The Status of Drinking Water in Ontario, Canada (1992-1999)

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ABSTRACT

Objective: This study was conducted to investigate the characteristics of public water works (PWW) in southern Ontario with respect to their water sources and treatment regimes.

Methods: Data from 481 PWW covering the period 1992-1999 were collected and cartographic manipulations as well as descriptive analyses of the PWW attributes were performed. Tests of associations between different PWW attributes were done using Fisher's Exact test and Cochran-Mantel-Haenszel statistics.

Results: Water sources for the PWW included surface water (SW) (21% lakes; 13% rivers), ground water (GW) (64%) and mixed sources (2%). Most (81%) of the population was supplied with SW. Filtration was performed by 84% and 8% of the PWW using SW and GW, respectively. Similarly, disinfection was performed by 99% and 91% of the PWW using SW and GW respectively. There was no significant difference in treatment regimes between PWW in urban and those in rural areas but treatment regime was a function of water source. Overall, most PWW (87.8%) met the minimum treatment requirements of the then Ontario Drinking Water Objectives (ODWO).

Discussion: The study shows that most PWW complied with the minimum treatment requirements of the then ODWO.¹ The minimum treatment required by the ODWO was disinfection for GW and both disinfection and filtration for SW. The non-compliant PWW will need to comply for continued provision of safe drinking water. Suffice it to say that both watershed protection and improved water treatment will be imperative for the continued provision of safe drinking water and control of waterborne diseases.

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

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Safe drinking water continues to be a subject of concern for many Canadians.²⁻⁶ The quality of drinking water depends on the source and treatment process. If the sources are not adequately protected, contamination by pathogenic organisms may result.^{7,8} Improper treatment may lead to adverse exposure of the population to pathogenic organisms, and accompanying health risks. Moreover, chlorination alone does not provide adequate protection against all waterborne diseases since a significant proportion of cases may be due to protozoa (e.g., *Cryptosporidium*) that are resistant to normally acceptable levels of chlorine.⁹

In Ontario until recently, there have been no laws governing treatment of drinking water by public water works (PWW).^{10,11} Drinking water quality standards were based only on guidelines, which were not legally binding and yet drinking water has been a source of major outbreaks of gastrointestinal infections in Canada.¹ Examples include outbreaks of *E.coli* O157:H7 in Walkerton, Ontario³ as well as the cryptosporidiosis outbreaks in Cranbrook and Kelowna, British Columbia⁸ and North Battleford, Saskatchewan.¹² These incidences have aroused much interest in the quality of drinking water. This study was conducted to investigate the characteristics of PWW in southern Ontario with respect to their water sources and treatment regimes in order to assess the proportion of PWW not meeting the minimum water treatment requirements of the Ontario Drinking Water Objectives (ODWO).¹ In Ontario, a PWW is any water works capable of supplying water at a rate greater than 50,000 litres per day and serves more than five private residences.¹

METHOD

Data collection

A database containing water attribute and distribution information from 481 PWW in Ontario was compiled for the years 1992-1999. Attribute data, including water sources, treatment regimes and population served by each PWW during 1999, were obtained from the Ontario Ministry of the Environment and Energy. Attribute data for the years 1992-1998 were collected from each PWW. Maps showing water distribution areas of each PWW were obtained from municipalities. All the maps were digitized using CanMap 2.0 (Desktop Mapping

Figure 1. Spatial distribution of Ontario's water distribution areas shown by water source (1999)

Technologies, Markham, Ontario). CanMap data use the 1983 North American Datum (NAD 83) and contain streets, water bodies, and administrative boundaries. These were used as visual guides for on-screen digitizing of water distribution areas.

Data analysis

Cartographic manipulations and statistical analyses were performed in ArcView GIS¹³ and SAS,¹⁴ respectively. Tests of associations between different PWW attributes were performed using Fisher's Exact test and Cochran-Mantel-Haenszel statistics. Comparison of different water characteristics were also made between rural and urban areas. Urban areas were those with population density of at least 400 persons/km² and a minimum of 1,000 persons.¹⁵

RESULTS

General PWW characteristics

The study included 481 PWW supplying water to approximately 6.5 million people. There were no major changes in the water treatment attributes from 1992 to 1999.

Only 7% of the PWW made changes in water treatment regimes of which only 4% were positive (e.g., from 'no filtration' to 'filtration'). Since there were very few changes, all subsequent results refer to the latest year (1999). Figure 1 shows the spatial distribution of the water distribution areas by water source.

