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Determinants of tap water mistrust among Phoenix, Arizona Latinx adults

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ABSTRACT

The purpose of this investigation was to characterize factors that predict tap water mistrust among Phoenix, Arizona Latinx adults. Participants (n = 492, 28 ± 7 years, 37.4% female) completed water security experience-based scales and an Adapted Survey of Water Issues in Arizona. Binary logistic regression determined odds ratios (OR) with 95% confidence intervals (95% CI) for the odds of perceiving tap water to be unsafe. Of all participants, 51.2% perceived their tap water to be unsafe. The odds of mistrusting tap water were significantly greater for each additional favorable perception of bottled compared to tap water (e.g., tastes/smells better; OR = 1.94, 95% CI = 1.50, 2.50), negative home tap water experience (e.g., hard water mineral deposits and rusty color; OR = 1.32, 95% CI = 1.12, 1.56), use of alternatives to home tap water (OR = 1.25, 95% CI = 1.04, 1.51), and with decreased water quality and acceptability (OR = 1.21, 95% CI = 1.01, 1.45; $P < 0.05$). The odds of mistrusting tap water were significantly lower for those whose primary source of drinking water is the public supply (municipal) (OR = 0.07, 95% CI = 0.01, 0.63) and with decreased water access (OR = 0.56, 95% CI = 0.48, 0.66; $P < 0.05$). Latinx mistrust of tap water appears to be associated with organoleptic perceptions and reliance on alternatives to the home drinking water system.

Key words: behavior, bottled water, Hispanic adults, hydration, Latinx adults, plain water intake

HIGHLIGHTS

- Over half of the Latinx participants believe that their tap water is not safe to drink.
- Latinx adults' mistrust of tap water appears to be related to negative perceptions of tap water, such as unpleasant smell and taste.
- Latinx adults who mistrust their tap water appear to rely on bottled water and gallon containers for drinking water as alternatives to tap water.

INTRODUCTION

Underhydration, dehydration, and low water intake have been linked to various adverse health outcomes, including cardiovascular dysfunction, chronic diseases, and death (National Academy of Medicine 2005). Latino and Hispanic (herein Latinx) adults have significantly lower total water intake (Drewnowski *et al.* 2013; Brooks *et al.* 2017; Rosinger *et al.* 2018) and are 1.42 times more likely to be inadequately hydrated (Brooks *et al.* 2017) compared to non-Hispanic (NH) White adults. Moreover, Latinx adults tend to consume significantly higher proportions of sugar-sweetened beverages (Rosinger *et al.* 2017), which can increase the risk for obesity, type 2 diabetes, and cardiovascular diseases (Huang *et al.* 2014).

The Centers for Disease Control and Prevention (CDC) recommend individuals to 'Rethink Your Drink' by replacing sugar-sweetened beverages with water. Some tips to accomplish this include improving the flavor of water by adding berries, lime, lemon, or cucumber, storing water in the fridge, and using a reusable water bottle that can be refilled while on the go (Centers for Disease Control and Prevention 2019). These strategies may not be effective in Latinx adults as they are significantly more

likely to perceive their tap water as unsafe compared to NH White adults (Onufrak *et al.* 2012; Pierce & Gonzalez 2017; Javidi & Pierce 2018) and bottled water serves as a costly alternative (Javidi & Pierce 2018).

Water insecurity is prevalent across the United States (US). Perceptions of unsafe tap water are likely valid for some populations and individuals. Minority and low-income communities are at a greater risk of water insecurity due to factors such as historical planning processes, redlining and under bounding, reduced enforcement of water regulations and standards, and repeat water violations (Balazs & Ray 2014; Meehan *et al.* 2020a). Yet mistrust in tap water also occurs when tap water is designated safe by federal agency standards (Wilson *et al.* 2022).

As an alternative to tap water, bottled water is not necessarily safer to consume. US Government Accountability Office testimony concluded that while the Environmental Protection Agency (which regulates tap water) and the US Food and Drug Administration (FDA, which regulates bottled water) have similar regulations for drinking water, the FDA is less capable of enforcing them for bottled water (United States Government Accountability Office 2009). In particular, the FDA cannot require bottled water to be tested in certified laboratories or test results (e.g., violations of water quality standards) to be reported (United States Government Accountability Office 2009). There also are no requirements for bottled water labels to include information regarding regulation compliance, the presence of contaminants, or potential health risks associated with contaminants (United States Government Accountability Office 2009).

Tap water safety perceptions generally appear to be influenced by geography, household and neighborhood characteristics, demographics, prior experiences with tap water, organoleptic (sensory) perceptions, and availability and sources of information about water (Colburn & Kavouras 2021). However, recent investigations have not consistently or comprehensively evaluated the same factors. Additionally, only one investigation (Park *et al.* 2019) included a sample comprised entirely of Latinx adults, and many factors in the remaining investigations were not evaluated for differences by race or ethnicity. Therefore, the factors that have previously been identified to influence tap water safety perceptions may not all be relevant to Latinx adults, specifically.

