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Original Contribution

Drinking Water Quality in a Mexico City University Community: Perception and Preferences

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Abstract: A transversal study was conducted at the University City campus of the National Autonomous University of Mexico (UNAM) in Mexico City, with the goal of estimating the university community preference for drinking either tap water or bottled water and the reasons for their selection. A representative sample of three university community subpopulations (students, workers/administrative staff, and academic personnel) were interviewed with respect to their water consumption habits. The results showed that 75% of the university community drinks only bottled water and that the consumption of tap water is low. The interviewees responded that the main reason for this preference is the organoleptic features of tap water independent of quality. In general, the participants in this study do not trust the quality of the tap water, which could be caused by the facilities that distribute bottled water encouraging a general disinterest in learning about the origin and management of the tap water that is distributed on campus.

Keywords: drinking water, water quality, bottled water, perception, Mexico

INTRODUCTION

The increasing consumption of bottled water has shown that it is an important source of water for many people. Bottled water is a main source of drinking water in places where there the water distribution system is inefficient or where water quality is not acceptable (Ferrier 2001; Doria 2006). However, there is also a high consumption of bottled water in cities that have an efficient water distribution network and high-quality tap water. This phenomenon is related to beliefs that bottled water is healthier and safer than tap water and preferences for the organoleptic properties of bottled water (Hu et al. 2011), which is induced, in part, by expensive publicity campaigns from the main bottled water companies. However, the increase in bottled water consumption may be largely determined by consumer perception. According to Schiffman and Kanuk (2010), perception is a personnel phenomenon, in which the reception of stimuli and previous individual experiences comprises an individual interpretation of the

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surroundings. Drinking water produces stimuli in the consumer, which are received through the eyes (color), nose (odor), and mouth (taste). Thus, organoleptic drinking water properties are basic for consumer choices.

It is necessary to take into account that bottled water consumption impacts the environment in several ways. Landfills become overloaded with plastic bottles because the cost of recycling or incinerating plastic bottles is high, and water bottling may result in overexploitation of water supply sources (Hu et al. 2011; Saylor et al. 2011; Yao 2011).

The Mexico City Metropolitan Area (MCMA) is a megacity of >20 million inhabitants that faces important challenges regarding its water supply. Approximately 70% of the main water supply is from groundwater sources, and there is a complex network distribution system that combines new facilities and very old ones. Management and maintenance of the distribution system is inadequate and insufficient, and it is estimated that approximately 40% of the contained water is lost to leakage (Morales-Novelo and Rodríguez-Tapia 2007; Perló and González 2005).

Since the September 1985 earthquake in Mexico City, the population has increasingly consumed bottled water because for a time, it was not safe to consume water directly from the distribution system (Pan American Health Organization (PAHO) 1985). Although authorities have reported that the drinking water network was reestablished 40 days after the occurrence of the earthquake (PAHO 1985), 25 years later, the majority of the population does not drink tap water, and the consumption of bottled water has reached a historical peak (González et al. 2010).

The sixth cholera pandemic that occurred during the 1990s also exerted an influence on the high consumption of bottled water in Mexico City. According to official data, this pandemic resulted in 45,977 cases of cholera between 1991 and 2002, with a fatality rate of 1.3% (Sepúlveda et al. 2006). However, in the early 2000s, Mexico City and other regions of the country experienced increased coverage of piped chlorinated water that benefited from improved disinfection methods and sewer services (Sepúlveda et al. 2006).

Nevertheless, Mexico is one of the top countries in per capita bottled water consumption, with a total volume of more than 5 billion liters consumed per year (INEGI 2010). In 2010, bottled water consumption per capita was 243 l/year, while in countries such as Germany and the US, bottled water consumption per capita was 134 and 107 l/year, respectively (Gleick et al. 2011). Brasil, a Latin-American country with cultural similarities to Mexico, had a per capita consumption of 63 l/year in 2004, while in Mexico, it was 169 l/year (Gleick et al. 2006). However, the bottled water market in Brazil has been increasing at 5.1% per year between 2004 and 2009 (Research and Markets 2013).

In Mexico City, bottled water was reported as the drinking water source for more than 76% of the population, of which, the major consumers are lower income inhabitants (González et al. 2010), mainly due to the fact that their communities lack basic water supply services that are expected as minimal urban infrastructure provided by the government.

