Survey of Bottled Drinking Water Available in Manitoba, Canada

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Forty domestic and imported brands of bottled water were purchased in Manitoba, Canada and examined for total dissolved solids (TDS), chloride, sulfate, nitrate–nitrogen, cadmium, lead, copper, and radioactivity. The samples showed great variation in quality, and some exceeded the Canadian Water Quality Guidelines for drinking water for TDS, chloride, and lead. Carbonation, ozonation, and type of packaging were not associated with differences in metal levels, although carbonated samples tended to show higher TDS values. A number of deficiencies were found with respect to product labeling. *Key words*: bottled water, cadmium, chloride, copper, lead, nitrate, radioactivity, sulfate, total dissolved solids. *Environ Health Perspect* 108:863–866 (2000). [Online 1 August 2000]

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Annual consumption of bottled water in North America and Europe is substantial (*1,2*). Many consumers choose this alternative because they dislike the taste of chlorinated tapwater, or because they believe that bottled water contains fewer contaminants and is a healthier choice (*2,3*). In Manitoba, consumers may be concerned about heavy metals such as lead, trihalomethanes, or asbestos from asbestos-cement pipe in their municipal water supply, or nitrates, pesticides, and pathogens in rural areas. In addition, algal toxins such as microcystin have been detected in numerous raw and treated waters in the province (*4,5*).

The bewildering array of brands offered for sale includes various domestic and imported spring and mineral waters, tapwaters treated by filtration, reverse osmosis, or distillation, and miscellaneous waters supplemented by the addition of specific salts. To compound the confusion, labeling is extremely variable. Label designs can feature attractive pictures of blue mountains or glaciers that may bear no relationship to the actual provenance of the water. Descriptions of the product often contain terms that imply purity, such as "glacial," "alpine," "natural," "crystal," "premium," or "pure." Unfortunately, definitions of terms differ in various jurisdictions and in the understanding of individual bottlers. The water source is not always identified on the product, and a brand may use more than one source (*6*). Some Canadian domestic brands may collect the water in one province and bottle it in another.

Similarly, chemical analysis may not be provided at all, or only for highly selected parameters. The consumer is faced with difficulty in interpreting the information that does exist on the label. For example, the U.S. Food and Drug Administration has permitted water with < 5 mg Na/8 fluid ounce serving to be labeled as "sodium free"(*2*). However, for most consumers, it is impractical to gauge how a sodium value on a label compares with this threshold when the label values are reported in units of micrograms per liter or parts per million. Most consumers are also unaware of how label values compare with their local tapwater.

Given the extensive consumption of bottled water, the question naturally arises of the long-term impact of waters of various chemical composition on human health. Elements such as magnesium and calcium have been linked to reduced frequency of sudden death and osteoporosis, respectively (*1*), and both may exert protective effects against gastric cancer (*7*). Garzon and Eisenberg (*1*) advocated the consumption of brands that are high in magnesium and calcium and low in sodium. However, individuals with stones in the upper urinary tract are ill-advised to consume bottled waters with a high calcium content (*8*).

High concentrations of sulfate in drinking water have been associated with gastrointestinal effects such as decreased transit time (*9*). Nitrate is a common contaminant in groundwater (*8*) and has been implicated in gastric cancer mortality and other disorders (*7,10*). Through conversion to nitrite, nitrate is the causative agent of methemoglobinemia in infants.

Cadmium and lead are toxic heavy metals with long retention times and significant tissue accumulation. Cadmium may have a half-life in bone of 38 years (*11*) and has carcinogenic properties (*12*). Lead is a neurotoxin, responsible for the most common type of human metal toxicosis (*11*). Low-level lead exposure has been associated with reduced IQ in children (*13*) and attention deficit disorders (*14*). Copper is an essential element in human nutrition, but it may reach high levels in tapwater through contact with copper fittings. Guidelines for copper in drinking water are primarily aesthetic; at high concentrations taste of the water may be affected.