A greater understanding of tap water aversion could enhance efforts to improve water intake and reduce sugar-sweetened beverage intake in Latinx adults with access to safe tap water. Therefore, the purpose of this investigation was to evaluate perceptions, knowledge, behaviors, and experiences related to drinking water in Latinx adults residing in Phoenix, Arizona. We aimed to characterize the degree to which various factors predict the perception that tap water is not safe. Education level, annual income, and nativity status were explored as potential moderators.

METHODS

English- and Spanish-speaking adults (18–65 years) who self-identify as Hispanic or Latinx (question: 'What is your ethnicity?'; response options: 'Hispanic or Latinx', 'Not Hispanic or Latinx') in Phoenix, AZ (evaluated via self-reported zip code) were recruited for participation. The sample was selected using non-probability methods and recruited through Facebook ads, printed flyers, a university research participant registry, university banner ads, and word of mouth. Eligibility was evaluated via an online survey (Qualtrics, Provo, UT, USA). Participants were excluded if they satisfied at least one of the following criteria: pregnant, use diuretics, do not have access to a desktop, laptop, tablet, or smartphone, or do not have internet access. Potential participants were informed of participation risks and benefits and their rights as a participant. Free and informed consent was obtained electronically, and the study protocol was approved by the Institutional Review Board of Arizona State University, Arizona, USA (protocol no. STUDY00014055; approval date: June 1, 2021). This study was registered at clinicaltrials.gov (NCT04997031) and was conducted in compliance with the Helsinki Declaration as revised in 1983. Data collection occurred from September 2021 to February 2022 in Phoenix, Arizona, USA.

Ultimately, 1,029 individuals consented to voluntary participation, enrolled, and completed the study online. Data from 537 participants were excluded due to multiple submissions by the same person ($n = 63$), straight-lined data ($n = 471$), or missing data ($n = 3$), resulting in $n = 492$ for the analysis. Multiple submissions by the same person were identified by the use of the same email address and/or name, similar email addresses, and/or variations of similar first and last names. Participants were contacted to verify the completion of multiple surveys. Several survey questions were utilized to identify straight-lined data. For example, participants were asked to rank 11 items based on their level of importance. In many instances, items were ranked 1–11 in the order in which they were presented to the participant. Additionally, some questions asked participants to select 'yes' or 'no' to a list of items, some of which were contradictory statements. Specifically, one question asked: 'Select 'yes' if you agree or 'no' if you disagree with each of the following statements about your home drinking water

system'. Some individuals selected 'yes' for all eight items, which included: 'I often use bottled water for drinking purposes', 'I never buy bottled water', 'I am satisfied with my current drinking water (piped in house)', and 'I am not satisfied with my current drinking water (piped in house)'. Finally, participants were excluded from analysis if pertinent data was missing (i.e., nativity status [$n = 1$] and age [$n = 2$]).

Enrolled participants completed an online survey (Qualtrics, Provo, UT, USA), which took an average of 37.14 minutes to finish. All responses were coded in Qualtrics before any participants completed the survey, which allowed researchers to download a coded version of the dataset. Participants completed an Adapted Survey of Water Issues in Arizona (Supplementary material, Figure 1), which was adapted from previous national water survey needs assessments from the US Department of Agriculture-Cooperative State Research, Education, and Extension Service Southwest States and Pacific Islands Regional Water Quality Program (Castro *et al.* 2011). This survey evaluates participant awareness, aptitudes, attitudes, and actions toward water quality (specifically, feelings about the environment, environmental perspective, water safety and quality perceptions, water quality education, governance, and demographics). Adaptations to the survey were minimal. One question previously utilized in literature was added to evaluate prior experiences with tap water: 'What is your level of agreement with the following statement: I had a bad experience with tap water' (Gorelick *et al.* 2011). The question 'What is your gender?' was updated to 'What is your biological sex?' due to differences in gender and biological sex. Two questions were added to evaluate participant nativity status (born in the US vs. born outside of the US) and race. Participants also completed household water security experience-based scales developed for low-income peri-urban and rural communities on the US-Mexico border (Jepson 2014).

Variables

Survey items used to measure all variables are outlined in Table 1. The outcome variable was the perception of tap water safety. Responses were classified as a safe (agree and strongly agree) or an unsafe (disagree and strongly disagree) perception of tap water. Covariate variables included sex, age, race, education level, annual income, and US nativity. Mutually exclusive categories were created for the race (Caucasian, African American/African/Black/Caribbean, Native American, and other), education levels (high school graduate or less, some college, and college graduate or more), and annual income ($<$\$25,000, \$25,000–\$69,999, and $\geq$\$70,000).