Water quality information is partially public but is not updated; therefore, Mexico City residents do not have access to recent information regarding the quality of the water being distributed. Trust regarding tap water has not improved, and the consumption of bottled water has increased year by year (González et al. 2010). This lack of information coupled with the population's perception of water quality have strengthened bottled water consumption, which assumes a level of household spending and little awareness of solid waste generation and recycling.

The National Autonomous University of México is the largest university in the country, with a total population of over 330,382 people. The school system is public and free and is composed of nearly all the socio-economic classes found in the Mexico City Metropolitan Area. According to INEGI (2010), bottled water consumption habits are not related with educational level. Although the socio-economic composition of the metropolitan area and the University main campus is not similar, we will assume that water consumption habits inside the University campus are similar to those in the city, in the sense that the proportion of bottled water consumers for each population stratum is the same on campus as it is in the city. Therefore, similar results regarding water consumption habits can be assumed for the entire Mexico City Metropolitan Area population.

The main goal of this work is to assess the proportion of water consumed in the University City from two water sources: the water distribution system (tap water) and bottled water. We also included in the evaluation the reasons for the preference of tap water or bottled water, which was based on the population perception of water quality.

METHODS

UNAM is the largest university in Mexico, and the University City is the main campus. The only water source for the campus is groundwater extracted from three wells, with 54 km of pipeline making up the distribution network. Certain sections of the pipeline have been in operation for nearly 50 years. For each extraction well, a disinfection system based on sodium hypochlorite is added to the water through a peristaltic pump (Fig. 1). The distribution system provides water for 144 buildings and three water storage tanks that supply water to 131,832 people. Operation of the water network system, including the disinfection process prior to distribution throughout the campus, is managed by the UNAM Works Department (Dirección General de Obras y Conservación, UNAM).

A program to manage the use and reuse of water (Programa de Manejo, Uso y Reuso del Agua, PUMAGUA) was implemented at UNAM in 2008. The program conducted a transversal survey study of water consumption habits on the University City campus in which the university community was stratified as students, academic personnel, and workers/administrative staff. To acquire a representative sample of the university community, we used a blocked sampling design that had three strata inside each block. The university units were considered as blocks, and 20 out of 144 were chosen with simple random sampling (Cochran 1977). Inside each block, we used the directory of students and academic personnel and workers/administrative staff from each unit within a block sampling frame and used stratified sampling to select the interviewees. Sampling probabilities inside each block were proportional to the population of each stratum. We kept records of the individuals who belonged to each of the three strata into which the population was classified to evaluate the global number of students and academic and workers/administrative personnel surveyed. The percentages of each subpopulation were used to design a size-proportional, stratified sampling for applying the surveys (Table 1), which only considered members of the University City community who were localized directly inside the school, institute, administration, or green-area facilities. Twenty university units were included in this study and are considered as the strata.