Radioactivity is measured only rarely in bottled water, even though some natural springs can contain leached radionuclides (*15*) from radioactive minerals in rocks and soil. Measurable amounts of radium have been reported in a number of imported and domestic bottled waters in both the United States (*15*) and Australia (*16*). Canadian Water Quality Guidelines (CWQG) (*17,18*) have itemized some selected elements, with the recommendation that maximum additive conditions should be considered for different radionuclides that target the same organ or tissue.

Even when water quality is good at the source, it may deteriorate through subsequent handling, transportation, and storage. Growth of microorganisms may occur via agencies such as introduced flakes of human skin, particularly in nonozonated, noncarbonated waters (*19*). Warburton et al. (*20*) found that *Pseudomonas* and *Salmonella* could survive for longer than 100 days in bottled water, with the former having a synergistic effect on survival of the latter. Isolates from bottled water may be resistant to antibiotics (*20*).

Bottling and packaging can contribute a variety of inadvertent chemical contaminants. Materials used in filtering and processing may contribute asbestos (*21*). Organic compounds such as toluene, cyclohexane, dichloromethane, pentane, benzene, phthalate esters, and others with tumor-inducing properties may leach from plastic packaging, polystyrene cap liners, or unknown sources (*22,23*). Leaching of volatile and semivolatile organic compounds from packaging materials into the water has been shown to increase with length of storage time, temperature, and exposure to sunlight (*23*). Glass containers may present the risk of leaching lead into the water. Because bottled water is usually stored at room temperature (*24*), and many consumers may buy large quantities at a time for later use or stockpile it for emergencies, this elevates the risk for leaching.

In Canada, bottled water comes under the purview of the Canadian Food and Drugs Act and Regulations (*25*). Those regulations

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applicable to bottled water are currently under review.

The objective of the present study was to examine bottled waters available in Manitoba retail stores for total dissolved solids (TDS), chloride, sulfate, nitrate–nitrogen (nitrate-N), cadmium, lead, copper, and total radioactivity and to determine whether these parameters could be correlated with labeling, packaging, and disinfection qualities.

Methods

Forty brands of bottled water were purchased in urban and rural stores in southern Manitoba. We analyzed chloride, nitrate, and sulfate using methods recommended by the American Public Health Association (*26*). Total dissolved solids were measured directly using a TDSTestr 1 (Oakton, Wards Natural Science, St. Catharines, Ontario). Total radioactivity was measured for a 1-cm deep sample from a freshly opened bottle using the RM-60 Radiation Counter (Aware Electronics, Wilmington, DE) calibrated against cesium-137, with a window area of 65.6 mm^2 and a distance of 1 cm from the sample surface. The sample was not evaporated to avoid the loss of volatile radionuclides. We made three replicate counts of 1 min each for each sample. We made background counts using empty counting dishes.

We determined cadmium, copper, and lead using a PDV2000 digital anodic stripping voltameter (Chemtronics Ltd, Bentley, Australia). Three 5-mL aliquots were analyzed for each bottle to obtain a mean value. The standard additions method (*27*) was applied to compensate for matrix absorption effects, using three incremental additions of each metal as certified atomic absorption standards (Fisher Scientific Co., Fair Lawn, NJ).

Cochran's *C* and Bartlett-Box *F* tests for homogeneity of variance were used to determine the suitability of data for parametric tests (*28*). The critical significance level for all statistical tests was $p = 0.05$.

Results

The majority of the domestic brands sold in Manitoba originated either from British Columbia (eight brands) or Alberta (seven brands). The Manitoba/Saskatchewan region was represented by four samples, and three originated from Ontario/Quebec. One brand displayed both an Ontario source and the word "imported" on its label, and another brand contained no source information other than "Canada." Two samples were Winnipeg tapwater treated by reverse osmosis. Imported samples consisted of 1 northeastern U.S. and 13 European brands (Italy, 7; France, 3; Germany, 2; and Slovenia, 1). One brand was a product of reverse osmosis of unidentified source to which unspecified amounts of salts had been added (labeled as "mineralized").

