Bottled vs tap water perceptions, choices and recommendations in a US Midwest university community

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Received 7 January 2022
Revised 22 June 2022
4 October 2022
Accepted 5 October 2022

Abstract

Purpose – This study aims to determine preference and concerns regarding tap vs bottled water and recommendations to increase tap water use in a US Midwest university. The authors propose interventions to increase tap water use based on survey results.

Design/methodology/approach – The authors conducted an online survey of the community of a regional comprehensive university in the St. Louis metro-east region (Illinois, USA). They analyzed 781 responses using mixed methods, and developed recommendations based on community-based social marketing principles.

Findings – Black respondents reported higher bottled water use than White respondents. Undergraduate students reported higher bottled water use than faculty or staff. Most respondents were concerned about cost and environmental impact for bottled water and taste and water quality for tap water. Chemical and safety concerns were specific and location-focused for tap water only. Concerns were similar to Safe Drinking Water Act mandated public information, such as prior reports of lead (Pb) in campus drinking water. Tap water taste concerns may relate to proximity to the water treatment plant, resulting in high residual chlorine levels. To increase tap water use in this community, the authors recommend persuasive information campaigns, improvements to infrastructure and distribution that increase tap water convenience, more transparent public reporting on tap water lead levels, management of residual chlorine levels, and establishment of institutional norms favoring tap water over bottled water.

Originality/value – The authors evaluate barriers to drinking tap water across multiple environmental and social systems. The methods used in this study combine mixed methods analysis and community-based social marketing. The findings integrate respondent demographics and concerns, local water quality, local and national contamination events, campus-specific sustainability initiatives and barriers, and national drinking water regulations.

Keywords African American, Consumer choice, College student, Drinking water quality, Opinion, Plastic

Paper type Research paper

The authors thank Nicholas Guehlstorf and Connie Frey-Spurlock (SIUE) for helpful feedback on study design and analysis. We thank two anonymous reviewers and Koh Hock Lye for their constructive reviews of the manuscript.

Funding: Support was provided by the National Science Foundation GEOPAths program to MS (Award # 1911512). Southern Illinois University Edwardsville provided project financial support to KO (Research Grant to Graduate Studies) and MS (Undergraduate Research and Creative Activities).

International Journal of Sustainability in Higher Education

1467-6370
DOI 10.1108/IJSHE-01-2022-0007

Introduction

Potable tap water and bottled water are often both available, and use of tap versus bottled water is a behavioral choice (Doria *et al.*, 2009; Doria, 2006; Hu *et al.*, 2011). Compared to tap water, bottled water use has multiple problems, including much higher cost and lower regulatory oversight (Gleick, 2010; Olson *et al.*, 1999). Bottled water is also less sustainable than tap water because of greater energy use, greenhouse gas emissions and impacts to ecosystems (Botto *et al.*, 2011; Gleick and Cooley, 2009; Villanueva *et al.*, 2021). Further, bottled water can harm public equity by exacerbating differences in safe water access between wealthy and low-income individuals (Cohen and Ray, 2018; Parag and Roberts, 2009).

Because of the environmental impacts and social inequalities resulting from bottled water, efforts are made to reduce bottled water and increase tap water consumption (Parag and Roberts, 2009). However, different populations encounter local socioeconomic, cultural, demographic and environmental factors that can reduce tap water preference (Doria, 2010, 2006). Local surveys can aid in understanding the specific concerns and behaviors of a target population, resulting in more effective methods to increase tap water use (Choate *et al.*, 2018; McKenzie-Mohr *et al.*, 2012).

We evaluate concerns and perspectives regarding tap vs bottled water, and make suggestions to improve campus sustainability by reducing reliance on bottled water. Our study focuses on Southern Illinois University Edwardsville (SIUE), a regional comprehensive university. We perform a mixed-methods analysis on a cross-sectional survey. We identify concerns and recommendations of this university population and propose interventions to increase tap water use. We compare these local results to existing findings in the global literature.

Our study answers four research questions:

RQ1. What is the association between demographic factors (e.g. age, race, students vs faculty) and self-reported consumption patterns?

RQ2. How do drinking water concerns and perceptions differ according to use of tap vs bottled water?

RQ3. What are the predominant concerns about tap and bottled water?

RQ4. What do respondents recommend to reduce bottled water consumption?

After addressing these questions, we summarize information on local tap water characteristics to determine possible causes of the high reported concern with tap water organoleptics (taste and odor). Finally, we explore options for community-based social marketing (McKenzie-Mohr *et al.*, 2012), informed by survey respondent opinions, to increase campus tap water use and reduce bottled water use.

Literature review

Environmental, economic, social and psychological factors influence drinking water choice (Doria, 2010, 2006). In high-income countries, tap water quality is maintained by legal regulations, such as safe drinking water requirements (EEA, 2016; USEPA, 2020). When public drinking water infrastructure is well developed, preference for bottled water presents a paradox; individual benefits are questionable while societal harms are significant.

There are many societal harms from bottled water. The first is public equity. Bottled water increases expense for low-income consumers, exacerbates economic disparities in

access to safe potable water, reduces public insistence on water safety testing and reduces public demand for and trust in clean and accessible tap water (Cohen and Ray, 2018; Parag and Roberts, 2009). Bottled water also causes a wide range of environmental impacts, including non-renewable resource depletion (e.g. petroleum), greenhouse gas emission and plastic waste production (Botto *et al.*, 2011; Gleick, 2010; Gleick and Cooley, 2009; Villanueva *et al.*, 2021).

For the consumer, bottled water can have comparable or greater risk than tap water. In the USA and many other countries, bottled water contamination and safety regulations are generally weaker and less protective than for tap water (Gleick, 2010; Olson *et al.*, 1999). Bacterial and chemical contamination of bottled water has been observed (Erythropel *et al.*, 2014; Lalumandier and Ayers, 2000; Saleh *et al.*, 2008). Additionally, bottled water does not provide fluoride to prevent tooth decay (Lalumandier and Ayers, 2000; Olson *et al.*, 1999; Saleh *et al.*, 2008).

In recent decades, global consumption of bottled water has dramatically increased (Cohen and Ray, 2018; Olson *et al.*, 1999). Given the above described harms, the reasons for increased bottled water use have been investigated. Public preference for bottled water stems from public concerns regarding tap water taste, health risk and water quality (Abrahams *et al.*, 2000; Doria, 2006; Hu *et al.*, 2011; Parag and Roberts, 2009). Bottled water marketing capitalizes upon and exacerbates these concerns, focusing on concepts such as purity, safety and natural sources, and promoting misleading notions that bottled water is safer and healthier (Gleick, 2010; Olson *et al.*, 1999; Opel, 1999; Parag and Roberts, 2009).