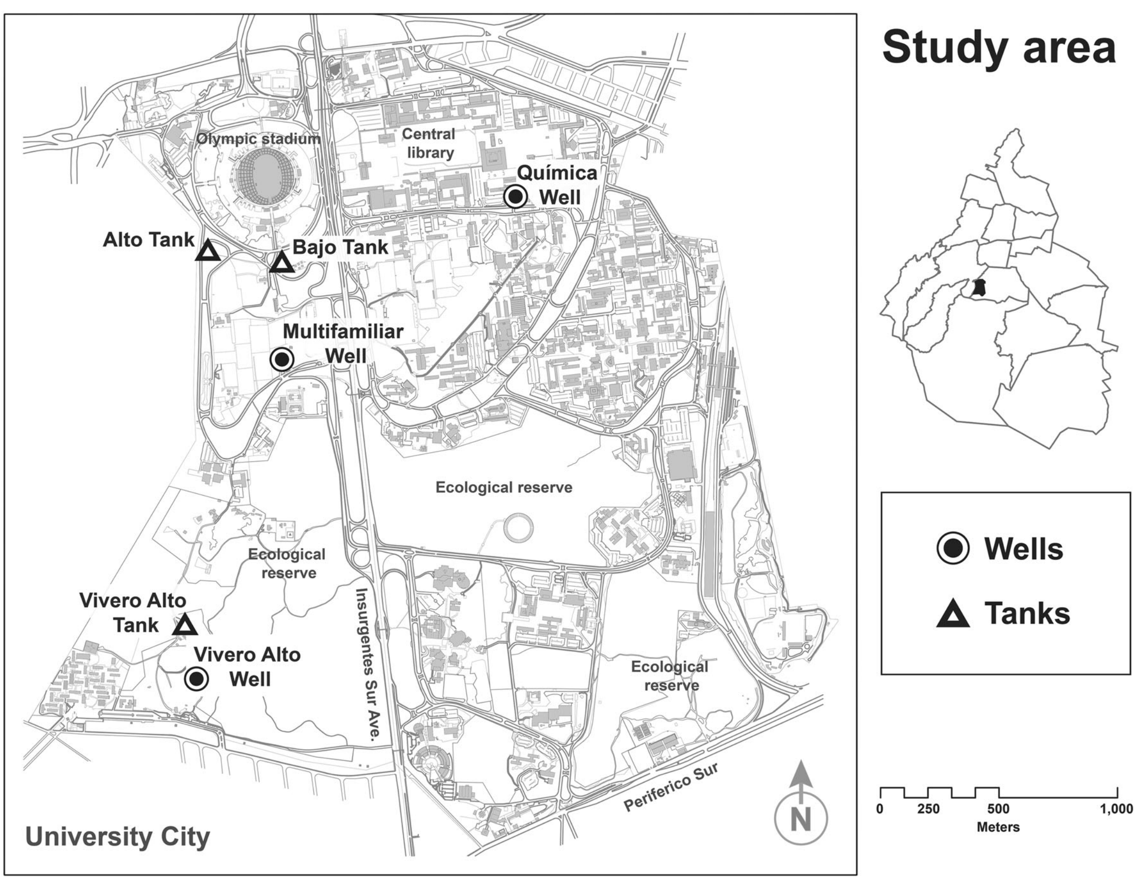

Figure 1. Localization of the study area at University City. Wells and tanks as part of the drinking water distribution system (modified from Martínez 2014).

Table 1. Participants in the Survey and Their Beverage Preferences

Subpopulation	Interviewed (*n*)	Water (+)	Another drink (+)	Water and another drink (+)
Students	394	169	32	193
Academics	76	33	6	37
Administrative	52	22	4	26

The following were the survey objectives: (a) to estimate the volume of drinking water consumed per capita as well as the proportion of that volume corresponding to bottled water and tap water (Table 2) and (b) to gain insight into the University City community's perception of water quality within the campus. With respect to water quality perception, the participants were questioned directly on the reasons why they do not consume water from the campus distribution system and what they based their decision on.

The survey was structured with questions and possible responses that considered the different response levels according to those surveyed on campus.

To test and adjust the questionnaire, a pilot study was conducted with ten people that included students, academics, and workers/administrative. The improved questionnaire was applied to interviewees.

To perform the survey, 30 interviewers were trained to apply the questionnaire. Using life-sized images of glasses of a known volume capacity, the interviewers estimated the volume of water that each subject consumes. Each interviewee defined the number and type of glasses they consumed per day. Each interviewer attempted to apply the questionnaire to 20 persons, including students, academic personnel, and workers/administrative staff.

A database was created for the survey responses to develop a descriptive and statistical analysis using exploratory data analysis techniques. Because survey responses were categorical and the survey was designed so that each interviewee belonged to a single non-overlapping category for each question answered; methods for the analysis of categorical data were those most adequate for testing the null hypotheses of independence among different responses to the survey questions. Because we were only interested in assessing possible independence between responses to different questions, methods for detecting the presence of groupings, such as correspondence analysis, were beyond the scope of this study. Statistical analyses included bar charts and contingency table analyses for independence between water consumption habits and population groups. For contingency tables, standard methods for testing independence with a fixed total were applied (Agresti and Finlay 1986).

Table 2. Percentage of Beverages Consumed with Respect to Interviewed Persons (*n*) and the Entire University Community

Drink type	Population		
	n	%	Extrapolating to population
Water	224	42.9	56,556
Another drink	42	8.04	10,599
Water and another drink	256	49	64,598

Results

A total of 522 persons answered the survey questionnaire for a response rate of 87%, and their responses constitute the data base. Table 1 shows the numbers of each subpopulation who participated in the survey. The University City community comprises 131,832 persons, corresponding to 76% students, 7.2% workers/administrative staff, and 16.7% academic personnel.

