes waterborne has been isolated from a case linked to an outbreak. No specific infectious hazard identified in the drinking water. Neither adequate epidemiological evidence nor microbiological proof of a drinking water source.

TABLE II

Outbreaks Categorized by Type of Drinking Water System and by Strength of Evidence of a Waterborne Source

	Public	Semi-public	Private	Total
Definitely waterborne	59 (60%*)	28 (20%)	12 (24%)	99
Probably waterborne	17 (17%)	25 (18%)	19 (37%)	61
Possibly waterborne	23 (23%)	85 (62%)	20 (39%)	128
Total	99	138	51	288

* The percentages in parentheses refer to the bottom total – that is, for each type of drinking water system, the proportion of outbreaks that were definitely, probably or possibly waterborne.

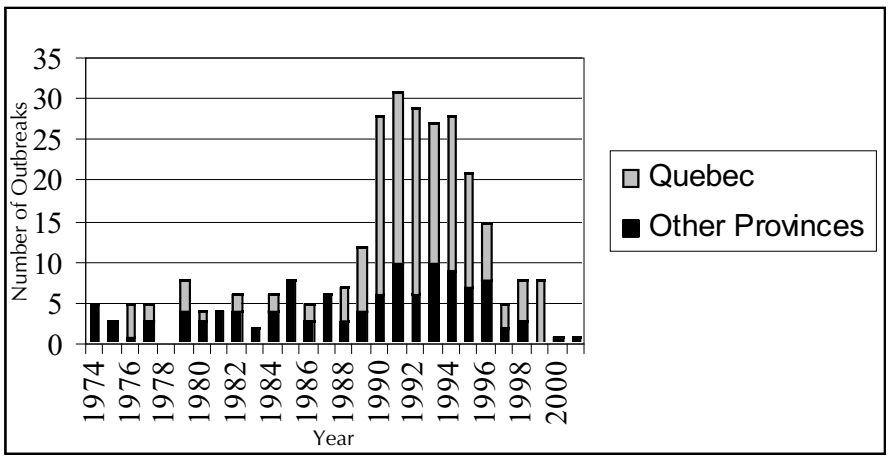

Figure 1. Number of outbreaks by year; also demonstrating the effect of enhanced surveillance in Québec through the INSPQ

RESULTS

The final data set consisted of 288 outbreaks of disease linked to a drinking water source (Table II). Almost half of the outbreaks were reported in semi-public sys-