Local conditions also affect water preference. Water quality perceptions and concerns vary among locations because of both water quality and population characteristics. Organoleptic properties (i.e. color, taste, odor and turbidity) are important for perceptions of drinking water quality and preferences (Doria, 2010, 2006; Doria *et al.*, 2009). Consumers often use water treatment systems or prefer bottled water because of poor tap water taste (Abrahams *et al.*, 2000; Curry, 1983; Levallois *et al.*, 1999; Turgeon *et al.*, 2004). Concern about specific chemicals such as lead (Pb) and chlorine can also vary greatly among studies and locations (Doria, 2010; Doria *et al.*, 2009; Turgeon *et al.*, 2004).

Public health failures because of tap water can also increase concern and shift preference toward bottled water (Parag and Roberts, 2009). For example, the Flint, Michigan (USA) water crisis, beginning in 2014, resulted in childhood lead poisoning and substantial media attention (Hanna-Attisha *et al.*, 2016; Henderson and Wells, 2021). This was followed by tap water avoidance and increased bottled water use among children (Rosinger and Young, 2020). In the USA, public drinking water that is safe and adequate may be less available than previously considered (Rosinger and Young, 2020). Serious violations of the Safe Drinking Water Act occur in 19% of US counties. These issues disproportionately affect low income residents (Mueller and Gasteyer, 2021), who are also less likely to consume tap water (Rosinger *et al.*, 2018; Rosinger and Young, 2020). As such, reduced reliance on tap water for drinking has environmental justice dimensions, and especially affects vulnerable subpopulations (Roller *et al.*, 2019).

Demographic traits, including gender, race and socioeconomic status, are also associated with drinking water behavior and perception of water quality (Abrahams *et al.*, 2000; Anadu and Harding, 2000; Doria, 2006; Hobson *et al.*, 2007; MEL Research, 1996; Pierce and Gonzalez, 2017; Saylor *et al.*, 2011; Vieux *et al.*, 2020). In the USA, African Americans, Hispanics, Asian Americans and individuals born in other countries are less likely to

consume tap water than non-Hispanic Whites and individuals born in the country (Doria, 2006; Hobson *et al.*, 2007; Rosinger *et al.*, 2018; Vieux *et al.*, 2020).

For university communities, there have been many investigations of drinking water preference. This is presumably because campus populations are readily accessible, engaged in learning and potentially responsive to interventions. Most campus studies are quantitative analysis of surveys (Díez *et al.*, 2018; Espinosa-García *et al.*, 2015; Güngör-Demirci *et al.*, 2016; Levêque and Burns, 2018; van der Linden, 2015; O'Donnell and Rice, 2012; Qian, 2018). Qualitative (Ward *et al.*, 2009) and mixed methods (Graydon *et al.*, 2019; Saylor *et al.*, 2011) analyses are uncommon. Santos and van der Linden (2016) found that students provided with reusable water bottles drank less water from disposable bottles. Saylor *et al.* (2011) proposed multiple strategies to reduce campus reliance on bottled water based on survey results combined with community-based social marketing. Community-based social marketing is an effective approach to increase sustainability by providing positive incentives and reducing barriers to behavior change (van der Linden, 2015; McKenzie-Mohr *et al.*, 2012).

In light of current knowledge, the novel contribution of our study is its multifaceted and integrative approach. We combine mixed-methods analysis with a detailed local examination of the multiple factors that influence drinking water choice. We examine multilevel social systems (sensu Bronfenbrenner, 1977), including personal concerns expressed in survey responses, institutional practices (sustainability initiatives and existing commercial partnerships), differences among ethnic and social groups and national legal policy. We combine this social analysis with examination of the environmental factors affecting local drinking water organoleptics (taste and odor), and their influence on reported concerns. Finally, we consider these combined findings in the community-based social marketing framework to propose barriers and strategies for increasing tap water use on campus.

Methods

Survey population and location

The SIUE population includes 12,860 students, 628 full-time instructional faculty and 1,474 administrative and civil service employees. SIUE is a regional comprehensive university, with 81% of students from Illinois and 12% from the adjoining state of Missouri (SIUE, 2021). SIUE obtains its drinking water from the City of Edwardsville, from a well field which draws water from the American Bottom Aquifer. The water is stored in a 400,000-gallon underground reservoir and pumped from the reservoir to serve campus needs (SIUE, 2020a). In 2016, SIUE reported several cases of elevated lead in campus tap water, including some water fountains (SIUE, 2016a, 2016b).

Sustainability initiatives on the SIUE campus were summarized in a 2016 online submission to the Sustainability Tracking, Assessment and Rating System (STARS). The university's strategic plan includes a long-term goal of "physical and financial sustainability [. . .] by practicing and promoting economic, environmental, and social sustainability campus wide" (SIUE, 2017). Neither the STARS report, nor the strategic plan specifically, refers to increased sustainable sourcing of drinking water or reduction of the waste stream from packaging or consumer products. Any such initiatives could be integrated into future efforts, such as the "Food and Beverage Purchasing" or "Waste Minimization" categories in the STARS program.

Survey instrument and data collection

The survey instrument was a self-administered questionnaire, delivered on the week of April 26, 2017. The 17 survey questions included six multiple choice, eight multiple selection

(select all that apply) and three open-ended questions. Questions address tap and bottled water consumption behavior and concerns, and methods of water treatment. Separate questions evaluate participant characteristics, including age, ethnic identification, university affiliation and location of residence. Preliminary versions of the survey were tested with student volunteers to ensure clarity of format, expectations and questions.

The first two survey questions were on what type of drinking water respondents personally drink at home and outside the home. Ordinal scale answers were: 1 = only tap water, 2 = mostly tap water, 3 = similar amounts of tap and bottled water, 4 = mostly bottled water and 5 = only bottled water. Question 3 (multiple selection) asked respondents to select their concerns regarding tap and bottled water. Possible choices included cost, taste, convenience, availability, environmental impacts, plastic bottles and four indicators of water quality and treatment. Question 4 (multiple selection) asked respondents to select among nine potential concerns that, "you think cause important health risks for drinking water in the USA." Possible choices included seven known or potential health concerns (bacteria, chlorination byproducts, endocrine disrupting compounds, fluoride, lead, asbestos and nitrates) and two additional hazards that are not concerns for drinking water (carbon monoxide and microwave radiation). These latter two provided a general sense of the proportion of respondents that would report concerns that are scientifically unwarranted. Responses to individual concerns were tabulated and the total number of answers selected (zero to nine) was also summed. Three demographic questions included age (seven categories), relationship to SIUE (graduate student, undergraduate student, faculty, administration, staff, alumni and other) and ethnicity (multiple selection; nine options, including prefer not to respond). Three open-ended questions asked for opinions and concerns regarding tap water; opinions and concerns regarding bottled water; and recommendations to encourage people to drink tap water more often.