Only 13 of the 40 brands indicated an expiration date. In one additional case the expiration heading on the label was blank. Of those samples that did have expiration dates, two samples were not legible, two were > 1 year past the expiration date, and another was > 2 years past the expiration date. The most frequently listed parameter on the label was TDS, which was found on 35 brands. None of the samples treated by reverse osmosis displayed TDS information. Other listed parameters were Na (28 brands), K (27), F (23), Ca and Mg (24 each), sulfate (21), Cl (19), bicarbonate (18), nitrate, Pb, and Cu (17 each), As (15), Zn (14), silica (8), Fe (5), Al and Cr (3), Sr, (2) and Ba (1). Four brands listed pH. Three brands provided no chemical data. None of the brands provided information on radioactivity.

The results for the inorganic parameters examined are given in Table 1. Seven of the 40 brands exceeded the CWQG of 500 mg/L for TDS in drinking water. Six of these seven samples were designated as mineral water on the label; the seventh sample was neither labeled as mineral water nor was any chemical analysis provided. One European brand was labeled as mineral water but contained only 130 mg/L TDS. Samples with the lowest TDS values (≤ 10 mg/L) were labeled either as "glacial water" or were tapwater that had been treated by reverse osmosis.

For chloride (Table 1), only one brand of mineral water (from Quebec) exceeded the CWQG of 250 mg/L. None of the sulfate concentrations approached the CWQG of 500 mg/L. Similarly, all nitrate-N values were substantially below the CWQG of 10 mg/L, with a maximum of 4.1 mg/L observed for a French brand.

When samples were grouped according to geographic origin, Kruskal-Wallis tests showed significant regional differences for TDS ($\chi^2 = 24.4$, $p < 001$), chloride ($\chi^2 = 29.0$, $p = 0.0001$) and nitrate-N ($\chi^2 = 24.2$, $p < 0.001$). European samples showed the highest mean values for TDS and nitrate-N, and the second highest values for chloride (after Ontario/Quebec; Table 2).

Three brands exceeded the CWQG of 10 µg/L for lead, and three were below the detection limit of 0.1 µg/L. Copper values were inconsequential compared to the CWQG of 1 mg/L, with the highest sample concentration only 16.5 µg/L. Ten samples had copper levels < 0.1 µg/L. Cadmium values averaged 0.2 µg/L, although different bottles of the same brand purchased in different stores could show some variation. Kruskal-Wallis or ANOVA tests (as appropriate) showed no statistically significant regional differences for sulfate, cadmium, copper, lead or radioactivity. However, Student's *t*-tests identified two samples, both from Alberta, that showed significantly higher radioactivity than the background.

Pearson correlation coefficients showed significant positive correlations between TDS and chloride ($r^2 = 0.43$, $p = 0.005$), between TDS and sulfate ($r^2 = 0.42$, $p = 0.008$), and between cadmium and lead ($r^2 = 0.41$, $p = 0.008$).

Eight of the 40 brands were packaged in glass and the remainder in plastic. Five of the plastic packaged brands used mildly or intensely blue-tinted bottles; seven of the glass-packaged brands (all European) used strongly tinted glass, either green (six) or deep blue (one). Some plastics were labeled as biodegradable.

Thirteen of the samples were ozonated only, 11 were carbonated only, 5 were both ozonated and carbonated, and 11 were neither ozonated nor carbonated. No statistical association between ozonation and carbonation was found, nor did ozonated waters show any significant tendency to be packaged in either plastic or glass. A comparison of carbonated and noncarbonated waters using *t*-tests showed that carbonated waters averaged significantly higher TDS ($t = 2.8$, $p = 0.012$) and sulfate ($t = 2.7$, $p = 0.011$) concentrations than noncarbonated brands. Differences for other parameters were not significant. Ozonated versus non-ozonated waters showed statistically significant differences only for nitrate-N ($t = 2.4$, $p = 0.023$), with a tendency for higher values to occur in nonozonated samples. Samples with lower TDS tended to be packaged in plastic containers rather than glass ($t = 2.1$, $p = 0.03$).

