Drinking Water Supply and Management Practices in British Columbia, 1997-98

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ABSTRACT

Background: Questions regarding control over a water fluoridation system in a British Columbia (BC) community led to a drinking water management survey in 1997-98.

Method: A questionnaire was constructed based on published drinking water control and management criteria and was sent to 91 communities.

Results: 73/91 surveys were returned (80% response rate); 31 reported a protected water supply system, 40 reported logging and/or cattle grazing in watershed areas, 25 reported a lack of primary disinfection. Water fluoridation was reported in 12 locations, 3 of which did not monitor fluoride levels. Testing for protozoans was done routinely in 19 locations, 15 using approved laboratories. 15 water contamination events were reported, 9 of biological origin. Statistically significant associations were found between contamination events and: wooden delivery systems, lack of primary chlorination, increased number of protozoan tests, and increased number of personnel.

Interpretation: At the time of the survey in British Columbia, a number of communities were vulnerable to preventable drinking water contamination.

During a 1987 investigation of several Down's syndrome births, all registered within a couple of months in a small British Columbia (BC) community,¹ a number of issues became apparent. As some of these births occurred in families living a few blocks from one another and serviced by the same local water supply substation, this water supply was investigated. During investigations of this nature, one often encounters anomalies that are not necessarily related to the problem that initiated the research. In this case, it was observed that the water supply was fluoridated and the person looking after this process was a local municipal employee. This employee would take a "bucket" from "this container" and add it to a reservoir on the self-metering fluoridation system. There was no apparent display of knowledge by the employee regarding the critical concentrations and the potential toxic effects of the material that he added to the water system. The monthly fluoride concentrations recorded by the Ministry of Health, based on weekly water sample analyses, indicated levels at, or below, the 1 ppm therapeutic dose.² Upon further questioning, it became apparent that these levels were based on the concentration in pooled samples, composed from weekly samples that had accumulated. Subsequent analyses of individual daily samples indicated wide fluctuations in water fluoride levels. These observations led us to investigate in 1997-98 the type of drinking water management practices that were in use in British Columbia.

METHODS

A questionnaire was constructed based on recommended drinking water treatment, distribution, control, and maintenance practices, which are available and have been described in numerous publications.³⁻⁶ The questionnaire was tested with a local water purveyor, and corrected prior to being mailed to the water purveyors of 91 communities in BC. A self-addressed return envelope was included. Follow-up telephone calls were made to remind individuals to complete and return the questionnaires.

RESULTS

Of the 91 questionnaires sent out, 73 were returned (80% response rate). The ques-

The translation of the Abstract appears at the end of the article.

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tionnaire included a question regarding the position held by the individual who was providing the details, and it was found that in 62/73 locations, the questionnaires had been filled out by individuals who held supervisory positions.

The collective information that was obtained from the questionnaires has been summarized in Table I. Some of the main findings were that, out of the 73 locations, only 36 had a protected water supply system, 5 of which were only partially protected. A total of 40 locations reported logging and/or cattle grazing in the watershed areas. Some kind of water filtration was present in 23 locations. Primary disinfection using chlorine was present in 48 locations, and 1 location used ozone. Secondary disinfection was only present in 7 communities. Water fluoridation programs were reported in 12/73 locations, 3 of which did not check their outgoing fluoride levels. Concrete was most often used as a reservoir storage material (47 locations), followed by steel (23 locations). The material used in the water delivery system was plastic in 64 locations, followed by asbestos cement in 59 locations and lined mild steel or cast iron in 40 locations. Wood was still used in 3 locations.

Licensed operators were present in 43/73 locations and 41 of these had a licensed operator training program. Coliform testing of the water in the distribution system was done routinely in 62 locations. A total of 19/73 locations routinely tested for giardia and other protozoans, 15 used an approved laboratory, i.e., one that participated in a proficiency testing program.