The survey target population was adult (18 years or older) members of the SIUE community, including students, current and retired employees and alumni. The survey was delivered to several university electronic mailing lists (listserves). These included the discussion list (available to all faculty, staff and administrators), alumni list, retirees list and all campus student residential mailing lists. The survey was developed in SurveyMonkey and then sent to the student lists on May 1, 2017 and all other lists on April 26, 2017. As a participation incentive, $20 Amazon gift cards were given to 12 randomly chosen respondents. Institutional Review Board approval was obtained from the SIUE Office of Research and Projects prior to study inception.

Quantitative analysis

Data extracted from all survey questions were analyzed for univariate trends and for bivariate associations. We performed univariate (e.g. frequency of response) and bivariate analysis of drinking water preference, demographic factors and concerns reported for tap vs bottled water. We used the Kruskal–Wallis test to compare ranked versus categorical variables, followed by a multiple comparison of pairwise significance using the Nemenyi test with χ^2 approximation (R package PMCMR). We used the Wilcoxon rank-sum test to compare ranked vs dichotomous variables. We used Spearman rank correlation coefficients to compare numeric or ordinal variables. Significance of pairwise correlation coefficients, or of multiple Wilcoxon rank-sum test results, was adjusted using the Benjamini and Yekutieli (2001) false discovery rate control procedure. For all tests, significance was evaluated at α = 0.05, after adjustment for multiple comparisons. Respondents who selected "Prefer not to

say" for ethnicity were excluded prior to bivariate analyses with ethnicity. Statistical and graphical analyses were performed in R v4.0 (R Core Team, 2020).

Open-ended questions, objectives of mixed-methods, and qualitative analysis

Following the framework of Greene *et al.* (1989), the primary goals of the mixed-methods analysis are complementarity and expansion. The two open-ended questions on respondent concerns and opinions regarding tap and bottled water were complementary to the closed-ended questions on these topics. The open-ended questions thus provided "elaboration, enhancement, illustration, [and] clarification" (Greene *et al.*, 1989). The open-ended question asking for recommendations to encourage people to drink more tap water expanded our study, allowing us to examine possible interventions to increase tap water use on campus. Following Bryman's (2006) framework, this achieves the goal of utility, the applied usefulness of study findings. Other goals of our mixed-methods analysis include completeness, different research questions, explanation, illustration and enhancement (Bryman, 2006, pp. 106–107).

We coded answers to the three open-ended survey questions using thematic analysis; themes were identified inductively and reflexively (Braun *et al.*, 2018; Braun and Clarke, 2006; Vaismoradi *et al.*, 2013) as follows. All question answers were initially coded into one or more themes. Themes were then examined and compared, along with answers, with some themes combined or separated in an iterative process based on theme uniqueness. For example, "cleanliness" was chosen as a theme that encompassed general water quality as well as specific constituents that entered or could enter the water. Answers deemed unusual or not previously identified were flagged for future evaluation. These flagged answers were later reexamined for potential new themes. Because of prior reports of lead in campus water, specific themes of "lead" as well as other commonly reported chemical concerns [bisphenol A (BPA), fluoride and chlorine] were included. Simple content analysis was also performed, by examining the count of answers corresponding to each identified theme. Therefore, analysis of the open-ended questions included both qualitative and quantitative aspects (Vaismoradi *et al.*, 2013).

Results

Study population

The 781 survey responses included 392 undergraduate students (50.2% of total), 208 academic staff (26.6%), 98 faculty (12.5%), 39 graduate students (5.0%), 15 administration (1.9%), 5 alumni (0.6%), 20 other (2.6%) and 4 (0.5%) who did not identify affiliation. Race reported by undergraduate respondents was similar to the SIUE undergraduate population in 2017 (SIUE, 2019) for African Americans (hereafter, Black: 14.8% versus 14.3%), non-Hispanic Whites (hereafter, White: 73.7% versus 73.3%) and other races/ethnicities (10.5% versus 11.1%). Among SIUE employees, a lower proportion of the respondents identified as Black (5.6%) compared to the SIUE employee population in 2017 (13.4%). Examining ages, the number of young respondents (18–21 years old) was 80% in the survey versus 73% in the SIUE undergraduate population. The discrepancy may be because undergraduates were recruited using the university housing mailing lists, and undergraduates who live on campus are younger than the general undergraduate population.

Quantitative analysis

Among nine possible health and safety concerns with United States water, survey respondents most frequently selected lead ($N = 651$; 83.4%), followed by bacteria ($N = 519$, 66.4%), chlorination byproducts ($N = 354$; 45.3%) and fluoride ($N = 268$; 34.3%). Among the

putative hazards that are not known to be concerns, 8.7% and 9.3% (N = 68 and 73) of respondents selected carbon monoxide or microwave radiation, respectively, and 5.0% (N = 39) chose both.

Drinking water choice both in the home and outside the home was significantly associated with SIUE affiliation (Kruskal–Wallis $\chi^2_{df=5} = 48.8$, $p < 0.0001$ in the home; $\chi^2_{df=5} = 57.8$, $p < 0.0001$ outside the home). Alumni were excluded from this analysis because of small sample size (N = 5). Both in the home and outside the home, tap water preference was greatest for faculty, intermediate for staff and lowest for undergraduate students (Figure 1).

Drinking water choice both in the home and outside the home was also significantly associated with ethnicity (Kruskal–Wallis $\chi^2_{df=6} = 58.6$, $p < 0.0001$ in home; $\chi^2_{df=6} = 68.0$, $p < 0.0001$ outside home). To avoid confounding, we also analyzed ethnicity vs drinking water choice within specific SIUE roles. We performed this separate analysis for undergraduate students and for staff only, because they had at least five respondents for at least three ethnicities. Ethnicity was associated with drinking water choice outside the home for both undergraduates ($\chi^2_{df=5} = 33.1$, $p < 0.0001$, n = 389) and staff ($\chi^2_{df=5} = 11.1$, p = 0.048, n = 201). The association inside the home was significant for undergraduates (Kruskal–Wallis $\chi^2_{df=5} = 31.9$, $p < 0.0001$) but not for staff (Kruskal–Wallis $\chi^2_{df=5} = 9.46$, p = 0.09). For all respondents and for undergraduates, White respondents more often reported drinking tap water, while Black respondents more often reported drinking bottled water (Figure 2). Post hoc pairwise analysis was not significant for staff.