Discussion

The results of this study showed great variation in the quality of bottled water available in Manitoba, agreeing with similar findings in other jurisdictions (*1,8*). Values for brands previously tested by Consumers' Research (*2*) for TDS, nitrate, sulfate, and chloride agreed in most cases with the values found for the same brands in the present study, except for those which use more than one source.

In some cases parameter values on the labels did not agree with the present analytical

Table 1. Summary of water chemistry parameters for the samples tested.

	Mean ± SE	Min	Max
TDS (mg/L)	405 ± 97	5	3,400
Chloride (mg/L)	24 ± 10	< 0.1	391
Sulfate (mg/L)	27 ± 3	< 0.1	66
Nitrate-N (mg/L)	0.65 ± 0.12	< 0.01	4.1
Cadmium (µg/L)	0.2 ± 0.04	< 0.1	1.1
Lead (µg/L)	5.3 ± 0.6	< 0.1	17.8
Copper (µg/L)	5.5 ± 0.8	< 0.1	16.5

Abbreviations: Max, maximum; Min, minimum.

results. The label analysis is normally for the water at the source, but the source may vary in quality over time, or some parameters may change by the time the water reaches the consumer. However, in certain instances the sum of the listed parameters on the label exceeded the listed TDS value.

The amount of information presented on the labels varied greatly, from no analytical data at all to numerous inorganic parameters, and occasionally, parameters such as osmotic pressure and source temperature. Trace elements were often listed as 0 mg/L or 0 ppm, which provides little information when the analytical detection threshold is unknown and guidelines for these parameters are specified in micrograms or parts per billion. Furthermore, the information on the label, particularly for low-level substances such as metals, did not always reflect what was actually in the bottle at the time of purchase.

The TDS in surface waters in Manitoba has been found to range from 18 to 5,533 mg/L (*29*), whereas in Canadian drinking water it has been reported as 20–3,800 mg/L for surface and groundwater sources (*17*). Bottled waters in this study therefore showed a range of TDS that was similar to that of Canadian tapwater. However, the designation of "mineral water" was not always correctly applied, nor was this label always found on waters with high TDS. Even when appropriately labeled, mineral waters are invariably sold intermixed with other types of bottled water, and the consumer is generally not aware of the difference between them. In some cases health claims were made on labels of brands which exceeded the CWQG. One European mineral water with 570 mg/L TDS, purporting to contain a calcium concentration of 20% of the TDS, claimed to be beneficial as a diuretic and to assist in the elimination of uric acid.

The mean chloride value was 24 mg/L for bottled waters, which decreased to 15 mg/L when the single high sample from Quebec was removed. Chloride levels in Canadian drinking water are generally < 10 mg/L (*17*), and, therefore, from the standpoint of this parameter, bottled water offers little advantage. However, the mean sulfate concentration of 27 mg/L in bottled waters compared favorably with some Canadian drinking waters, which may range to 1,795 mg/L (*17*), although in Winnipeg tapwater sulfate is negligible.

Nitrate is highly variable in drinking water, but may reach concentrations in excess of 1,000 mg/L in some groundwaters and > 100 mg/L in surface waters, although in the latter nitrate rarely exceeds 5 mg/L (*17*). In Manitoba, nitrate may be encountered in waters impacted by intensive livestock production, fertilizer application, or septic effluent, and some private water supplies subject to such contamination can approach or exceed the CWQG (*30,31*). However, public water supplies in the province do not exceed, but may approach, the CWQG of 10 mg/L nitrate-N (*32*). In the present study, all of the bottled waters (except for one French brand) contained < 2 mg/L nitrate-N.