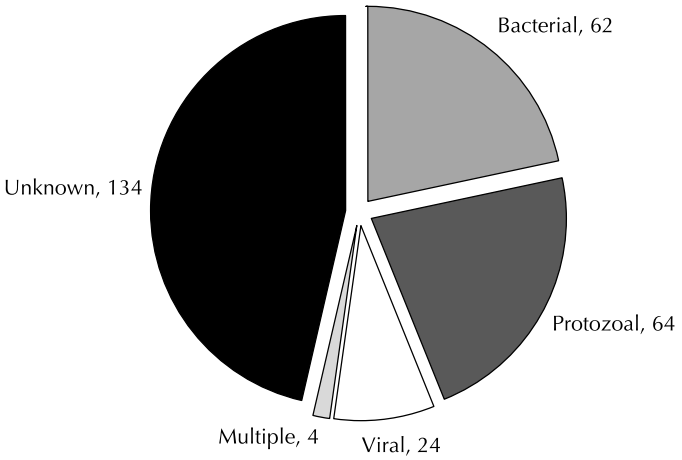

Figure 2a. Types of pathogens identified in outbreaks 1974-2001

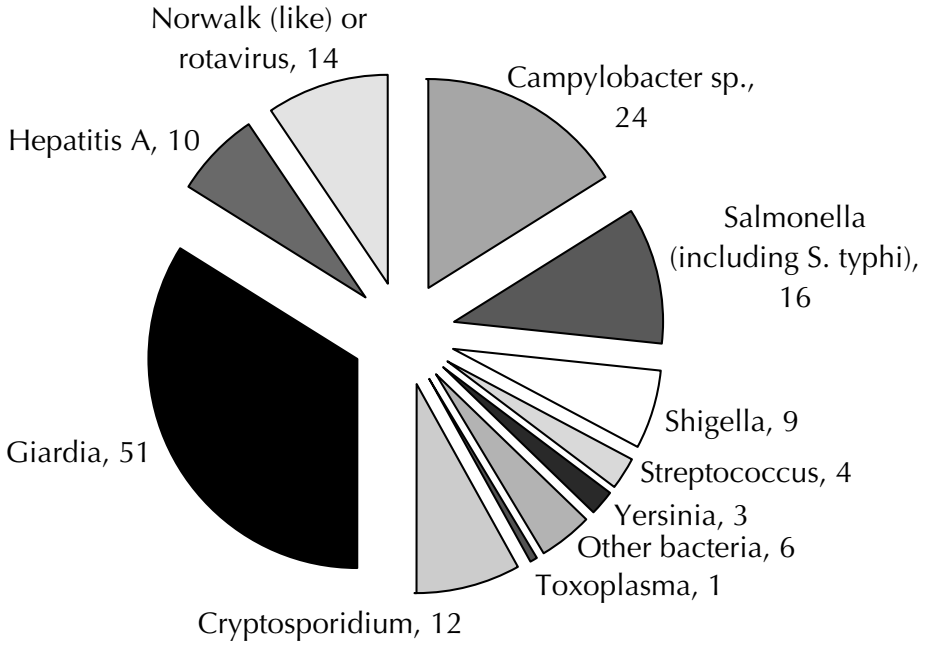

Figure 2b. In outbreaks where a single pathogen was identified (n=150), distribution of pathogens with number of outbreaks attributed to each pathogen shown (other bacteria include: *Aeromonas hydrophilia, Bacillus cereus, Enterobacter hafniae, pathogenic E. coli, Pseudomonas spp. Staphylococcus aureus*)

tems, followed by 99 (34%) in public systems and 51 (18%) in private systems. Over one third of all outbreaks were categorized as definitely waterborne based on adequate epidemiological evidence in the available documentation. Another 61 outbreaks (21%) were categorized as probably waterborne, while 128 of the outbreaks (44%) could only be categorized as possibly waterborne, based on the available information. Of the outbreaks categorized as definitely waterborne, most were in public systems. Outbreaks in semi-public, and to a greater extent in private systems, were less likely to be categorized as definitely waterborne.

The annual totals for all outbreaks were highest during the period 1989 to 1996 (Figure 1). Of the 288 outbreaks, 194 (67%) were reported during this period. The large increase in 1991 is presumed mainly to be a result of the in-depth reporting by INSPQ, which started its publications in 1991.[5]

Pathogens

The pathogen responsible for a given outbreak was unknown in 134 (47%) of the outbreaks. In the remaining outbreaks, the most commonly reported causative agent was *Giardia lamblia*, in 51 outbreaks. *Campylobacter* was the next most common cause (24 outbreaks), and *Cryptosporidium*, hepatitis A, Norwalk-like viruses and *Salmonella* each accounted for 10 or more outbreaks (Figures 2a and 2b). Four of the outbreaks were the result of infection involving more than one pathogen (e.g., Walkerton, Ontario[8]). The majority of outbreaks in semi-public and private systems had not documented a particular pathogenic source of the outbreak. In outbreaks in public water systems, the documentation more often included information on a laboratory-confirmed pathogen.

Causative factors

For the majority of outbreaks, the accompanying documentation contained information on circumstances or barrier failures that were considered by the investigators of the outbreak to have contributed to the outbreak. For this analysis, these data were grouped into 10 categories (Table III).

In some cases, several factors were documented as having contributed to the outbreak. The outbreak in Walkerton, Ontario (2000) was a good example of multiple factors clustered in time and space causing a major disease outbreak. There, the combination of heavy rainfall, an insecure well, the presence of pathogenic bacteria in the environment, inadequate water treatment and human error all culminated in the outbreak.[8] Of the 288 outbreaks documented here, 223 of them documented a single contributing factor or circumstance. In 9 outbreaks, more than three contributing factors were documented.

Issues with the water treatment process and the need for more stringent or enhanced treatment techniques were reasons most frequently cited in outbreak reports as contributing to the occurrence of an outbreak.

Seasonality

In all three water system categories, the majority of outbreaks occurred in the spring and summer seasons (79 and 93 outbreaks, respectively). Failures or inadequacies in water treatment did not display a seasonal pattern in any of the water system categories. Meteorological conditions or specific weather events were most often

implicated in spring. Several outbreaks occurring in public systems in summer were also attributed at least in part to weather events.

DISCUSSION

In presenting data on Canadian waterborne disease outbreaks in order to gain a better understanding of the impact of drinking water quality on public health and disease burden, this study highlights the wide range in data quality available for historical waterborne disease outbreaks in Canada. Generally, the quality of existing information associated with waterborne disease outbreaks is inadequate. Basic information is often missing on the precise date and location of the outbreak, the number ill, the population at risk, and the source. However, there appear to be some periods in some provinces and some particular outbreaks where data are more complete. The Health Canada Summary Reports clearly illustrate how little information is available for waterborne outbreaks relative to that available for foodborne disease outbreaks. Outbreaks linked to public drinking water systems are generally more thoroughly documented, as are those affecting large numbers of people. However, there is no consistent requirement for reporting or report format. Each province/territory has evolved distinct surveillance systems and priorities that affect the number of outbreaks captured, the level of detail of the reports, and the types of pathogens that may be identified. The data available for this review suggest some trends in the occurrence of waterborne disease outbreaks, most of which are consistent with findings from other developed countries.[9] However, there is a lack of follow through in many of the outbreak investigations documented here, including details of the scope of the outbreaks, and the quality of evidence used to implicate drinking water and identify the causes of contamination. Thus, a detailed assessment of the burden of waterborne disease to Canadians, or of contributing factors, could not be done.