Exposure variables measured prior experience with poor water quality, organoleptic perceptions, sources of information about water, and the home drinking water system. Responses for experience with poor water quality were classified as bad experience (agree and strongly agree) or no bad experience (neither agree nor disagree, disagree, and strongly disagree) with tap water. Both questions measuring organoleptic perceptions were utilized to create continuous, composite variables. 'Favorable perceptions of bottled water compared to tap water' (0–3, mean $\pm$ standard deviation [SD] $= 2.18 \pm 1.14$) was created with each 'yes' response scored as 1 and each 'no' response scored as 0 for organoleptic perceptions question one. Reliability was good (Cronbach's $\alpha = 0.81$). 'Negative home tap water experiences' (0–6, mean $\pm$ SD $= 3.02 \pm 2.12$) was created with each 'yes' response scored as 1, and each 'no' response scored as 0 for organoleptic perceptions question two. Reliability was good (Cronbach's $\alpha = 0.82$). Items for the sources of information about the water question were reduced to clusters in meaningful ways: media (newspaper and television), government sources (environmental agencies, consumer confidence reports, and extension service), non-government sources (environmental groups, universities, and schools), friends/family, and healthcare provider. Finally, participants' home drinking water systems were evaluated by the three Idealized Guttman scales (Jepson 2014) in addition to four questions listed in Table 1. The Idealized Guttman water scales evaluated water access, water quality and acceptability, and water distress. Water access was scored 0–7 (mean $\pm$ SD $= 3.11 \pm 2.43$), had good reliability (Cronbach's $\alpha = 0.83$), and was classified as adequate (0), marginal (1–3), low (4–5), and very low (6 –7). Water quality and acceptability were scored 0–6 (mean $\pm$ SD $= 2.96 \pm 2.09$), had good reliability (Cronbach's $\alpha = 0.79$), and were classified as acceptable (0), marginal (1–2), low (3–4), and very low (5–6). Water distress was scored 0–6 (mean $\pm$ SD $= 2.89 \pm 2.26$), had good reliability (Cronbach's $\alpha = 0.85$), and was classified as low (0), marginal (1–2), high (3–4), and very high (5–6). Responses for home drinking water systems questions one and two were classified as good quality (good or excellent, good and improving, good but deteriorating, fair, and no opinions/don't know) or bad quality (poor but improving and poor) of water. A continuous, composite variable, 'Use of alternatives and/or modifications to home tap water' (0–6), was created with each 'yes' response scored as 1 and each 'no' response scored as 0 for home drinking water systems question four. Reliability was acceptable (Cronbach's $\alpha = 0.68$). 'I am not satisfied with my current drinking water (piped in house)'

Table 1 | Survey questions and responses utilized to measure variables

Measures	Question	Responses
Outcome variable		
Perception of tap water safety	Do you feel that your home water is safe to drink?	Strongly disagree, disagree, agree, strongly agree
Covariate variables		
Sex	What is your biological sex?	Male, female
Age	What is your age?	[text entry]
Race	What is your race?	African American/African/Black/Caribbean, Asian/Pacific Islander, Caucasian, Native American, Other, Multiracial, or Biracial
Education	What is your highest level of education?	Less than high school, high school graduate, some college, college graduate, post graduate course work
Annual income	What is your annual income?	$< \$25{,}000$; \$25,000–\$44,999; \$45,000–\$69,999; $\geq$ \$70,000
United States nativity	Which country were you born in?	United States, other
Exposure variables		
Prior experience with poor water quality	What is your level of agreement with the following statement: I had a bad experience with tap water?	Strongly disagree, disagree, neither disagree nor agree, agree, strongly agree
Organoleptic perceptions 1	In your opinion, how do bottled and tap water compare? - Bottled water tastes/smells better - Bottled water is of higher quality - Bottled water is safer	Yes, no for each comparison
Organoleptic perceptions 2	Which, if any, of the following have you experienced with the tap water in your home over the past year? - Hard water/mineral deposits - Unpleasant taste - Sediment - Unpleasant smell - Rusty color - Other contaminants	Yes, no for each item
Sources of information about water	Have you received water quality information from the following sources? - Newspaper - Television - Environmental agencies (government) - Environmental groups (citizen groups) - Universities - Consumer confidence reports - Schools - Extension service - Friends/family - Healthcare provider	Yes, no for each source
Home drinking water systems 1	In your opinion, what is the quality of groundwater (sources of well water) in your area?	Good or excellent, good and improving, good but deteriorating, fair, poor but improving, poor, no opinions/don't know

(*Continued.*)