All but three numeric and ordinal variables were significantly correlated (Table 1; sample size ranging from 775 to 778). Drinking water choice in vs outside the home was highly correlated (Spearman ρ = 0.62). Age was weakly negatively correlated (ρ from 0.10 to 0.21) with most variables. Younger respondents reported higher use of bottled water in the home and outside the home. Younger respondents also had more concerns from health risks, from tap water or from bottled water. These correlations with age were no longer significant when examining undergraduates (N = 392) or staff (N = 206–207) alone. Thus, the association with age reflects differences between the younger undergraduates and the other groups, which were older.

Correlations were also observed between drinking water choice and health concerns (Table 1). Drinking water choice was associated more with concerns regarding tap water than bottled water. For example, the number of tap water concerns was associated with choosing

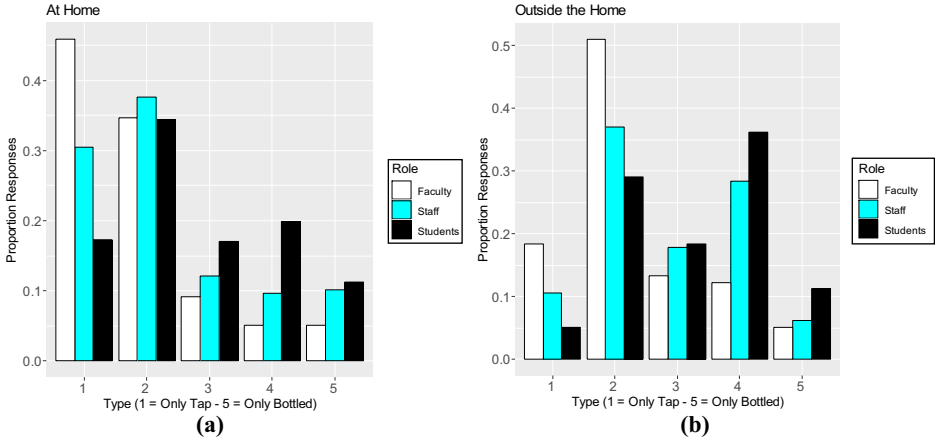

Figure 1. Proportion of faculty, staff and undergraduate students reporting different drinking choices

Notes: (a) At home; (b) outside of the home

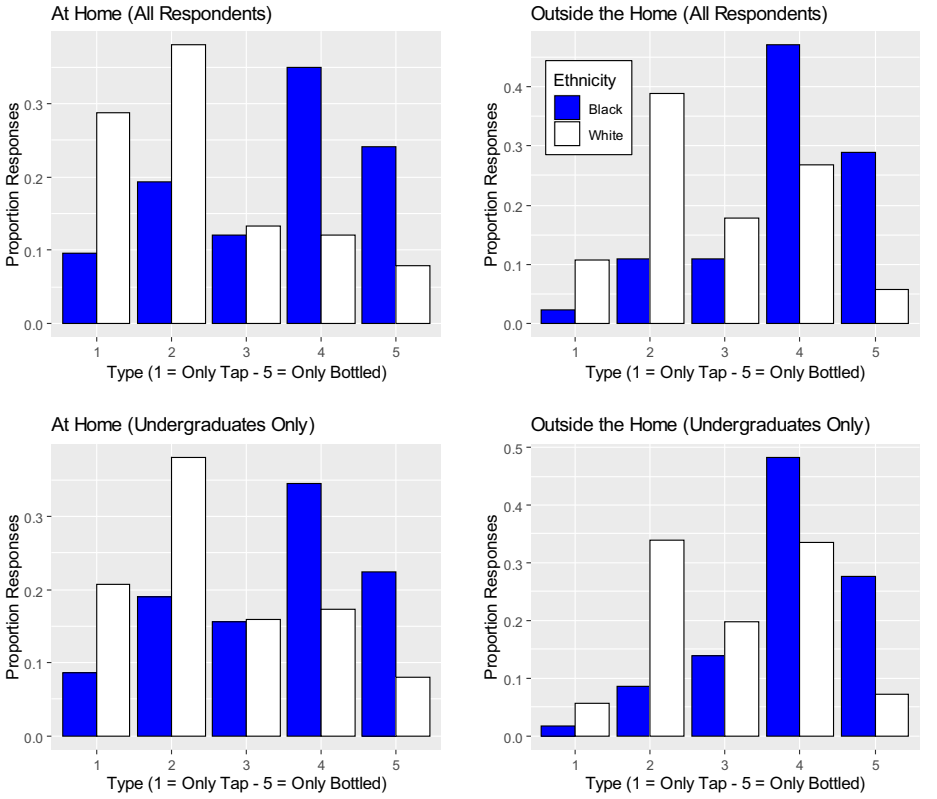

Figure 2.
Proportion of Black (African American) and non-Hispanic White respondents reporting different drinking choices at home (left panels) or outside the home (right panels) for all respondents (top panels) and undergraduate students only (bottom panels)

Variable	Age (Q7)	Drink at home (Q1)	Drink outside home (Q2)	Health risks (Q4)	Bottled water concerns (Q3)
Drink at home (Q1)	*−0.20*				
Drink outside home (Q2)	*−0.23*	*0.62*			
Health risks (Q4)	−0.06	0.05	*0.11*		
Bottled water concerns (Q3)	*−0.10*	*−0.11*	−0.03	*0.31*	
Tap water concerns (Q3)	*−0.21*	*0.18*	*0.25*	*0.38*	*0.36*

Note: Results in italics were statistically significant ($p < 0.05$)

Table 1.
Spearman rank correlation coefficients among numeric or ordinal variables

bottled water outside the home. In contrast, the number of bottled water concerns was not associated with water choice outside the home (Table 1). Positive correlations were also observed between the number of concerns selected for tap water, for bottled water and for health risks from drinking water. These correlations may indicate variation in risk aversion from water in general, as well as level of responsiveness to "select all that apply" questions.