The preferred beverages in all groups fell into the classification "both," which includes beverages such as water, sparkling water, bottled or canned fruit juices, and coffee. A high proportion of respondents in all groups prefer to drink either bottled or tap water, and only a very small fraction did not show a preference for water over other beverages (Fig. 2). Responses were obtained from a representative university sample population; therefore, it is possible to estimate the preferences of general consumers from the responses given by the University City community. The percentage and population that consume each beverage type are listed in Table 3, with water being the

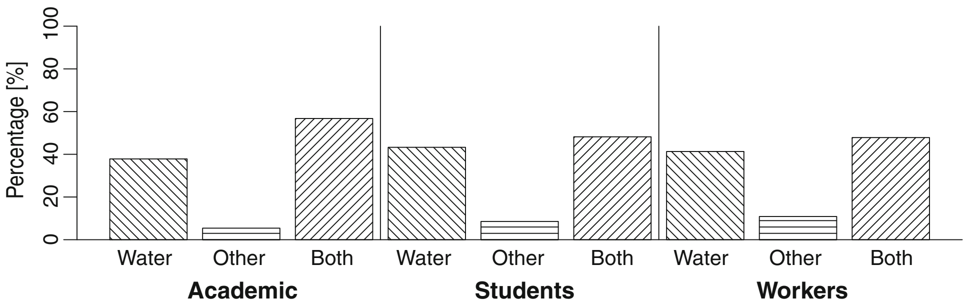

Figure 2. Percentage of beverages type consumed by group at the University City campus.

Table 3. Percentage of Water Type Consumed by the University Community

Type of water	At home			At university		
	n	%	Extrapolating	*n*	%	Extrapolating
Tap water exclusively	109	20.8	27,421	69	13.3	17,534
Bottled water exclusively	391	74.9	98,808	390	74.8	98,610
Tap water and bottled water	22	4.2	5,577	59	11.3	14,897

predominant drink. The consumption pattern is similar for all three subpopulations considered in the analysis. In fact, the χ^2 test for the null hypothesis of independence between population group and beverage type was not rejected ($P = 0.835$). Thus, we are able to state that preference for a beverage type was the same for the whole sample, regardless of whether the person interviewed was a student, worker/administrative staff, or academic personnel. A similar result was found regarding water type preference at home for the three subpopulation groups. The null independence hypothesis was not rejected ($P = 0.510$), leading to the conclusion that the preference pattern is the same for the sample regardless of the group.

Specific results with respect to water type consumed at home for each of the three groups are shown in Fig. 2.

Some questions in our survey were designed to ascertain whether the water consumption percentages are similar if the participants are at home or on campus; the responses were complementary and are presented in Fig. 2. As we have been assuming, these responses can be a good base for performing approximations with respect to water consumption habits within the University City community. Comparisons of the type of water consumed at home and during the participant's daily stay on campus are shown in Table 3 and Fig. 3.

Extrapolating the volume of tap water consumed by the campus population gives a figure equivalent to 12.9 ml/day; thus, water extracted from the University City wells is drunk at the rate of 17,000 l, or nearly 13 ml/person. However, based on the responses received from the surveyors, an estimate of the actual volume of consumed water (from both tap and bottled water) is approximately 128,000 l/day.

An interesting result is that water is consumed by the University City community at a rate of 1,344 ml/day/person, independent of the source and place. Exclusively inside the University City campus, the average volume consumed is 976 ml/day/person. However, nearly 75% of consumed water was bottled water. Daily water volume consumed as tap water, bottled water, or both is presented in Table 4.

The analysis by subpopulation showed that there were no differences with respect to water preferences, and for all of groups, bottled water was the first choice of water source. The percentage of bottled or tap water consumed with respect to subpopulation is shown in Fig. 2.