Table 1 | Continued

Measures	Question	Responses
Home drinking water systems 2	In your opinion, what is the quality of surface waters (rivers, streams, lakes, channels, and wetlands) where you live?	Good or excellent, good and improving, good but deteriorating, fair, poor but improving, poor, no opinions/don't know
Home drinking water systems 3	Where do you primarily get your drinking water?	Private supply (private well, river, pond, lake), public supply-municipal, public supply-rural district water, purchase bottled water, I don't know
Home drinking water systems 4	Select 'yes' if you agree or 'no' if you disagree with each of the following statements about your home drinking water system - I have water softener - I have a water treatment system (softener, etc.) - I purchase $\geq$ 1-gallon containers of drinking water - I often use bottled water for drinking purposes - I am not satisfied with my current drinking water (piped in house) - My drinking water is separate from my water supply system	Yes, no for each statement
Descriptive variables		
Influential sources of information	Have you ever changed your mind about an environmental issue as a result of: - News coverages - Conversations with other people - Public meetings - Classes or presentations - Speech by elected representative - First-hand observation - Financial considerations	Yes, no for each source
Water quality responsibility	In your opinion, who should be most responsible for protecting water quality in your community?	Federal government, state government, local government (county, city, or town), individual citizens, don't know, other
Learning opportunities	If you had the following kinds of learning opportunities available, which would you be most likely to take advantage of for water quality issues? (Check up to three items)	Read printed fact sheets, bulletins, or brochures, read a newspaper article or series, or watch TV coverage; visit a website; look at a demo or display; watch a video of information; take part in a onetime volunteer activity to learn or do something (e.g., water monitoring); attend a fair or festival; ask for a home, farm or workplace water assessment; get trained for a regular volunteer position (e.g., watershed steward, or water quality monitor); attend a short course (weekend, evening); take a course for credit/certification

was excluded from the composite variable to improve reliability (Cronbach's $\alpha = 0.71$, mean $\pm$ SD $= 3.48 \pm 1.55$). Finally, descriptive variables measured influential sources of information, water quality responsibility, and learning opportunities.

Statistical analysis

Data analyses were completed using commercial software (IBM SPSS Statistics Version 27.0.0). Data are presented as odds ratio (OR), 95% confidence interval (95% CI) unless otherwise specified. A $P < 0.05$ was considered statistically significant for all analyses. Multicollinearity was assessed for predictor variables and interaction terms via bivariate correlation.

Binary logistic regression was utilized with tap water safety perceptions as the outcome variable (0 = safe, 1 = unsafe). All covariate variables were included in the model. Exposure variables were included as predictors based on relevance in the literature. Interactions between various predictors and nativity (i.e., prior bad experience with water, government information sources, and non-government sources), annual income (i.e., the past year home tap water composite variable, home drinking water system composite variable, water access score, water quality and acceptability score, and water distress score), and education level (i.e., media information sources, government information sources, non-government information sources, friends and family information source, and health care provider information source) were explored based on previous literature. Variables were centered before evaluating interactions to account for multicollinearity. Interactions were individually added to the model and evaluated for statistically significant effects via the likelihood ratio test. Predictors that did not have a statistically significant effect were removed from the model (Hosmer & Lemeshow 2000).

RESULTS

Participants were 28 ± 7 years and mostly male, educated (>90% have at least some college education), and born in the US (Table 2). 51.2% mistrusted their tap water safety. Household water insecurity was prevalent as <20% of participants had adequate water access, ~30% had acceptable water quality, and ~25% had low water distress. Contrarily, >80% of the sample perceived groundwater and surface water in their area positively. Tap water safety perceptions were only significantly different among education levels, with the highest prevalence of mistrust observed in adults with some college education (χ^2 test, $P < 0.05$).

Tap water safety perceptions significantly varied among many survey items (Table 3). Over half of individuals previously had a bad experience with tap water. However, about half of the individuals with and without prior bad experiences mistrusted their tap water (χ^2 test, $P > 0.05$). Most of the sample perceive bottled water to taste and smell better, have higher

Table 2 | Sample demographics by the perception of tap water safety ($n = 492$)

	All		Safe perception of tap water		Unsafe perception of tap water		
	n	(%)	*n*	(%)	*n*	(%)	*P*-value[a]
Sex							0.48
Male	308	(62.6)	154	(50.0)	154	(50.0)	
Female	184	(37.4)	86	(46.7)	98	(53.3)	
Race							0.09
Caucasian	93	(18.9)	56	(60.2)	37	(39.8)	
African American/African/Black/Caribbean	147	(29.9)	65	(44.2)	82	(55.8)	
Native American	43	(8.7)	21	(48.8)	22	(51.2)	
Other	209	(42.5)	98	(46.9)	111	(53.1)	
Education level							**< 0.001**
High school graduate or less	35	(7.1)	19	(54.3)	16	(45.7)	
Some college	142	(28.9)	50	(35.2)	92	(64.8)	
College graduate or more	315	(64.0)	171	(54.3)	144	(45.7)	
Annual income							0.77
< $25,000	87	(17.7)	45	(51.7)	42	(48.3)	
$25,000–$69,999	310	(63.0)	151	(48.7)	159	(51.3)	
≥ $70,000	95	(19.3)	44	(46.3)	51	(53.7)	
Nativity							0.62
United States	452	(91.9)	222	(49.1)	230	(50.9)	
Other	40	(8.1)	18	(45.0)	22	(55.0)	

[a]χ^2 tests were used to assess differences across categories for each variable.
Significant differences ($P < 0.05$) are formatted in **bold**.