Among the 13 specific concerns that could be selected for tap or bottled water (Table 2), most respondents were concerned about cost and environmental impact (79% and 78%

Table 2. Selection of 13 concern types for bottled water and tap water

Concern type	% selected ($N = 781$)	Concern about tap water: p-value[a]	Concern about tap water: Drinker type more concerned	Concern about bottled water: (%) Selected	Concern about bottled water: p-value[a]	Concern about bottled water: Drinker type more concerned
Cost	4	NS		79	0.04	Tap
Taste	70	<0.001	Bottled	24	NS	
Convenience	29	NS		34	0.001	Bottled
Environmental impact	11	NS		78	<0.001	Tap
Safety and health	61	<0.001	Bottled	31	NS	
Availability	29	NS		35	<0.001	Bottled
Don't like to drink out of plastic bottles	8	NS		33	<0.001	Tap
Treatment process	52	<0.001	Bottled	33	NS	
Cleanliness of the water source	68	<0.001	Bottled	27	NS	
Worry about the building water pipes	64	<0.001	Bottled	7	NS	
Insufficient regulations of its quality	46	<0.001	Bottled	28	0.04	Tap
I have no concerns about this water source	15	<0.001	Tap	16	<0.001	Bottled
Other	5	NS		3	NS	

Notes: Concerns are listed following the order presented in the survey question; p-values are for pairwise comparison of whether the concern was selected vs self-reported type of water consumed outside the home. [a]Wilcoxon rank-sum test; NS = false discovery rate corrected p value > 0.05

selected, respectively) for bottled water. For tap water, most respondents were concerned about taste (70%) and quality concerns, including cleanliness of the water source (68%), worry about the building water pipes (64%), safety and health (61%) and treatment process (52%). These tap water concerns were more likely to be chosen by respondents with higher bottled water consumption outside the home (Table 2 and Fig. 3). In contrast, respondents with higher tap water consumption were more likely to be concerned about bottled water plastic, environmental impacts, cost and insufficient regulations of bottled water quality (Table 2).

A total of 13% of respondents reported concern for either microwave radiation or carbon monoxide in drinking water (i.e. issues that are scientifically unwarranted). The percentage was higher for undergraduates (20%) than faculty (5%), staff (8%) or graduate students (5%). Respondents concerned with either of these scientifically unwarranted issues reported greater bottled water use, both in the home (Wilcoxon rank sum test, $W = 39{,}151$, $p = 0.016$) and outside the home ($W = 39{,}628$, $p = 0.014$).

Analysis of narrative responses

There were 505 and 522 written answers to the open-ended questions on opinions and concerns regarding tap water and bottled water, respectively. Regarding tap water, similar to the closed-ended question, respondents most frequently expressed concern regarding water cleanliness ($N = 206$ responses to the tap water question), organoleptics (taste or odor; $N = 136$) and health and safety ($N = 90$). Common cleanliness terms included *clean*, *dirty*, *contaminated*, *purity* or specific constituents of the water, such as *particles*, *bacteria*, *pH* and *chlorine*. Frequency of these concerns was lower for bottled water: 72 respondents mentioned cleanliness, 54 mentioned organoleptics and 52 health and safety.

The most common theme for bottled water concerns was environmental impacts ($N = 271$ responses to the bottled water question). Nevertheless, environmental or safety regulations were more frequently mentioned on the tap water question ($N = 28$) than the bottled water question ($N = 14$). Specific environmental concerns were also more frequently mentioned for tap water. This included the water contamination incident at Flint, Michigan ($N = 14$ tap water answers and no bottled water answers) and drinking water lead ($N = 60$ tap water answers vs no bottled water answers). Tap water narrative responses also mentioned several other constituents more than bottled

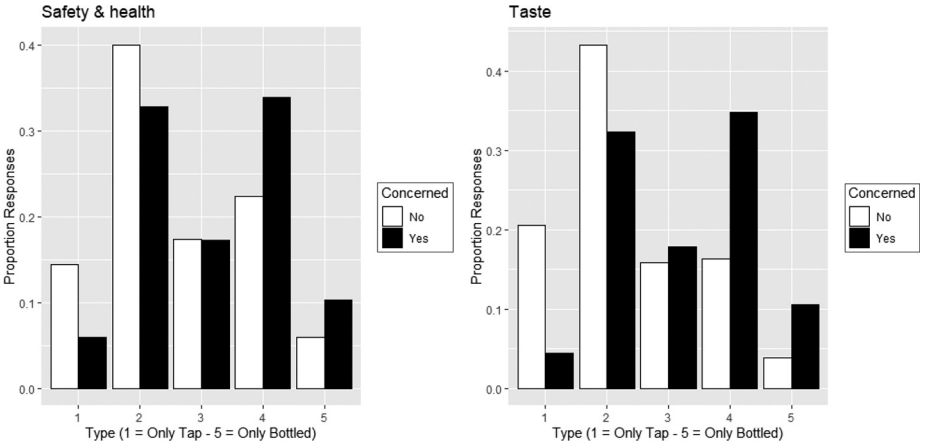

Figure 3.
Respondent concerns regarding tap water safety and health (left panel) and tap water taste (right panel) in comparison to self-selected drinking type outside the home

water responses, including chlorine (8 tap water responses vs 2 bottled water responses), fluoride (15 vs 3 responses) and bacteria (15 vs 4 responses). In total, respondents referred to lead, microbes (e.g. bacteria), chlorine and fluoride 97 times in survey tap water narrative responses, but only 9 times for bottled water.

For bottled water, 10 responses referred to BPA, 1 referred to *leaching of the plasticizers such as phthalates* (Respondent 505) and 27 others mentioned general health, contamination or toxicity hazards from plastic. For example, Respondent 559 indicated that *the polymer molecules leach into the bottled water – I can taste them when I drink bottled water*. Eight bottled water responses mentioned concerns regarding cancer and eight responses expressed concern when the bottles encounter high temperatures: *the plastic bottled [sic] might have been exposed to heat that makes it a health risk as well, that will lead to cancer* (Respondent 706). The majority of safety and organoleptic descriptions for bottled water were very general, using words such as *safety*, *contaminants*, *purity*, *tastes cleaner*, *toxins* or *chemicals in plastic*.

Tap water answers frequently mentioned geography or infrastructure. For example, 83 answers mentioned specific locations such as towns, compared to just 4 mentions for bottled water. Additionally, 41 tap water answers referenced infrastructure, vs only one answer for bottled water. Pipes were often mentioned, and other infrastructure concerns such as water fountains and *old buildings* were raised. Tap water contamination concerns often connected to the original source or delivery infrastructure: *principally old pipes leaking contaminants (metals) into water and contaminants to ground water/water sources from industrialized process, mining, etc.* (Respondent [R.] 745). Location-specific answers regarding tap water taste and safety concerns included specific campus residences:

> The tap water in Evergreen [a campus dorm] sometimes has a strong copper taste to it. Other times it smells like bleach (R. 244).