Of the 18 locations that did not respond to our questionnaire, 13 had been involved in the 28 waterborne outbreaks since 1980, as registered by the Ministry of Health.⁷ Of the 15 locations with outbreaks that did respond, 9 were traced to a biological agent. These included giardia and campylobacter (1 location), giardia (2 locations), campylobacter (1 location), cryptosporidium (1 location), toxoplasma (1 location), fecal coliform (2 locations). One location reported a boil advisory for which the agent involved was not provided. Three locations provided information regarding outbreaks that the Ministry of Health was apparently not aware of, 2 of which occurred since the provincial epidemiologi-

cal reporting system came into effect in 1993.⁷

The possible statistical association between the various water management parameters reported on in Table I and the occurrence of a biological contamination event was also investigated. The statistically significant associations ($p \leq 0.05$) that were found were the use of wood in the delivery system ($p=0.0001$) although this was based on only two locations, the lack of primary chlorination ($p=0.02$), the lack of testing for chlorine byproducts 3/year ($p=0.04$), an increased frequency of testing for protozoans, and an increased number of personnel.

The average yearly maintenance costs of the water supply system ranged from a low of \$2000 to a high of \$6 million and was initiated most often by improved technology, followed by health concerns, and increased demand for capacity.

DISCUSSION

The results from this questionnaire have to be interpreted with caution because there was no control over the individual who eventually provided the information requested. Although the majority of the respondents held a supervisory position that was directly related to the management of the water supply system, 11 of the questionnaires were filled out by secretaries, treasurers, and clerks.

Fecal coliform (*E. coli*) determinations are routinely done as an indicator for the presence of potential pathogenic bacteria and should never be present in treated water supplies.⁸ The presence of fecal *E. coli* indicates the possible presence of pathogenic bacteria due to water contamination and/or a failure of the disinfection procedure. Such an event was observed in 1989 where a pathogenic strain of *E. coli* (0157:H7) was identified for the first time in a waterborne outbreak in Missouri.⁹ Since then this particular strain, which is usually associated with food contamination,^{9,10} has been found in other water supply systems, resulting in bloody diarrhea and occasionally death.^{9,11} Contamination of these water systems has been linked to mains failure and/or reservoir contamination due to flooding in conjunction with poor chlorination. The May 2000 outbreak in Walkerton, Ontario of *E. coli*

0157:H7 resulting in 2,300 cases of illness and 7 deaths, is a striking example.^{12,13} In this instance, heavy rains were suspected of washing infected manure into the water supply. It would appear that the 40 communities that reported a non-protected water supply are, or were, at the time of the survey, vulnerable to water contamination, especially those that lack a disinfection system. Since cattle are a well-known source of the pathogenic strain of *E. coli* (0157:H7),^{8,9} care should be taken to prevent water contamination from surface runoff into the water supply, especially in areas where the catchment area is also used as range-land. Perforation of the soil layers into the water table, such as from abandoned surface wells, are additional avenues of introducing surface contaminants from industrial and animal wastes into the water supply system.

Disinfection of the water supply is based on CT number, defined as the residual disinfectant concentration (C), usually chlorine, in mg/L multiplied by the effective contact time (T).^{3,5} Depending on the sensitivity of the particular biological contaminant, different CT values are used. For instance a 99.9% removal of *Giardia* in a water supply at 5°C and at pH 7 requires a CT value of 149, i.e., when there is 1 mg/L of chlorine residual and a contact of 149 seconds.⁵ To achieve the same results with *E. coli* contamination, this would take about 20 seconds.⁵ Based on the reported chlorine residuals from the questionnaires, the CT values for each location were calculated, and showed a wide variation ranging from a minimum value of 2 to a maximum of 4,320. The three locations that had experienced giardia outbreaks in the past reported information corresponding to CT values of 312, 0, and 3 respectively. It appears therefore that only 1 of the 3 locations did take precautions to prevent a repeat. The other two did not have alternate means of giardia removal and/or prevention such as filtration, flocculation or water reservoir protection.⁵

In this study, 11 communities used fluoride; of these, 3 did not check the water concentration. Research studies as early as 1939¹⁴ indicated that the presence of fluoride in drinking water at 1 mg/L provides protection against tooth decay. Mottling of teeth (dental fluorosis) has been observed