Table 3 | Survey responses by tap water safety perceptions ($n = 492$)

	All (%)	Safe perception of tap water (%)	Unsafe perception of tap water (%)	*P*-value[a]
Total sample	100.0	48.7	51.2	–
Prior bad experience with tap water				0.11
Yes	52.4	45.3	54.7	
No	47.6	52.6	47.4	
Perceptions of how bottled water compares to tap water				
Bottled water tastes/smells better				**< 0.001**
Yes	69.3	37.8	62.2	
No	30.7	73.5	26.5	
Bottled water is of higher quality				**< 0.001**
Yes	75.4	39.1	60.9	
No	24.6	78.3	21.7	
Bottled water is safer				**< 0.001**
Yes	73.8	38.3	61.7	
No	26.2	62.7	37.3	
Experiences with home tap water over the past year				
Hard water/mineral deposits				**< 0.001**
Yes	65.7	41.5	58.5	
No	34.3	62.7	37.3	
Unpleasant taste				**< 0.001**
Yes	62.0	38.0	62.0	
No	38.0	66.3	33.7	
Sediment				0.59
Yes	49.6	47.5	52.5	
No	50.4	50.0	50.0	
Unpleasant smell				**0.008**
Yes	47.8	42.6	57.4	
No	52.2	54.5	45.5	
Rusty color				1.00
Yes	41.7	48.8	51.2	
No	58.3	48.8	51.2	
Other contaminants				**0.02**
Yes	35.6	41.7	58.3	
No	64.4	52.7	47.3	
Have changed their mind about an environmental issue as a result of				
News coverage (TV, newspaper, etc.)				0.72
Yes	83.1	48.4	51.6	
No	16.9	50.6	49.4	
Conversations with other people				0.40
Yes	81.1	47.9	52.1	
No	18.9	52.7	47.3	
Public meetings				0.25
Yes	75.2	47.3	52.7	

(*Continued.*)

Table 3 | Continued

	All (%)	Safe perception of tap water (%)	Unsafe perception of tap water (%)	*P*-value[a]
No	24.8	53.3	46.7	
Classes or presentations				0.53
Yes	74.6	48.0	52.0	
No	25.4	51.2	48.8	
Speech by elected representative				0.78
Yes	66.5	49.2	50.8	
No	33.5	47.9	52.1	
First-hand observation				0.20
Yes	79.9	47.3	52.7	
No	20.1	54.5	45.5	
Financial considerations				0.44
Yes	64.2	47.5	52.5	
No	35.8	51.1	48.9	
Have received water quality information from each of the following sources				
Newspaper				0.06
Yes	80.3	50.9	49.1	
No	19.7	40.2	59.8	
Television				0.08
Yes	81.1	46.9	53.1	
No	18.9	57.0	43.0	
Environmental agencies (government)				0.47
Yes	74.4	49.7	50.3	
No	25.6	46.0	54.0	
Environmental groups (citizen groups)				0.40
Yes	71.7	47.6	52.4	
No	28.3	51.8	48.2	
Universities				0.38
Yes	72.8	50.0	50.0	
No	27.2	45.5	54.5	
Consumer confidence reports				0.10
Yes	58.3	51.9	48.1	
No	41.7	44.4	55.6	
Schools (elementary and secondary)				0.85
Yes	66.7	49.1	40.9	
No	33.3	48.2	51.8	
Extension service				0.09
Yes	60.8	51.8	48.2	
No	39.2	44.0	56.0	
Friends/family				0.69
Yes	76.6	48.3	51.7	
No	23.4	50.4	49.6	

(*Continued.*)