> It's interesting that back home [. . .] there was really no problems with water. Then when I moved here for school (Edwardsville, specifically living on campus at SIUE) and all of a sudden there are all of these notifications to not drink the water from such buildings on campus, or the water in Cougar Village [campus apartment complex] needs to be boiled before use. Either SIUE has a lot of water problems, or they're keeping track of it and notifying people about it better than my hometown (R. 253).

In combination, these results suggest more awareness of tap water quality issues as something with a specific geographic origin and physical (structural) basis, to be addressed by location-specific remedies, both on and off campus. In contrast, environmental impacts and health concerns of bottled water (e.g. trash production) may be more perceived as a personal issue originated from the bottles themselves.

Some answers linked tap water taste to cleanliness [*The taste is terrible and therefore I question its purity* (R. 75)] and safety [*The varying taste concerns me about the various health risks* [R. 99]; *Is it safe to drink when you can "taste the minerals"?* (R. 451)]. Some indicated that they could taste or smell specific chemicals, including eight respondents mentioning a chlorine taste or odor: *I think the taste of bottled water is far superior to tap water, because I can clearly taste the chlorination and fluoride in tap water* (R. 724).

The issues of personal uncertainty and lack of knowledge were raised for both tap and bottled water (N = 23 and 17 answers, respectively). Example terms included *need more information*, *unsure*, *difficult to know*, *question*, *trust* and *sketchy*. For tap water, the concerns linked to the abovementioned issues, including cleanliness, organoleptics, location, sources and treatment.

> Unsure about where it's acquired from, also unsure about the purification process and number of contaminants (R. 440).

> We get our tap water from [city deidentified] water supply and we frequently receive notices and problems with the water due to higher than normal substances (not sure what these are). The problem is we don't receive any other information about how is it being resolved and any potential short-term or long-term impact (R. 102).

For the bottled water concerns, the most frequent themes were environmental impacts (N = 271), plastic (N = 138) and cost (N = 102). Nonrenewable waste was the common concern with plastic (e.g. *plastic waste*, *longevity of plastic*, *hurting our earth*, *filling landfills everywhere*). A few answers described groundwater depletion or other issues with private interests controlling water delivery:

> Environmental impact and social justice issue: causes too much waste in the environment and depletes aquifers and water sources that the public needs while making a large profit. Issues of water ownership and pollution are problematic [. . .] (R. 101).

Similar to Saylor *et al.* (2011), very few (N = 4) responses referred to the energy or carbon footprint of bottle production and delivery: *the plastic waste generated by bottled water is contributing the degradation of the environment and climate change* (R. 58).

Recycling was posted as a solution in 42 answers [*I always recycle every plastic water bottle* (R. 515)], though there was concern regarding individual behavior [*People need to recycle them more* (R. 485)] and effectiveness [*Where are all those used bottles going? You can't make recycled rugs out of all of them* (R. 559)].

There were 481 responses to the open-ended question about what could be done to encourage people to drink tap water more often. In these answers, promotion and communication strategies (including education) was the most common theme (N = 205). This indicated a perception that increased information could change behavior. Common terms included *advertising*, *campaigns*, *commercials*, *post signs*, *public information* and *telling*. Education and advertisements were recommended to dispel tap water quality and health concerns, and to promote tap water environmental and economic benefits:

> Some sort of ad campaign which showcases its cost effectiveness, health benefits, and low environmental impact when compared to other sources of water (R. 44).

Many respondents (N = 90) indicated that the safety of tap water needed to be addressed or communicated, including concerns regarding contamination and infrastructure (e.g. pipes):

> Increase constituents' confidence regarding the safety of their tap water. This can be done by ensuring pipes are clean and there are no harmful materials in the water (R. 196).

Other respondents (N = 36) called for more education on the environmental impacts of bottled water, including the bottles themselves, and the bottled water industry.

Many answers included the words *ensure* and *reassure*, suggesting concerns about individual or public confidence in tap water. These included addressing uncertainty in tap water regulation, treatment, processing and safety: *ensure the tap water meets regulations, maybe advertise the filtration process to show the water's cleanliness* (R. 198).

Beyond communication and education, the other recommendations were physical items and changes to policies and regulations. Physical items included water filters (N = 98), reusable water bottles and bottle filling stations (N = 22), water fountains (N = 49) or other changes to the campus, such as adding additional infrastructure or treatment processes. Physical change recommendations focused on improving access to tap water, in addition to

its safety and health. Respondents frequently recommended installing more filters on campus tap water sources to decrease bottled water reliance: *My tap water intake has greatly increased since the filtration systems were added to some campus water fountains. I think if all fountains had that it would increase further* (R. 746). Campus drinking fountains have simple informational displays indicating maintenance status of installed filtration systems, which were mentioned as a good practice to increase. Finally, policy recommendations included taxes or other cost incentives ($N = 19$), increased regulation of the tap water industry ($N = 14$) and improved transparency of water companies ($N = 7$).

Discussion

Study limitations and objective

Our use of residential student lists and campus discussion lists to recruit study participants is a convenience sample. This sample may not provide unbiased estimates of the entire campus population, although racial makeup was similar between the study and campus student populations. Other potential bias sources include self-reported estimates of behavior (use of tap vs bottled water), and limited response rates for online surveys. To improve response rates, we made the survey short, and included a brief introduction indicating low time commitment, confidential results and a gift-card lottery incentive (Crawford *et al.*, 2001; Edwards *et al.*, 2009).

Given the study limitations, we restrict our analysis to associations and trends in question responses, respondent narrative concerns and suggestions and agreement of findings with existing literature. As discussed below, our study quantitative results were consistent with prior studies, suggesting valid results overall. We interpret these results to infer factors that may cause overreliance on bottled water in this university community and possible interventions to improve campus sustainability by increasing tap water use.

Why were respondents so concerned about tap water quality?

Most (>60%) of the study respondents were concerned with tap water safety and health, source cleanliness, treatment process, water quality regulations and building pipes. Respondents who drank more bottled water were more concerned with these issues, consistent with prior studies (Doria *et al.*, 2009; Doria, 2006; Hu *et al.*, 2011; van der Linden, 2015; Saylor *et al.*, 2011). Many respondents in our survey indicated that bottled water is cleaner and healthier than tap water. Efforts to improve perception regarding tap water quality and safety could increase tap water use at SIUE. The first step is to understand the basis for these concerns.