Of the PWW with data on ownership (378), 97% were owned by municipalities, 2.4% by the provincial government and the rest by the Ontario Clean Water Association (OCWA). Of the municipally owned PWW, 85% were operated by the municipalities themselves, 12% by OCWA and 3% by private individuals/companies. Eight of the PWW owned by the province were operated by the OCWA and one by a municipality. The OCWA operated both of the plants they owned. Controlling for water source, there was no association ($p=0.252$) between PWW operator and treatment regime. All the PWW that performed disinfection used chlorine. Therefore, disinfection and chlorination are used interchangeably subsequently. Most plants, irrespective of the operator,

performed disinfection, with 86%, 91% and 100% of PWW operated by private individuals, municipalities and OCWA respectively, performing disinfection. Similarly, 38%, 26%, and 51% of PWW operated by private individuals, municipalities and OCWA respectively, performed filtration.

Water sources from lakes and rivers were classified as surface water (SW) whereas ground water (GW) was from wells. The PWW in rural areas mainly used GW and served a smaller proportion of the population. However, the urban systems used the two water sources in almost equal proportions (54.6% GW; 43.1% SW; 2.3% Mixed). Significantly ($p<0.0001$) more PWW (42.2%) carried out filtration in the urban areas than in rural areas (20.8%). However, this association became non-significant ($p=0.694$) after controlling for water source. The proportion of PWW in rural areas that carried out disinfection was high (92.7%) but significantly ($p=0.045$) lower than in urban areas (94.9%). Again, this association was non-significant ($p=0.563$) after controlling for water

TABLE I

Attributes of Southern Ontario's Public Water Works Using Surface Water and Proportion of Population they Served (1999)

Water Treatment Plant Attribute		No. of PWW*	% PWW* under SW†	% of all PWW*	Median Population	% of Population under SW†	% of Total Population
All Plants using Surface Water		161	100%	33.5	2928	100	81.1
Source of Water:	Lakes	100	62.1	20.8	3500	81.7	66.3
	Rivers	61	37.9	12.7	2400	18.3	14.9
Coagulation:	Yes	127	78.9	26.4	4600	97.8	79.4
	No	34	21.1	7.1	1217	2.2	1.7
Flocculation:	Yes	124	77	26.8	4400	96.8	78.5
	No	37	23	7.7	1400	3.2	2.6
Filtration:	Yes	135	83.9	28.1	3997	98.3	80.0
	No	26	16.1	5.4	1217	1.7	1.4
Pre-chlorination: (For PWWs that filtered)	Yes	107	66.5	22.2	5000	91.9	74.8
	No	28	17.4	5.8	1456	6.4	5.2
Disinfection: (Chlorination/post-chlorination)	Yes	160	99.4	33.3	2957	99.97	79.98
	No	1	0.62	0.2	1456	0.03	0.02
Form of chlorine:	Gas	103	64.4	21.4	5000	86.3	70.0
	Hypochlorite	57	35.6	11.9	650	13.7	11.1
De-chlorination:	Yes	7	4.4	1.5	72,500	56.2	45.5
	No	153	95.6	31.9	2900	43.8	35.6

* Public water works

† Surface water

TABLE II

Attributes of Southern Ontario's Public Water Works Using Ground Water and Proportion of Population they Served (1999)

Water Treatment Plant Attribute		No. of PWW*	% PWW* under GW†	% of all PWW*	Median Population	% of Population under GW†	% of Total Population
All plants using ground water		306	100	63.6	551	100	13.6
Coagulation:	Yes	4	1.3	0.8	350	0.2	0.03
	No	300	98.7	62.4	554	99.8	13.6
Flocculation:	Yes	5	1.6	1	500	0.7	0.1
	No	299	98.4	62.1	553	99.3	13.5
Filtration:	Yes	24	7.9	5	500	5.9	0.8
	No	280	92.1	58.2	570	94.1	12.8
Pre-chlorination: (For PWWs that filtered)	Yes	9	2.9	1.9	908	1.5	0.2
	No	16	5.0	3.1	485	4.4	0.6
Disinfection: (Chlorination)	Yes	277	91.1	57.6	546	96.7	13.1
	Partial	1	0.3	0.2	123	0.1	< 0.01
Form of chlorine:	No	26	8.6	5.4	950	3.2	0.44
	Gas	25	8.3	5.2	4500	33.9	4.5
De-chlorination:	Hypochlorite	251	83.7	52.2	500	66.1	8.7
	Yes	2	0.7	0.4	140	0.1	< 0.01
	No	302	99.3	62.8	554	99.9	13.6