Table 3 | Continued

	All (%)	Safe perception of tap water (%)	Unsafe perception of tap water (%)	*P*-value[a]
Healthcare provider				**0.02**
Yes	70.3	45.4	54.6	
No	29.7	56.8	43.2	
Primary source of drinking water				**0.005**
Public supply (municipal)	25.6	59.5	40.5	
Private supply (private well, river, pond, lake)	7.1	45.7	54.3	
Public supply (rural water district)	15.7	58.4	41.6	
Purchase bottled water	50.2	40.9	59.1	
I don't know	1.4	42.9	57.1	
Agreement with each of the following statements about their home drinking water system				
I have water softener				0.45
Yes	69.5	47.7	52.4	
No	30.5	51.3	48.7	
I have a water treatment system (softener, etc.)				0.07
Yes	63.2	45.7	54.3	
No	36.8	54.1	45.9	
I purchase $\geq$ 1-gallon containers for drinking water				**0.01**
Yes	72.6	45.4	54.6	
No	27.4	57.8	42.2	
I often use bottled water for drinking purposes				$<$ **0.001**
Yes	77.6	43.2	56.8	
No	22.4	68.2	31.8	
I am not satisfied with my current drinking water (piped in house)				**0.006**
Yes	55.5	43.2	56.8	
No	44.5	55.7	44.3	
My drinking water is separate from my water supply system				$<$ **0.001**
Yes	65.0	40.0	60.0	
No	35.0	65.1	34.9	
Perception of groundwater (sources of well water) quality in their area				0.63
Positive	88.2	48.4	51.6	
Negative	11.8	51.7	48.3	
Perception of surface water (rivers, streams, lakes, channels, and wetlands) quality in their area				0.18
Positive	83.5	50.1	49.9	
Negative	16.5	42.0	58.0	
Water access classification				$<$ **0.001**
Adequate	18.9	19.4	80.6	
Marginal	38.6	49.5	50.5	
Low	18.1	42.7	57.3	
Very low	24.4	75.0	25.0	
Water quality classification				0.39
Acceptable	29.9	50.3	49.7	
Marginal acceptability	12.8	49.2	50.8	

(*Continued.*)

Table 3 | Continued

	All (%)	Safe perception of tap water (%)	Unsafe perception of tap water (%)	*P*-value[a]
Low acceptability	28.5	42.8	57.1	
Very low acceptability	28.9	52.8	47.2	
Water distress classification				**0.04**
Low	24.4	42.5	57.5	
Marginal	21.7	59.8	40.2	
High	22.6	44.1	55.9	
Very high	31.3	49.4	50.6	
Most likely to take advantage of each of the following learning opportunities for water quality issues[b]				
Read printed fact sheets, bulletins, or brochures				**< 0.001**
Yes	38.4	64.0	36.0	
No	61.6	39.3	60.7	
Read a newspaper article or series, or watch TV coverage				**0.005**
Yes	48.6	55.2	44.8	
No	51.4	42.7	57.3	
Visit a website				**0.03**
Yes	36.8	55.2	44.8	
No	63.2	45.0	55.0	
Look at a demo or display				0.21
Yes	26.2	53.5	46.5	
No	73.8	47.1	52.9	
Watch a video of information				0.10
Yes	37.0	44.0	56.0	
No	63.0	51.6	48.4	
Take part in a onetime volunteer activity to learn or do something (e.g., water monitoring)				**< 0.001**
Yes	35.2	38.2	61.8	
No	64.8	54.5	45.5	
Attend a fair or festival				**0.002**
Yes	17.5	64.0	36.0	
No	82.5	45.6	54.4	
Ask for a home, farm, or workplace water assessment				0.47
Yes	21.5	51.9	48.1	
No	78.5	47.9	52.1	
Get trained for a regular volunteer position (e.g., watershed steward or water quality monitor)				**0.007**
Yes	23.6	37.9	62.1	
No	76.4	52.1	47.9	
Attend a short course (weekend, evening)				0.55
Yes	16.9	51.8	48.2	
No	83.1	48.2	51.8	
Take a course for credit/certification				0.13
Yes	14.2	57.1	42.9	
No	85.8	47.4	52.6	

[a]χ^2 tests were used to assess differences across categories for each variable.
[b]Participants were instructed to select up to three learning opportunities.
Significant differences ($P < 0.05$) are formatted in **bold**.

quality, and be safer than tap water, and >60% of individuals with each of these perceptions mistrusted their tap water (χ^2 tests, $P < 0.001$). Additionally, hard water/mineral deposits and unpleasant taste in home tap water were the most common experiences in the previous year, while the presence of other contaminants was the least common experience. Tap water mistrust was more prevalent for those experiencing hard water and mineral deposits, unpleasant taste, unpleasant smell, and other contaminants (χ^2 tests, $P < 0.05$).

Individuals change their minds about an environmental issue most commonly as a result of news coverage and least commonly as a result of financial considerations. Moreover, water quality information was most commonly received via television and least commonly received via consumer confidence reports. Overall, sources of information did not differ widely between tap water perceptions. The only difference observed was that a higher proportion of individuals with unsafe perceptions received water quality information from their healthcare provider (χ^2 test, $P < 0.05$).

Half of the participants purchased bottled water as their primary source of drinking water. Tap water mistrust was less prevalent among those using public supplies (municipal and rural) and more prevalent among those using private supplies or purchasing bottled water for primary sources of drinking water (χ^2 tests, $P = 0.005$). Several differences were observed regarding home drinking water systems. Tap water mistrust was more prevalent among those purchasing ≥1-gallon containers for drinking water, those who often used bottled water for drinking purposes, dissatisfaction with home drinking water infrastructure, and obtaining drinking water separately from the home water supply system (χ^2 tests, $P < 0.05$). The Idealized Guttman scale for water access revealed that tap water mistrust was more prevalent among those with adequate or low water access but less prevalent among those with very low water access (χ^2 test, $P < 0.001$).