TABLE I**Summary of Descriptive Parameters of Water Management Practices Across British Columbia**

Parameter	Community Size Served (Numbers in Thousands)					Total n	% 100
	0.100-0.999 7(9.6)	1-9.999 43(58.9)	10-49.9 18(24.7)	50-99.9 4(5.5)	>100 1(1.4)		
Number of locations, n (%)						73	100
Water source							
Confined aquifer	3	13	5	0	0	22	30
Unconfined aquifer	0	13	1	1	0	15	20.5
Lake	2	7	7	2	1	19	26
River	2	16	9	1	0	28	38.4
Daily water production							
10 ⁶ gallons/day (mean)	0.2	2.4	5.8	11.8	50.0	70.2	
Protected water system	5	18	5	2	1	31	42.5
Partial	0	2	3	0	0	5	6.8
Activity							
Logging, range-land	1	24	12	2	1	40	54.8
Water treatment							
Pre-clarification	5	19	11	2	1	38	52.0
Coagulation (general)	1	3	0	0	0	4	5.5
Coagulation (alum)	0	0	0	0	0	0	0
Coagulation (FeSO ₄)	0	0	1	0	0	1	1.4
Coagulation (resin)	0	1	0	0	0	1	1.4
Coagulation (poly aluminum Cl)	0	0	2	0	0	2	2.8
Filtration							
Silica	0	1	3	0	0	4	5.5
Charcoal	0	1	2	0	0	3	4.1
Silica, rapid	0	1	3	0	0	4	5.5
Gravel, rapid	0	1	3	0	0	4	5.5
Slow sand	1	1	1	0	0	3	4.5
Silica, slow sand	0	0	0	0	0	0	0
Rock, slow sand	1	0	0	0	0	1	1.4
Anthracite	0	1	0	0	0	1	1.4
Filter cloth	0	1	0	0	0	1	1.4
Poly aluminum Chloride	0	1	0	0	0	1	1.4
Garnet	0	0	1	0	0	1	1.4
Disinfection, primary							
Chlorine	4	24	15	4	1	48	65.8
Checked 2/day	0	1	3	0	0	4	5.5
1/day	4	21	7	3	0	35	47.9
2/week	0	3	2	0	0	5	6.8
Chlorine dioxide	0	0	0	0	0	0	0
Ozone	0	1	0	0	0	1	1.4
UV	0	0	0	0	0	0	0
Disinfection (secondary)							
Chlorine	0	4	3	0	0	7	9.6
Checked 1/day	0	3	1	0	0	4	5.5
2/week	0	1	1	0	0	2	2.8
Continuous on line	0	0	1	0	0	1	1.4
Chloramine	0	1	0	0	0	1	1.4
Checked 1/day	0	1	0	0	0	1	1.4
Chlorine dioxide	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
Secondary chlorination stations	0	2	1	0	0	3	4.1
Additives							
Fluoride	0	6	5	1	0	12	16.4
Fluoride, partial	0	0	0	1	0	1	1.4
Checked 2/day	2	4	6	0	0	12	16.4
1/day	0	1	0	0	0	1	1.4
Not checked	0	2	0	1	0	3	4.1
Corrosion control							
Lime	0	1	0	0	0	1	1.4
Phosphate	0	0	0	0	0	0	0
Other	0	0	1	0	0	1	1.4
Reservoir type							
Balanced	1	6	5	1	0	13	17.8
Storage	4	31	10	2	1	48	65.8
Both	1	5	3	1	0	10	13.7
None	1	0	0	0	0	1	1.4
Reservoir material							
Concrete	3	30	11	3	0	47	64.4
Steel	2	17	3	1	0	23	31.5
Plastic lined	2	6	1	0	0	9	12.3
Clay and earth	0	4	0	0	1	5	6.8
Natural rock (lake)	0	1	1	0	0	2	2.8
Wood	0	3	0	0	0	3	4.1
Full circulation	4	26	9	2	0	41	56.2
Location of reservoir							
Before chlorination	1	4	3	0	0	8	11
After chlorination	6	36	13	4	0	59	80.8
Both	0	3	2	0	1	6	8.2