Improvements to the current data could be achieved through the implementation of a nationally standardized surveillance system and the provision of epidemiological training to improve the quality of the information obtained during outbreak investigations.

TABLE III

Factors Contributing to Waterborne Disease Outbreaks*

Causative Factor	Public	Semi-Public	Private	Total
Weather Events				
Heavy rainfall	6	0	3	9
Drought	1	1	0	2
Flood	1	0	1	2
Spring runoff	8	1	1	10
Snow melt	1	0	0	1
Animals				
Wildlife	31	2	1	34
Livestock	6	2	0	8
Frozen wastes	2	0	0	2
Agriculture	4	0	1	5
People				
Septic tanks	1	13	7	21
Sewage	8	4	1	13
Cess pool	0	0	1	1
Non-specific Contamination†	6	45	14	65
Water Treatment Issues	34	11	2	47
Human				
Human source	1	0	0	1
Human error	4	2	0	6
Recommendations ignored	4	0	0	4
Sanitation	1	3	1	5
Communication	0	1	0	1
No community resistance to pathogen	1	0	0	1
Legislation/Enhanced Treatment Techniques‡	34	10	5	49
GWUDI§	3	5	1	9
Water Recycling	0	0	1	1

* Some outbreaks were associated with multiple causative factors
† Faecal coliforms were identified as being present, but the exact source was unknown
‡ If legislation had been in place or enhanced treatment technologies used (e.g., filtration), the outbreak would not have occurred
§ Groundwater under direct influence of surface water

Examination of the distribution of outbreaks between definitely, probably and possibly waterborne in nature highlights the problems associated with the existing data set. Almost two thirds of outbreaks could not be categorized as definitely waterborne based on the available documentation. When taken by water system type, the number of possible outbreaks increased through semi-public and private systems. Often investigators do not have enough information to be able to identify whether an outbreak definitely results from a drinking water source. Evidence of the contamination can be hard to find, as the illness may not occur until after the contamination has been cleared from the drinking water system, either naturally or through treatment or repair. The incubation period of some pathogens may be quite long, delaying the onset of illness and hindering the identification of the source. In many instances, once it is confirmed that there are faecal indicator bacteria present in the water, the investigation is terminated with a presumptive waterborne source, and laboratory investigations of the pathogen responsible for the illness are not pursued. This is not a problem solely with Canadian data. Many developed countries report the need for enhanced resources and expertise to improve outbreak investigations and thus the quality of the information gathered.[10]

It appears that waterborne disease outbreaks in Canada follow a seasonal distribution, with a peak in spring/summer. Spring melt events can provide concentrated, pathogen-rich runoff to streams and rivers. Increased overland flow events resulting from melt and rainfall events in spring and sporadic, intense rainfall events separated by dry conditions in summer may, in part, explain the seasonal increases of illness in those seasons. However, the prevalence of a pathogen in the environment and its presence in the water supply do not necessarily lead to an identifiable outbreak of disease.

Our examination of the documented contributing factors to waterborne outbreaks found frequent mention of water treatment failures due to system maintenance or equipment failure. Extreme weather events were also frequently documented contributors to waterborne disease outbreaks. Weather events tend to exacerbate underlying vulnerabilities created by inadequate water protection, for example heavy rainfall leading to increased turbidity

in the absence of a requirement for filtration.

Water regulation should include measures to protect the watershed and the drinking water distribution system, as well as to reduce the risk of waterborne disease and improve the response to outbreaks that may still occur. Initiatives are being implemented to attain these goals. For example, a majority of the provinces and territories have adopted, or are moving toward the adoption of (all or part of) the Guidelines for Canadian Drinking Water Quality.[11]

General awareness of the vulnerability of drinking water supplies and the impact that waterborne disease outbreaks can have has increased significantly during the study period. It is hoped that improving the quality of waterborne disease reporting will provide policy-makers with the information needed to identify risks and assess the impact of water safety regulations to ensure safe drinking water for Canadians.