Overall, the top three water quality learning opportunities of interest were to read a newspaper article or series or watch TV coverage, to read printed fact sheets, bulletins, or brochures, and to watch a video of information (Table 3). However, greater proportions of individuals who trusted their tap water comprised those who selected reading printed fact sheets, bulletins or brochures, reading a newspaper article or series or watching TV coverage, visiting a website, or attending a fair or festival (χ^2 test, $P < 0.05$). Contrarily, greater proportions of individuals who mistrusted their tap water (>60%) comprised those who selected wanting to take part in a onetime volunteer activity or to get trained for a regular volunteer position (χ^2 test, $P < 0.01$).

Beliefs about whether the environment receives the right amount of emphasis from local government and elected officials in Arizona (χ^2 test, $P = 0.002$) and about who should be most responsible for protecting water quality in the community (χ^2 test, $P < 0.001$) varied significantly by tap water safety perception. While 42.3% of individuals believed the environment receives the right amount of emphasis, 34.6% believed it does not. Moreover, 62.9% of individuals who believed the environment does not receive the right amount of emphasis also believed their tap water is unsafe. The remaining individuals believed the environment receives too much emphasis (17.9%) or did not have an opinion/did not know (5.3%). The majority of the sample believed the county, city, or town (34.1%) or individual citizens (29.7%) should be most responsible for protecting water quality in their community. Interestingly, 63.1% of those who believed the county, city, or town were responsible, and 38.4% of those who believed individual citizens are responsible mistrusted their tap water. The rest of the sample believed the state government (21.5%), the federal government (12.8%), or 'other' (0.6%) should be responsible. A small proportion (1.2%) did not know who should be responsible.

The binary logistic regression model is presented in Table 4. The odds of perceiving tap water to be unsafe were significantly greater for African American, African, Black, and Caribbean individuals compared to Caucasian individuals ($P < 0.05$). Perceptions were not influenced by education, sex, age, annual income, or nativity. The odds of mistrust were also significantly greater for each additional score for favorable perceptions of bottled water compared to tap water, negative home tap water experiences, use of alternatives and/or modifications to home tap water, and water quality and acceptability ($P < 0.05$). Conversely, the odds of mistrust were significantly lower for individuals whose primary source of drinking water is the public supply (municipal) as well as for each additional score for water access ($P < 0.05$). No sources of information had an influence on tap water safety perceptions. Finally, no significant interactions were observed between predictors and education level, annual income, or nativity status.

DISCUSSION

Tap water mistrust in Latinx adults appears to be related to organoleptic perceptions and behavioral changes to the home drinking water system. Overall, 51.2% of Latinx adults in this Phoenix, Arizona sample perceived their tap water to be

Table 4 | Odds of an unsafe perception of tap water ($n = 492$)

Variable	Reference category	Odds ratio (95% CI)	*P*-value
Female	Male	1.17 (0.72, 1.90)	0.52
Age (years)	–	1.00 (0.96, 1.03)	0.79
Race (of Latinx origin)			**0.02**
African American/African/Black/Caribbean	Caucasian	3.28 (1.58, 6.80)	**0.001**
Native American	Caucasian	2.50 (0.96, 6.50)	0.06
Other	Caucasian	1.73 (0.87, 3.44)	0.12
Education level			**0.03**
Some college	College graduate or more	0.38 (0.14, 1.03)	0.06
High school graduate or less	College graduate or more	1.43 (0.84, 2.45)	0.19
Annual income			0.37
$25,000–$69,999	≥ $70,000	1.85 (0.78, 4.41)	0.16
< $25,000	≥ $70,000	1.27 (0.68, 2.39)	0.45
Born outside of the US	Born in the US	1.33 (0.50, 3.55)	0.57
Prior bad experience with tap water	No prior bad experience with tap water	0.74 (0.43, 1.28)	0.28
Favorable perceptions of bottled water compared to tap water	–	1.94 (1.50, 2.50)	< **0.001**
Negative home tap water experiences	–	1.32 (1.12, 1.56)	< **0.001**
Use of alternatives and/or modifications to home tap water	–	1.25 (1.04, 1.51)	**0.02**
Have received water quality information from each of the following sources			
Media	Not media	0.75 (0.30, 1.87)	0.54
Government	Not government	0.63 (0.28, 1.39)	0.25
Non-government	Not non-government	0.43 (0.17, 1.11)	0.08
Friends/family	Not friends/family	0.71 (0.40, 1.26)	0.24
Healthcare provider	Not healthcare provider	0.97 (0.50, 1.89)	0.93
Primary source of drinking water			
Public supply (municipal)	Not public supply (municipal)	0.07 (0.01, 0.63)	**0.02**
Private supply (private well, river, pond, lake)	Not private supply	0.13 (0.01, 1.19)	0.07
Public supply (rural water district)	Not public supply (rural water district)	0.18 (0.02, 1.51)	0.11
Purchase bottled water	Not bottled water	0.15 (0.02, 1.21)	0.08
Positive perception of groundwater quality	Negative perception of groundwater quality	0.61 (0.27, 1.42)	0.25
Positive perception of surface waters quality	Negative perception of surface waters quality	1.87 (0.88, 3.97)	0.1
Water access score	–	0.56 (0.48, 0.66)	< **0.001**
Water quality and acceptability score	–	1.21 (1.01, 1.45)	**0.04**
Water distress score	–	1.16 (0.98, 1.36)	0.09