Lead levels exceeded the CWQG of 10 µg/L in three of the samples. As a comparison, the average concentration in Canadian tapwater has been reported as 7.6 µg/L (*17*), although lead in Winnipeg tapwater may range from 2 to 450 µg/L, depending on the type of distribution pipe, amount of older high-lead solder in the plumbing system, and length of contact time (*30,33*).

Cadmium concentrations in some brands were higher than the maximum of 0.27 µg/L in Canadian distributed waters (*17*), although the maximum of 1.1 µg/L in the present study was the same as the maximum in Canadian raw waters (*17*). Differences in handling and type of packaging (e.g., cap liners, and cadmium-based stabilizers in plastics) may contribute to differences in metal concentrations among brands, while length and conditions of storage time may lead to differences among individual bottles. For example, in the present study, three different brands that purported to come from the same British Columbia source showed a 3- and 2-fold variation in the cadmium and the lead concentrations respectively.

The greatest difference between bottled and tapwaters was in copper. In Canadian tapwaters, copper levels are consistently higher (*17*) than the maximum observed for bottled waters in this study, and concentrations as high as 1.59 mg/L have been reported in Winnipeg first-draw tapwater (*33*), primarily as a result of leaching from copper pipe. Although water softness and pH influence the leaching rate of metals (e.g., *33*), the present study showed no measurable association between metal content and carbonation, even though carbonation may decrease the pH to < 5. Similarly, no significant differences for metal concentrations were found for ozonation or TDS, nor for waters labeled as spring or mineral, agreeing with a previous study (*25*) that found differences only for fluoride, but not for lead, cadmium, arsenic or aluminum between spring or mineral waters.

Carbonation has antibacterial properties (*35*). Bottled waters with higher TDS and sulfate concentrations showed a significantly higher tendency to be carbonated to improve taste. The adverse effects of carbonated beverages on tooth enamel wear have been investigated (*36*), but other physiological effects of the consumption of large volumes of carbonated fluids have not been well documented. Pouderoux et al. (*37*) found that carbonated water did not affect gastric emptying compared to still water, although it did affect intragastric meal distribution.

In the present study, although overall regional differences in radioactivity were not notable, two domestic samples were significantly higher than the background. Excessive radium levels have been reported in some bottled waters available in Australia (*16*), and 6 of 22 imported and U.S. brands contained measurable radium activity (*15*). It is apparent that this issue requires further investigation, particularly with regard to total radioactivity of samples, as more than one radionuclide may be present.

In conclusion, this study demonstrates the need for more stringent standardization of the bottled water market, particularly with regard to quality control, labeling and monitoring, as well as further study of the effects of packaging materials and storage conditions on final product quality.

Table 2. Regional differences for TDS, chloride, and nitrate-N, as mean ± SE (range).

	TDS (mg/L)	Chloride (mg/L)	Nitrate-N (mg/L)	No.
British Columbia	96 ± 31 (10–250)	0.9 ± 0.7 (< 0.1–6.0)	0.18 ± 0.04 (< 0.01–0.32)	8
Alberta	290 ± 12 (230–330)	3.6 ± 1.6 (< 0.1–10)	0.68 ± 0.12 (0.33–1.11)	7
Manitoba/Saskatchewan	250 ± 20 (220–310)	1.5 ± 0.6 (< 0.1–2.8)	0.06 ± 0.03 (< 0.01–0.13)	4
Ontario/Quebec	687 ± 283 (280–1,230)	164 ± 114 (24–391)	0.71 ± 0.22 (0.43–1.15)	3
Northeast United States	20	< 0.1	0.13	1
Europe	777 ± 258 (120–3,400)	33 ± 8 (4–99)	1.25 ± 0.28 (< 0.01–4.09)	13
Reverse osmosis	7.5 ± 0.3 (5–10)	< 0.1	0.36 ± 0.34 (0.02–0.69)	2

Reverse osmosis brands are treated Winnipeg tapwater.

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