REFERENCES

1. Rothman KJ, Greenland S. Causation and causal inference. In: Rothman KJ, Greenland S (Eds.), *Modern Epidemiology,* 2nd Edition. Philadelphia, PA: Lippincott, Williams and Wilkins, 1998.
2. Wallis PM. *Risk Assessment for Waterborne Giardiasis and Cryptosporidiosis in Canada*. 1995. Final Report. Project No. K221366-1.
3. Flint JA, Doré K, Majowicz SE, Edge VL, Sockett P. From stool to statistics: Reporting of acute gastrointestinal illnesses in Canada. *Can J Public Health* 2004;95(4):309-13.
4. Todd E. Foodborne and Waterborne Disease in Canada, annual summaries. Health Protection Branch, Health Canada. 1974-2001.
5. Institut national de santé publique du Québec. *Bilan des éclosions de malades d'origine hydrique signalées dans les directions régionales de la santé publique de Québec*. 2001; 2000; 1998; 1994; 1991.
6. Furtado C, Adak GK, Stuart JM, Wall PG, Evans HS,Casemore DP. Outbreaks of waterborne infectious intestinal disease in England and Wales, 1992-5. *Epidemiol Infect* 1998;121:109-19.
7. Nazareth B, Stanwell-Smith RE, Rowland MGM, O'Mahony MC. Surveillance of waterborne disease in England and Wales. *Communicable Disease Report* 1994;4(8):R93-R96.
8. Bruce Grey Owen Sound Health Unit. *The Investigative Report of the Walkerton Outbreak of Waterborne Gastroenteritis, May-June 2000*. 2000 http://www.publichealthgreybruce.on.ca/_private/Report/ (Accessed March 2004).
9. Hrudey SE, Hrudey EJ. *Safe Drinking Water: Lessons from Recent Outbreaks in Affluent Nations.* London, ON: IWA Publishing, 2004;486.
10. Lee SH, Levy DA, Craun GF, Beach MJ, Calderon RL. Surveillance for Water-borne Disease Outbreaks – United States, 1999-2000. *Surveillance Summaries* November 22nd, 2002. *MMWR* 2002;51;No SS-8 http://www.cdc.gov/mmwr/PDF/ss/ss5108.pdf (Accessed May 2004).
11. Health Canada. *Guidelines for Canadian Drinking Water Quality,* 6th Edition, 1996.

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RÉSUMÉ

Introduction : Les éclosions récentes d'infections d'origine hydrique à Walkerton et à North Battleford ont galvanisé l'attention publique sur la qualité des réserves d'eau potable. Nous avons analysé des renseignements sur les éclosions d'origine hydrique ayant eu lieu au Canada entre 1974 et 2001 afin de dégager des tendances, de réexaminer le niveau de déclaration et d'accroître notre compréhension de l'impact de la qualité de l'eau potable sur le fardeau des maladies d'origine hydrique à l'échelle nationale.

Méthode : Nous avons rassemblé des données d'enquêtes sur des éclosions d'origine hydrique à partir de sources publiées et non publiées recueillies auprès de professionnels de la santé publique au Canada. Nous avons catégorisé les données selon le type de service d'eau potable (public ou non). En tenant compte de la valeur probante des données disponibles, nous avons aussi catégorisé les éclosions selon notre certitude d'une origine hydrique (possible, probable ou certaine).

Résultats : En tout, 288 éclosions de maladies ont été reliées à une source d'eau potable. Il y a eu 99 éclosions associées aux systèmes publics d'eau, 138 aux systèmes parapublics, et 51 aux systèmes privés. Les causes infectieuses connues (en ordre de fréquence) étaient *Giardia, Campylobacter, Cryptosporidium,* les norovirus, *Salmonella* et le virus de l'hépatite A.

Discussion : Nous avons constaté que les conditions météorologiques, la proximité de populations animales, le mauvais fonctionnement du système de traitement et les carences dans les pratiques de traitement ou d'entretien étaient associés aux éclosions provenant de réserves d'eau potable. Notre recherche soulève plusieurs questions rattachées à l'exactitude, à la comparabilité, au niveau de détail et à la coordination des données. Un système de surveillance national, systématique et coordonné permettrait de mieux dégager des tendances et d'effectuer des comparaisons d'une province ou d'un territoire à l'autre, et appuierait l'élaboration d'interventions visant à alléger le fardeau des maladies d'origine hydrique.

ERRATUM

In the May/June 2005 issue of the *Canadian Journal of Public Health* (Vol.96, No.3, page 236), the legends in Figures 1 and 2 of "Changes in maternal characteristics in Nova Scotia, Canada from 1988 to 2001" were incorrect.

In the legend for Figure 1, on both graphs, the second time period should read "1998-2001" instead of "1988-2001".

In Figure 2, the final category in the legend should read "Pre-pregnancy weight 90+ kg" instead of "Pre-pregnancy weight gain 90+ kg".

We sincerely regret any inconvenience these errors may have caused.