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TABLE 1 – CONTINUED

Summary of Descriptive Parameters of Water Management Practices Across British Columbia

Parameter	Community Size Served (Numbers in Thousands)					Total n	%
	0.100-0.999	1-9.999	10-49.9	50-99.9	>100		
Delivery system							
Asbestos cement	5	35	14	4	1	59	80.8
Wood	0	0	1	1	0	2	2.8
Plastic	6	39	14	4	1	64	87.7
Unlined cast iron or mild steel	1	17	10	4	1	33	45.2
Lined cast iron or mild steel	3	18	15	3	1	40	54.8
Galvanized iron	0	0	1	0	0	1	1.4
Leak detect program	3	5	4	0	0	12	16.4
Back-flow protection	5	22	13	1	1	42	57.5
Cross-connection control	1	15	7	2	1	26	35.6
Licensed operator training program	2	23	12	3	1	41	56.2
Licensed operator	2	25	12	3	1	43	58.9
Coliform, testing							
Source water	3	25	13	4	1	46	63.0
Treated water	4	24	13	4	1	46	63.0
Distribution system	4	38	15	4	1	62	84.9
No of samples/month							
Mean (range)	3 (1-4)	14(1-99)	27 (8-40)	113(88-160)	85(85-85)		
Testing agency							
Government	5	33	8	3	0	49	67.1
Private	1	4	4	0	0	9	12.3
Own staff	0	0	3	1	1	5	6.9
Other (did not know)	3	1	0	0	0	4	5.5
Approved laboratory*	1	7	8	1	1	18	24.7
Protozoans, testing							
Giardia	1	8	7	2	1	19	26.0
Cryptosporidium	1	6	7	2	1	17	23.3
Other	0	1	6	0	0	1	1.4
Frequency, testing for protozoa							
#s/month, mean (range)	48 (48-48)	17 (1-48)	51(1-288)	30 (12-48)	300(300-300)		
Testing agency							
Government	1	5	2	0	0	8	
Private	0	3	5	2	1	11	
Approved laboratory*	0	7	6	1	1	15	
Testing for chlorine byproducts	0	8	7	4	1	20	27.4
#test/year, mean (range)	0	3(2-4)	2(1-2)	4(4-4)	4(4-4)		
Personnel, quality control							
Full time, mean(range)	2.67(1-5)	2.16(1-7)	2.79(1-9)	4.75(1-7)	8(8-8)		
Part time, mean(range)	1.67(1-2)	1.88(1-4)	1.20(1-2)	1.00(1-1)			
Contamination events							
All	1	8	3	2	1	15	20.5
Biological	0	5	1	2	1	9	12.3
Physical	0	2	1	0	0	3	4.1
Chemical	1	0	0	0	0	1	1.4
Last modification							
Year, mean(range)	96(95-96)	92(75-97)	87(70-97)	87(82-92)	96(96-96)		
Estimated cost in \$x10 ⁶ mean (range)	0.135 (0.04-0.200)	0.915 (0.002-6)	0.953 (0.03-3)	4 (2-6)	1.5 (1.5-1.5)		
Reason for modification							
Regular maintenance	1	3	1	0	0	5	6.8
Physical break	1	4	1	0	0	6	8.2
Health	0	9	1	0	0	10	13.7
Improved technology	1	6	5	2	0	14	18.7
Other	1	3	5	1	0	10	13.7
Increased demand for capacity	1	3	4	1	0	9	12.3
Flow control	0	1	0	0	1	1.4	

* A laboratory that took part in a proficiency testing program.

at higher levels of intake (> 2.0 mg/L) and illustrates the narrow therapeutic window associated with the use of this element. Recent studies have shown that the prevalence of dental fluorosis has increased over the last 50 years¹⁵ and is likely due to excess exposure to fluoride, not only in drinking water, but also from fluoride supplements in toothpaste, gels, rinses, processed foods and beverages.² In view of this information, it would be prudent to daily monitor fluoride levels in outgoing water along with fluoride intake from

other sources. This is especially important for children 1 to 2 years of age with respect to dental fluorosis,¹⁶ and for the elderly with respect to hip fracture.¹⁷