* Public water works

† Ground water

source. A total of 12.2% of the plants did not meet the minimum water treatment requirements of the ODWO guidelines. Of these, 6.2% used SW and 6% used GW (Figure 2). The ODWO minimum water treatment requirement was disinfection for GW and both disinfection and filtration for SW.¹

There was a significant association ($p < 0.0001$) between water source and filtration even after controlling for URBAN/RURAL status. A similar result was obtained for the association between water source and disinfection ($p = 0.011$) after controlling for URBAN/RURAL status. All PWW in rural areas that used SW and most (99%) of those using SW in the urban areas performed chlorination. The remaining 1% did not use any alternative treatments.

Surface Water Systems

The characteristics of the PWW using SW are shown in Table I and Figure 2. Thirty-four percent of the PWW serving 81% of the population used SW (Figure 2). Although only 27.8% of the PWW using SW performed both filtration and disinfection, they supplied the majority (79.98%) of the population (Figure 2). Up to 66.5% of the PWW that used SW and filtered also performed pre-chlorination (Table I).

Ground Water Systems

Only 14% of the population was supplied with GW (Table II and Figure 2). The majority (91%) of systems that used GW performed disinfection. However, only about 5% of the PWW using GW performed both filtration and chlorination.

Mixed Water Systems

These were PWW that used both SW and GW. Most (75%) of these PWW were in urban areas. They comprised 2% of all PWW and served 5% of the population (Figure 2). They all performed disinfection whereas 77.8% performed filtration.

DISCUSSION

The minimum ODWO water treatment requirements during the study period were disinfection for GW and both disinfection and filtration for SW.¹ The study shows that most of the population was supplied with water meeting these treatment requirements and that the treatment regime was more a function of water source than of either the operator or the location of the PWW. Almost all (99.4%)

Figure 2. Characteristics of public water works in Ontario

of the PWW using SW and most (91%) of those using GW performed chlorination.

Although as much as 16% of the PWW that used SW did not perform filtration, they supplied water to a very small proportion of the population under SW (1.7%). However, most (58%) of the PWW that used GW (supplying 94% of the population under GW), did not filter. These figures reflect a general compliance of the PWW with the minimum drinking water treatment guidelines operating at the time.¹ A study done in the U.S. reported that unfiltered SW systems, whether chlorinated or not, may be associated with as many as 56% of all waterborne disease outbreaks in the U.S.¹⁶ In the current study, since most of the PWW that used SW performed filtration and most of those that did not filter were using GW, it implies that the risk of exposure of the population to unsafe water due to failure to filter may be minimal. However, PWW that used GW under the influence of SW and did not filter could potentially expose the population to waterborne pathogens such as *Cryptosporidium* which are resistant to chlorination. Due to unavailability of data, the study could not identify the proportion of PWW that used GW that might be

under the influence of SW. Continuous turbidity monitoring is recommended to assess if GW is under the influence of SW.

The lack of filtration in most of the PWW using GW might be due to the minimum treatment requirements operating at the time.¹ The less stringent treatment requirements for GW were based on the fact that natural purification by filtration of water through soil may occur for GW and thereby reduce the pathogen load.¹¹ However, GW may sometimes come into direct or indirect contact with SW, as happened during Walkerton's *E.coli* outbreak.⁴ In 2000 the ODWO, now called Ontario Drinking Water Standards (ODWS), was given the full force of the law.^{10,11,17} The new ODWS regulation stipulates that GW under direct influence of SW be considered as SW, and also differentiates between direct and indirect influence of SW, whereas the old guideline did not.

There is evidence that some water contaminants, such as *Cryptosporidium parvum*, cannot be removed by chlorination alone.^{18,19} Therefore, PWW may still be at risk of *Cryptosporidium* outbreaks if only chlorination is used. In addition, studies have reported that up to 43% of water-

borne disease outbreaks in the U.S. could be attributed to chlorinated, unfiltered drinking water, implying that chlorination alone may not destroy pathogens like *Cryptosporidium*.²⁰ It is also estimated that up to 31% of all waterborne disease outbreaks in the U.S. between 1981 and 1985 occurred in untreated contaminated GW that might have been under influence of SW.¹⁶ Moreover, it has been reported that sewage contamination of GW was responsible for a giardiasis outbreak in a ski resort in Colorado, U.S.¹⁶ These reports show that although properly protected GW may be safe, untreated contaminated GW or contaminated GW that has undergone an ineffective treatment process may present a significant risk to the population. There is need therefore for effective treatment of GW from sources that may not be properly protected.