For water consumers, the survey data showed the existence of a similar consumption pattern in the four different consumer groups considered in our study. In all groups, the preferred water type was bottled water, although a proportion of the interviewees expressed their preference for tap water (Fig. 2). The χ^2 independence test for population group and beverage preference was not rejected ($P > 0.5$), which implies that water consumption preference is not associated with any population group. Thus, the proportion of people who prefer bottled water is the same regardless of the population group, and the same is true for the other two categories of beverage preference. The reasons for these results are unclear but may reflect the

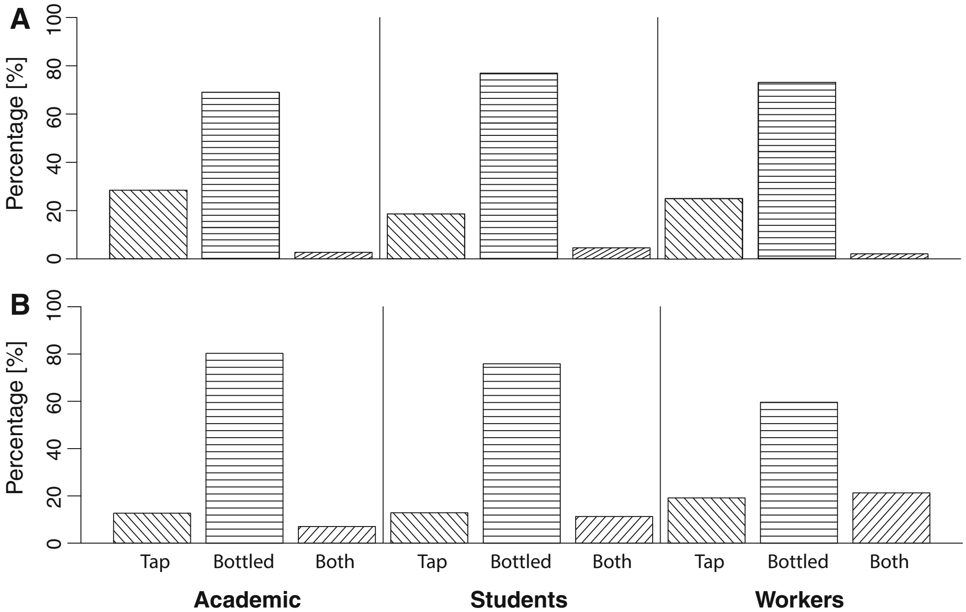

Figure 3. Percentage of water consumed by the University City community during their stay on campus (**a**) and during their time at home (**b**).

Table 4. Mean Volume of Water Consumed by the University Population

Volume	Tap water	Bottled water	Both
Consumption (ml/day/person)	961.0	969.7	1,043.0
Population (%)	13.3	74.8	11.3

Table 5. Reasons for Water Source Selection

Criteria group and consumers (%)	Reasons
Organoleptic (54.1)	Taste
	Odor
	Color/turbidity
	Concern of taste, odor, color/turbidity
Health concerns (26.1)	Distrust in disinfection
	Believe they will get sick
Others (19.8)	

effect of advertising on public preference for bottled water or other factors that satisfy the consumer's demand.

Causes for Tap Water or Bottled Water Preference

To understand the reasoning behind the selection of water from the University City campus distribution system or bottled water, we asked the study participants what selection criteria they applied to their choice. The responses were grouped according to the proportion of each criterion in Table 5.

Organoleptic reasons for water preference include the following: dirty, bad taste, odor, color/turbidity, and concerns related to taste, odor, color/turbidity based on previous experience with one or more of the characteristics of tap water.

Health reasons include ignorance of the disinfection process, mistrust concerning the disinfection process, thinking that tap water is only for irrigation, and thinking that tap water will cause sickness. Other reasons include the following: regularly drink water from the campus distribution system, wanting to drink another beverage, bringing water from home, and drinking bottled water exclusively.

The interviewees had a predominantly negative perception with respect to tap water quality; thus, they did not drink tap water. In contrast, the second reason for avoiding tap water was related to its health aspects, highlighting an ignorance with respect to the source of tap water and efficiency of the disinfection process.

Cost of Bottled Water vs. Tap Water

The data obtained on bottled water consumption allowed us to consider the cost of bottled water vs. the cost of tap water and the production of solid waste. Considering the price of bottled water on campus, we estimated the daily expenditures of at least 75% of the University population for the purchase of bottled water. The representative sample considered in this study allows an estimate of the cost of bottled water consumed daily on the campus.

The average price of 1 l of bottled water on campus is equivalent to $0.91 USD, and considering that our representative survey shows that 75% (98,610 individuals) of the University City population drink 969.7 ml of bottled water (95,622 l) daily, then the daily estimated investment is equivalent to $87,016 USD.

On campus, tap water does not constitute an expense because it is subsidized; however, for the purpose of comparing current water prices, the minimum price of water from the distribution system in Mexico City is $135.00 Mexican pesos (equivalent to $10.35 USD) for 10 m^3. Fees increase according to the water volume used, with a high volume of consumed water incurring a fee increase. Comparing the cost of bottled water and tap water shows a tremendous difference.