The materials used in the construction of the water delivery system also play an important role in ensuring a safe and reliable source of water to the consumer. Some generalities have been observed regarding failure of the distributing system.¹⁸ Most breaks appear to be associated with main barrels, which constitute 66-83% of main repairs, and joints

17-25%. Galvanized and cast iron mains appear to fail more often than asbestos cement, steel, ductile iron, and concrete. There is a generally higher failure rate when the mains diameter decreases likely because the thinner walls make them more vulnerable to corrosion, often resulting in circumferential breaks.¹⁸ Larger diameter mains tend to have more longitudinal failures.⁴ The age of the system is generally considered a poor predictor of leak and break rates.⁴ The results of this study indicate that the use of plastic in the delivery

system was most frequent (64 locations) followed by asbestos cement (59 locations) and lined cast iron or mild steel (40 locations). Leaks and repairs result in sudden abnormal flow patterns, which not only are capable of unsettling deposits and biofilms, but also can draw in contaminated groundwater.¹⁹ This is particularly problematic where sewers are located at higher elevations than the delivery system.¹⁹ Leak detection protection programs to guard against such contamination events were present in only 12 locations.

Cross-connection control prevents the physical connection between a potable water supply and a source of water that is not controlled.⁶ When there is a sudden demand on the water distribution system (resulting in a drop in pressure), and in the absence of back-flow protection, water can siphon back into the distribution system from boilers, swimming pools, and other reservoirs when these are physically connected to the distribution system. Only 26 locations had a cross-connection control program in place. Back-flow protection was present in 42 of the locations.

This communication has attempted to identify those parameters which could make a location more vulnerable to potential sources of drinking water contamination. These parameters include the presence, or absence, of systems or processes capable of identifying and treating such an event before the population is exposed. It is therefore interesting to note the direct relationship between an increase in the number of contamination events and 1) an increase in number of protozoan tests, and 2) an increase in personnel. Although these observations are counterintuitive, the increase in protozoan tests is likely due to the follow-up and increased vigilance after contamination events, and the increased number of personnel could be a reflection of the appropriate changes made to the

management structure also in response to such events.

It should be pointed out that appropriate modifications to water supplies, distribution systems, and management might have occurred in the various communities since this survey was conducted.

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RÉSUMÉ

Contexte : Les doutes concernant la régulation du système de fluoration de l'eau dans une localité de la Colombie-Britannique ont mené à une enquête sur la gestion de l'eau potable en 1997-1998.

Méthode : À partir de critères publiés sur la régulation et la gestion de l'eau potable, nous avons élaboré un questionnaire, que nous avons envoyé à 91 localités.

Résultats : On nous a retourné 73 questionnaires sur 91 (taux de réponse = 80 %); 31 localités avaient un réseau d'aqueduc protégé, 40 signalaient des activités de bûcheronnage et/ou de pacage du bétail dans les zones du bassin versant, et 25 n'effectuaient pas de désinfection primaire. Trois des 12 localités où l'on procédait à la fluoration de l'eau ne surveillaient pas les niveaux de fluorure. Les tests de dépistage des protozoaires avaient lieu systématiquement dans 19 localités, mais 15 seulement confiaient ce dépistage à des laboratoires agréés. On rapportait 15 cas de contamination de l'eau, dont 9 d'origine biologique. Nous avons établi des associations significatives entre les cas de contamination et : les systèmes d'adduction d'eau en bois; l'absence de chloration primaire; l'accroissement des tests de dépistage des protozoaires; et l'accroissement du personnel.

Interprétation : Au moment de l'enquête, en Colombie-Britannique, plusieurs localités s'exposaient à une contamination évitable de leur eau potable.

ERRATUM

Re: Ashley MJ, Cohen J, Ferrence R. 'Light' and 'mild' cigarettes: Who smokes them? Are they being misled? *CJPH* 2001;92(6):407-11.

In Table III of the above article (on page 409), under the column 2000 (Smoking L/M as a step toward quitting – Very important reason): the figure 169 should be 16.