Survey responses frequently mentioned tap water taste as a concern and a focus area to increase tap water use. Taste was selected as a tap water concern by 70% of respondents (versus 24% for bottled water) and 27% of narrative responses also mentioned tap water taste or odor. Some respondents associated tap water organoleptics with contamination and health risks. This corroborates prior studies; dissatisfaction with tap water organoleptics fosters concerns about quality, as well as greater preference for bottled water (Abrahams *et al.*, 2000; Doria *et al.*, 2009; Doria, 2006; Levallois *et al.*, 1999; van der Linden, 2015; Saylor *et al.*, 2011).

Concerns about safety may respond to mandated reporting requirements. The US Safe Drinking Water Act (SDWA) requires public reporting of tap water issues, but no such requirements exist for bottled water (Gleick, 2010). Saylor *et al.* (2011) and Parag and Roberts (2009) argue that these mandated public communications may actually increase awareness and concern for tap water hazards, relative to bottled water. Our narrative results support this argument: we saw frequent mentions of specific chemicals (e.g. lead, chlorine),

specific geographic locations (e.g. towns) and specific infrastructure systems for tap water only.

Lead was selected as a safety concern by 83% of respondents and was frequently mentioned in narrative responses. Concern regarding a lead hazard is warranted. Lead is a neurotoxin with no established safe dose (United Nations Environment Program, 2010; USEPA, 2004). Further, lead is frequently elevated in public drinking water, and EPA standard drinking water monitoring methods can underestimate consumer exposure (Triantafyllidou and Edwards, 2012). In our survey, the high concern about lead likely results from a combination of contemporaneous regional and local events. In 2016 (the year before the survey), a state of emergency was declared in Flint, Michigan, due to lead contamination of the tap water (Henderson and Wells, 2021). In the same year, campus monitoring at SIUE detected lead levels above the 15 ppb action level. Elevated lead was detected in five SIUE campus buildings, including three drinking water fountains in two buildings, which were planned to be replaced (SIUE, 2016a, 2016b). Single exceedances of the lead action level were also reported in SIUE's annual SDWA consumer confidence reports from 2017 and 2019, but not from 2018 or 2020. Brass plumbing devices and other water infrastructure in campus buildings may be a source of lead to drinking water (Elfland *et al.*, 2010; Triantafyllidou and Edwards, 2012), as the elevated lead in 2016 occurred at specific taps, such as utility sinks (SIUE, 2016a). To summarize, there was frequent concern regarding lead in campus drinking water, continued periodic exceedances of the lead action level in specific tap water sampling locations and limited information provided in the consumer confidence reports. Given all these factors, we recommend a more proactive reporting strategy for lead in SIUE campus drinking water, such as testing and reporting results on all public drinking water fixtures.

Why did many respondents report poor tap water taste?

Survey responses suggest high dissatisfaction with tap water taste is affecting water preference. To determine potential causes of these frequent organoleptic concerns, we examined public information and literature on local and regional tap water composition. The local water distributor to SIUE and the city of Edwardsville uses ion-exchange treatment to maintain drinking water below maximum benchmarks for water hardness (<120 mg/L) and multiple specific constituents (John Shaw, Veolia North America, pers. communication, July 21, 2020), which should also reduce organoleptic issues. The local distributor's standards for manganese (<0.035 mg/L) and iron (<0.05 mg/L) are below United States Secondary Drinking Water Standards for aesthetic concerns (USEPA, 2021). At these levels, these constituents are unlikely to cause substantial taste or odor concerns in the source water.

In the glacial aquifer system where Illinois is located, 39% of drinking water wells exceed a manganese benchmark, and 74% exceed a 120 mg/L hardness benchmark for aesthetic concerns (Warner and Ayotte, 2014). Illinois groundwater-supplied drinking water hardness is higher than the United States national average (USGS, 1954), and poor taste and water hardness were commonly reported concerns for water consumers in a Chicago-area survey (Curry, 1983). SIUE recently detected a water hardness of 153 mg/L (D. Meyer, SIUE, pers. communication, July 17, 2020), which is considered to be moderately hard to hard water (USGS, 2022; Whelton *et al.*, 2007). Hardness at these levels both on campus and throughout Illinois may cause taste concerns and negative preconceptions, such as for students who moved from other Illinois locations to reside on campus.

Chlorine may be a primary factor causing concerns with the taste of campus-supplied water, and several survey respondents mentioned a chlorine taste or odor. Chlorine, used as a chemical disinfectant, can impart taste and odor, and affect perceived risk by consumers

(Doria, 2010; Doria *et al.*, 2009; World Health Organization, 2022). Campus is approximately one mile from the publicly treated drinking water supply. The water is chlorinated at the plant to 1.5 mg/L to achieve acceptable residual chlorine levels at the furthest point of the system (John Shaw, Veolia North America, pers. communication, July 21, 2020). In two Quebec City (Canada) communities, tap water closer to a drinking water treatment plant has higher residual chlorine levels, lower taste satisfaction and higher perceived risks by residential consumers (Turgeon *et al.*, 2004). Because of SIUE's downstream proximity to the treatment point, the tap water likely has high residual chlorine levels. Though a chlorine residual is needed to prevent waterborne pathogen growth, reduction at points-of-distribution could potentially improve taste.

Black and undergraduate respondents reported higher bottled water use

Black (African American) respondents reported greater use of bottled water than White respondents, similar to multiple prior studies (Abrahams *et al.*, 2000; Doria, 2006; Hobson *et al.*, 2007; Pierce and Gonzalez, 2017; Rosinger *et al.*, 2018; Rosinger and Young, 2020; Vieux *et al.*, 2020). There have been repeated public failures to protect Black communities in the USA from drinking contaminated water, and other instances of environmental racism (Henderson and Wells, 2021). This may explain the greater mistrust in tap water, expressed by Black respondents.

Bottled water use was highest for undergraduate students, intermediate for staff and lowest for faculty. This finding is consistent with previous university studies in the USA (Graydon *et al.*, 2019; Saylor *et al.*, 2011) but not Mexico (Espinosa-García *et al.*, 2015). This trend may result from more negative perception of tap water (Doria, 2010) and higher bottled water consumption rates (Hu *et al.*, 2011; Saylor *et al.*, 2011; Vieux *et al.*, 2020) among younger versus older adults in the USA. Because students and Black respondents were more concerned about tap water and more likely to consume bottled water, strategies to increase tap water consumption could emphasize these populations.