Solid Waste Engendered by Consumption of Bottled Water

Bottled water is related to another problem: the generation of polyethylene terephthalate (PET) waste. At present, UNAM environmental authorities do not know the volume of PET discarded by the University City. However, it is possible to estimate PET waste on the campus assuming that bottled water consumption is a rough measurement of the production of this type of waste. Solid waste from bottled water not only has cost implications but also results in energy expenses related to production that should be considered. Based on Gleick and Cooley (2009), if the average 1 l bottle weighs 38 g and assuming the bottled water consumed daily is 95,622 l, the amount of discarded PET could be approximately 3.63 tons.

Energy expenses for this volume of PET production could be between 532,483 and 975,344 MJ (5.6–10.2 MJ/l), which is equivalent to 89–162 barrels of oil per day (6,000 MJ/barrel). Although these figures may be an overestimation, they are based on daily bottled water consumption for the University City campus and provide a rough idea of the associated problem.

Discussion

This study comprises an analysis of the water consumed by a section of the Mexico City population based on the water consumed by the University City community. Mexico City is not homogeneous (Parnreiter 2002), and the University City community that was sampled is representative of the city, considering that the university attracts people from the entire city (Estadísticas UNAM 2009–2010 2010; INEGI 2011).

The student subpopulation is predominant at UNAM (>70%), but the historic context of our data are noteworthy because it provides a clue to understanding the younger generation's water consumption habits.

The 1985 earthquake in Mexico City exerted a strong influence on the population. One of the most important effects was damage to the hydraulic system, which resulted in a change in water consumption habits from tap water to bottled water (PAHO 1985). Although this change was made as a temporary control measure to prevent outbreak of disease, the population continues to consume bottled water, complementing it with water from the distribution system, which presents important variations in quality (Mazari-Hiriart et al. 2005).

For Mexico City residents, it is not easy to obtain information on the quality of the water that is being distributed to their homes. In the *Sistema de Aguas de la Ciudad de México* website (www.sacmex.df.gob), information is available on the quality of the water distributed within the city; however, updates are irregular (August 2014 information shows data from 2012).

Information is only available for people with Internet access. The published data correspond to the free chlorine and bacteria presence with a monthly frequency. For example, the average of these two parameters appears each month and covers a population supplied as large as 1,875,786 inhabitants for Iztapalapa.

This lack of information has reinforced mistrust and has encouraged the consumption of bottled water, despite the lack of information regarding the origin and/or quality of bottled water.

The offending organoleptic features of tap water were declared to be the main reason for bottled water consumption. Health was the second reason for consuming bottled water, which was the main cause for recommending a change in water consumption to the population in 1985 and in the 1990s during the cholera pandemic.

Interestingly, other research results are in agreement with this finding, although the countries studied, France and Canada, present different conditions compared with Mexico City (Doria 2006).

In previous studies, it was found that university students have a preference for bottled water compared with tap water, with the perception being that bottled water is safer and has a more pleasant taste (Ward et al. 2009; Saylor et al. 2011; Yao 2011).

This finding is relevant to determine whether individuals drink bottled water because it is the only or the best option they have to preserve their health or whether they do not care about tap water quality and just drink bottled water as a habit. It is worth noting that most consumers have no idea what the quality is of the bottled water that they consume. There are reports that show microbial presence or other pollutants in bottled water, which undermines the belief that bottled water is safe (Raj 2005; Gleick 2010; Hu et al. 2011).

The results of this study show that the inhabitants of Mexico City do not drink tap water because of information on water quality; apparently, they are not interested in ascertaining water quality details and would rather continue with their habit of drinking bottled water.

There is a relationship between water quality perception (organoleptic) and healthy or safe water, with water odor and taste having been studied and associated with pollutants (Suffet and Rosenfeld 2007; Whelton et al. 2007). However, there is not enough evidence to suggest how odor or taste is related to a hazard.

Solid waste generated by bottled water consumption has serious implications, not only for waste management but also with respect to energy consumption. Although PET bottles can be recycled, the recycling process itself involves additional energy costs (Gleick and Cooley 2009). All of these considerations go against the most basic principles of sustainability and represent habits that need to change among the population, especially in the younger generations. The estimates presented in this study showed that 1 l of bottled water frequently costs nearly the same as 1 l of gasoline, but this figure does not take into account the related costs of solid waste management and/or recycling.