Since regular sand filtration is very expensive, more affordable filtration technologies such as ultra and micro-filtration membrane systems are worth considering. Not all communities, especially those in rural areas, can afford sand filtration. In such areas, it might be worth considering additions or alterations to the water systems to use these less expensive filtration technologies. However, stricter watershed

protection will also be imperative to ensure that the raw water is of good quality to begin with.

Since up to 66.5% of the PWW that used SW and performed filtration also pre-chlorinated, it is worth mentioning that although pre-chlorination may decrease bacteria and colour loading, it also has the potential of increasing the formation of trihalomethane and destroying blue-green algae – *Microcystis aeruginosa* – thus releasing microcystin into water.²¹⁻²³ Microcystin is hepatotoxic²⁴⁻²⁶ and may be associated with increased risk of colorectal cancer.^{27,28}

Overall, the proportion of PWW that did not meet the ODWO¹ was relatively high (12.2%), and supplied 1.42% of the population. Although this proportion seems small, the actual number of people involved (almost 100,000) cannot be ignored. It is therefore important that the non-compliant PWW improve their systems to meet the ODWO treatment guidelines. The ODWS required all the then non-compliant PWW to comply by December 31, 2002. Although this study did not assess the compliance rates after this deadline, the compliance is expected to improve since the ODWS requirements currently have the full force of the law.

This study did not assess the effectiveness of the water treatment processes *per se*. Since some outbreaks (for instance, the Walkerton *E.coli* outbreak³) have occurred in treated water, detailed studies should be conducted to assess the effectiveness of the treatment process. Such studies would provide more in-depth information on areas that need improvement and would also enhance data linkages with health data, thus enhancing investigation of the association of water characteristics and population health. Suffice it to say that improved methods of watershed protection and water treatment will be imperative for the continued improvement of drinking water and control of waterborne diseases.

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RÉSUMÉ

Objectif : Étudier les caractéristiques du réseau public d'aqueducs du sud de l'Ontario en ce qui a trait aux sources d'alimentation en eau et aux méthodes de traitement des eaux.

Méthode : Nous avons recueilli les données de 481 installations publiques d'adduction d'eau pour la période 1992-1999 et effectué des manipulations cartographiques et des analyses descriptives des attributs de ces installations. Les associations entre les attributs des diverses installations ont été testées par la méthode exacte de Fisher et le test de Cochran-Mantel-Haenszel.

Résultats : Les sources d'alimentation en eau des installations publiques d'adduction d'eau étaient les eaux de surface (lacs 21 %, rivières 13 %), les eaux souterraines (64 %) et les sources mélangées (2 %). La grande majorité (81 %) de la population était desservie par les eaux de surface. Quarante et une p. cent des installations utilisant des eaux de surface faisaient de la filtration, contre 8 % des installations utilisant les eaux souterraines. Par ailleurs, 99 % des installations utilisant des eaux de surface faisaient de la désinfection, contre 91 % des installations utilisant des eaux souterraines. Il n'y avait pas d'écart significatif dans les méthodes de traitement des eaux des installations en zones urbaines et rurales : la méthode choisie dépendait de la source d'alimentation en eau. Dans l'ensemble, la plupart des installations (87,8 %) répondaient aux normes minimales de traitement fixées dans les anciens objectifs de l'Ontario en matière d'eau potable (OOEP).

Débat : L'étude montre que la plupart des installations publiques d'adduction d'eau répondent aux normes minimales de traitement des anciens OOEP, à savoir la désinfection pour les eaux souterraines et la désinfection et la filtration pour les eaux de surface. Les installations non conformes devront se mettre à niveau pour assurer la continuité de l'approvisionnement en eau potable. Contentons-nous de dire que la protection des bassins versants et l'amélioration du traitement de l'eau seront deux éléments indispensables à la continuité de l'approvisionnement en eau potable et au contrôle des maladies d'origine hydrique.