University community feedback and strategies to increase tap water use

SIUE's high use of single-use bottled water is consistent with United States and global trends (Cohen and Ray, 2018; Rosinger *et al.*, 2018; Vieux *et al.*, 2020), but inconsistent with the university's campus sustainability goal (SIUE, 2017). Given this, what campus interventions would be most effective to increase tap water and reduce bottled water consumption? McKenzie-Mohr *et al.* (2012) recommend eight specific methods or tools to increase environmentally sustainable behaviors: commitment, prompts, norms, social diffusion, goods and services (products), communication (promotion), incentives/disincentives (price) and convenience (place). In our study, survey responses recommended all of these methods except commitment and social diffusion. McKenzie-Mohr *et al.* (2012) further recommend choosing strategies based on specific barriers and benefits identified for the local behavior and community. Our survey suggests two important barriers:

(1) dissatisfaction with campus tap water taste and odor; and

(2) concern and uncertainty regarding tap water safety.

Following Saylor *et al.* (2011), we analyze our study findings for marketing campaign strategies to increase tap water use at SIUE.

The most common recommendation among respondents was communication and promotion. Many respondents were uncertain or not knowledgeable about drinking water hazards from tap versus bottled water. Information dissemination strategies and campaigns

could specifically address these concerns. For example, information from SIUE's SDWA consumer confidence reports, describing the quality and management of local tap water (SIUE, 2016b), could be advertised and marketed. Potential strategies include attention-getting report formats and more memorable messages targeted to the audience. This could be augmented with personal interactions, and additional distribution methods, such as email, video announcements and social media (McKenzie-Mohr *et al.*, 2012). University social media accounts and campus announcement video monitors could be used to distribute short videos, emphasizing tap water safety in clear, simple formats. Although information campaigns alone have limited ability to promote changes toward sustainable behavior (McKenzie-Mohr *et al.*, 2012), prompts to remind people to drink from the tap can be beneficial. Several respondents proposed posting reminders to use tap water because of its treatment and safety. Environmental and economic costs of purchasing bottled water could also be emphasized (Levêque and Burns, 2018), as these were common concerns in this and other university studies (Graydon *et al.*, 2019; Saylor *et al.*, 2011; Ward *et al.*, 2009).

Respondents recommended material changes to campus and products to increase appeal, availability and convenience of tap water. The main suggestions were to add filters or purifiers to more campus drinking water sources, distribute and market reusable water bottles and increase availability and awareness of water fountains and bottle refill stations. At Princeton University (New Jersey, USA), distribution of water bottles to new students, with motivational information and questionnaires, was associated with greater tap water use (Santos and van der Linden, 2016). Narrative responses to our survey also mentioned automated count of number of plastic bottles avoided at refill stations as a motivator to refill reusable bottles; this serves as a simple prompt regarding the community norm of increasing sustainability. Increased use of point-of-distribution filters could address organoleptic concerns. For example, porous carbon filters at the tap could remove chlorine and improve taste and odor (Asada *et al.*, 2009; Jaguaribe *et al.*, 2005). Campus resources such as the SIUE Environmental Resources Training Center could evaluate and develop system-wide or point-of-distribution treatment methods to improve taste and odor.

Suggestions were raised to disincentivize bottled water use by banning sale of bottled water on campus, implementing bottled water taxes and not providing plastic bottled beverages at campus events. However, institutional barriers may impede such changes. SIUE has maintained a >10 year sole source purchase contract with PepsiCo, Inc., which stipulates the sale of Pepsi branded bottled water (e.g. Aquafina®, LIFEWTR®) and other beverages in single-use plastic containers. Further, some campus regulations prohibit distribution of other beverage sources; for example, the campus Student Organization Handbook states that "Student organizations are not permitted to distribute free non-Pepsi beverage products on University premises" (SIUE, 2020b). This relationship between SIUE and PepsiCo is a case scenario of corporate influence discouraging tap water consumption (Gleick, 2010).

For sustainability, it would be beneficial to develop campus policies that encourage free distribution and encourage use of tap water. Strategies based on social and behavioral psychology, including public commitments, social diffusion and norms (McKenzie-Mohr *et al.*, 2012), should also be combined with the environmental, informational and promotional strategies recommended by respondents. Persuasive information, institutional norm setting and purported peer-group behavior could increase university students' intent to reduce bottled water purchases (van der Linden, 2015; Santos and van der Linden, 2016). For example, campaigns by student groups (e.g. Student Government, sororities and fraternities) could report on switching from bottled to tap water (social norms) and encourage other students to commit to do so in public written pledges. The most effective strategies would integrate multiple methods to address barriers at both the campus and the individual level.

Conclusion

Our survey findings were consistent with prior US studies: the student population and Black respondents favored bottled water more than other populations, and respondents concerned about tap water taste and safety were more likely to rely on bottled water. We interpreted these findings in the context of the complex structures, systems and local variables that can reduce use of public tap water systems (Doria *et al.*, 2009). Legal policies such as the Safe Drinking Water Act mandate particular reporting requirements on tap water constituents such as public hazard notices and consumer confidence reports. These reporting mechanisms potentially increase concern about tap water and warrant reexamination. Physical factors and incidents affect both taste and trust. These included campus lead exceedances (in light of the Flint Michigan incident), which likely reduced trust. High naturally occurring hardness and nearby upstream chlorination potentially affected taste, odor and trust. A contractual relationship with a global beverage distributor encourages display and provision of bottled drinks at campus events; this sets an institutional norm that beverages in single-use bottles are preferred.

We propose a range of possible actions to increase tap water use, based on our findings and existing literature. Following principles of community-based social marketing, the most effective strategies would address barriers to change, at both the individual and the campus level. Strategies should especially target students, who report the greatest bottled water consumption. Communication strategies would include information campaigns coupled with prompts to remind people to drink from the tap, and more user-friendly messaging in consumer confidence reports. University social media accounts and campus announcement video monitors could be used to distribute short videos, emphasizing tap water safety in clear, simple formats. To support this messaging, expanded public reporting of test results from drinking water fixtures should confirm tap water safety (or identify issues for repair). That said, information strategies alone are inadequate to foster behavior change. University practices and norms encouraging bottled beverages (vs tap water) should be reexamined. Tap water taste could be improved by treatment at point distribution, to improve water taste. The university could distribute free reusable water bottles or develop other institutional norm-setting campaigns. By deploying and testing a combination of these strategies, SIUE and other regional comprehensive universities in the USA could further support the goals of understanding and improving campus sustainability.

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