While it is important to understand why bottled water is selected so frequently as the source of drinking water, it is even more critical to determine why bottled water is considered the only option for drinking water when families could redistribute their expenditures on other basic needs. This is a problem for Mexico as a country that must be solved.

It is extremely important to note that it is the responsibility of municipal-level water authorities to supply reliable drinking water and to inform their consumers of the details of these water issues. The general trend is that water supply and quality issues do not improve at the pace that new problems arise.

Federal and regional levels of government have an increased their technical capacity for addressing this issue in the emerging economy. Conditions have improved, but not at the rate required for one of the world's megacities. Providing reliable, quality drinking water to the inhabitants of Mexico City in the twenty-first century is a topic that should be resolved by the Mexican water authorities with the highest priority.

Official government reports list the issue of safe drinking water as being controlled, with approximately 90.7% of piped water for the whole country in 2009 receiving chlorine coverage, as reported by the federal authority, the National Water Commission (Comisión Nacional del Agua) (CONAGUA 2011). The Comisión Federal para la Protección contra Riesgos Sanitarios (COFEPRIS) report for April 2010 stated that throughout the country, residual chlorine coverage was approximately 90% in piped water; it was also reported that 85.76% of this population is not at risk associated with their exposure to drinking water (COFEPRIS 2010). It is important to highlight that these percentages are based on a sole parameter, residual chlorine, which is only one of the 38 parameters included in the current Mexican drinking water regulations (DOF 2000). We do not believe that the residual chlorine concentration reflects the quality of the water being distributed; it is only a starting point in what should be an evolving monitoring/surveillance program, which should be a priority for water authorities with a long-term goal of providing safe drinking water to the population.

Water distributed to the population is being disinfected and monitored for compliance by two different governmental institutions: the National Water Commission and COFEPRIS, which is part of the Ministry of Health. These agencies possess the technical capacity required to ensure safe drinking water but should increase their coverage and surveillance and share the results with the population of consumers.

While monitoring information for water that is bottled for drinking is unknown or at least scarcely available as public information, the Ministry of Health must approve the bottled water before permission is granted for its sale. Gleick (2010) reports a list of cases of contaminated drinking water in the U.S. and other countries, evidence that demonstrates the need for strict water control, a priority issue considering that Mexico is one of the top consumers of bottled water worldwide. An incongruity exists with official numbers that were previously reported;

Mexico is the second highest country worldwide in bottled water consumption (Gleick et al. 2006).

The rate of consumption of bottled water in Mexico encourages reflection on what the priority should be regarding water consumption. Should promoting strict surveillance of bottled water be prioritized over improving the entire water distribution system? Or should a strict program of monitoring and controlling piped water be instituted, with the goal of distributing quality drinking water that is acceptable to the population and would have a positive impact at the family-wellness level.

Based on this case study of a local issue in one of the most developed and monitored areas of Mexico, water quality appears to be a topic that has not yet been resolved for Mexico City or for the country as a whole.

Conclusions

The University City community consumes bottled water as the principal source of drinking water. The community's perception of tap water quality coupled with misinformation surrounding drinking water management and the disinfection process on the UNAM University City campus promotes distrust.

Improving actions for water disinfection and surveillance and conducting risk assessment studies should provide support for a strong campaign to promote tap water consumption in the UNAM, a goal that can be achieved if consumers trust the quality of tap water.

In Mexico, at the time that this study was carried out, there was no penalty system in place when faults occurred in the disinfection system that were attributable personnel mistakes. This must change, supported by technical, health, and social arguments.

The organoleptic characteristics of tap water perceived by the consumers, to which insufficient consideration in official water quality monitoring has been afforded, comprise the main reason that members of the university community do not consume tap water, while the secondary cause is related to health concerns.

Monitoring and surveillance of bottled water quality is not a priority for national health authorities despite its high consumption by the population.

Ensuring adequate drinking water quality in the distribution system gives consumers a choice between the consumption of tap or bottled water, compared with consumers having limited drinking water options at a higher cost.

To approach sustainable water consumption, the quality of tap water, in accordance with associated health, economic, social, and environmental issues, should be a priority for incoming federal and local authorities.

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