Binary logistic regression was performed to determine odds ratios for the odds of perceiving tap water to be unsafe.
95% CI, 95% confidence interval; US, United States.
P-values formatted in bold indicate a significant odds ratio (P<0.05).

unsafe. Previous studies observed the prevalence of mistrust from 14.7 to 33.8% in Latinx individuals (Onufrak *et al.* 2012; Pierce & Gonzalez 2017; Javidi & Pierce 2018; Park *et al.* 2019). It is not clear why the prevalence of mistrust was greater in the current sample, but it is unlikely that over half of the sample has access to unsafe water. Most drinking water in Phoenix, AZ is sourced from the Salt, Verde, and Colorado Rivers and regulated across five water treatment plants. Only ~2% of

drinking water in Phoenix is sourced from groundwater wells, which are operated by the city (City of Phoenix Water Services Department 2021). The City of Phoenix utilizes chlorine to disinfect all drinking water, which can generate disinfection byproducts in water. As of 2021, levels of chlorine, disinfection byproducts, and other substances were all below the maximum contaminant levels set by the EPA. Therefore, municipal tap water available to individuals in this sample was likely safe for consumption according to these regulatory standards. Participants appeared to agree with this as 88.2 and 83.5% had positive perceptions about the quality of local groundwater and surface waters. However, while the EPA monitors contaminants of emerging concern, there is currently no framework to regulate or act on these contaminants (Centers For Disease Control and Prevention). Accordingly, water that is deemed safe by federal agency standards may not be safe if contaminants of emerging concern are present (Post *et al.* 2017). Additionally, tap water quality can be affected by home infrastructure (e.g., premise plumbing). While water quality was not tested in participants' residences, the City of Phoenix tested for lead and copper in a small sample ($n = 71$) of residential water taps and the federal standards set by the EPA were met (City of Phoenix Water Services Department 2021).

Mistrust in the present sample did not follow the patterns previously observed across education or income levels. The prevalence of mistrust was lowest in both the lowest and highest levels of education. While education level was a significant predictor of tap water mistrust, the odds of mistrust were not significantly different between having a college education or more and having some college education or having a high school education or less. In comparison, the prevalence of mistrust was lowest in the higher levels of education in previous investigations (Onufrak *et al.* 2012; Park *et al.* 2019). Moreover, the odds of trusting tap water safety were greater in US adults with at least a high school degree who completed the American Housing Survey in 2013 (OR = 1.448 (Pierce & Gonzalez 2017)) and 2015 (OR = 1.15 (Javidi & Pierce 2018)). The difference in our findings compared to previous findings is likely related to our sample being highly educated (>90% have at least some college education). In comparison, 30.6% of the total Phoenix, AZ population (≥25 years) have a bachelor's degree or higher. Therefore, this sample likely does not represent the general Latinx population in Phoenix, AZ (United States Census Bureau 2021). Additionally, the prevalence of mistrust has typically declined with increased income (Onufrak *et al.* 2012; Park *et al.* 2019). A clear relationship between income and tap water mistrust was not observed in the present investigation. Furthermore, education level and income level were not observed to moderate any relationships between predictors and tap water mistrust.

The prevalence of tap water mistrust was not different across race categories in the present sample. However, racial categories as defined by survey makers may not align with self-identification in Latinx adults (Allen *et al.* 2011). Specifically, some Latinx individuals may conceptualize race as an identity that is determined by more factors than physical characteristics and ancestry, such as experiences with discrimination, personal connection with family and culture, and level of identification with White Americans (Allen *et al.* 2011). Lack of identification with defined racial categories can lead to a greater prevalence of Latinx adults selecting 'other race' (Allen *et al.* 2011), which was observed in the present investigation. While tap water mistrust is commonly least prevalent among NH Caucasian individuals (5.1–10.8%), the prevalence was greater in Caucasian adults in the present sample (39.8%) (Onufrak *et al.* 2012; Pierce & Gonzalez 2017; Javidi & Pierce 2018). In addition to potential non-identification with racial categories, differences in prevalence may be related to ethnicity as previous investigations only recruited Caucasian individuals who were NH, while the present investigation only recruited Caucasian individuals of Latinx descent. Moreover, after controlling for all other predictors in the model, Latinx African American, African, Black, and Caribbean adults were over three times more likely to mistrust their tap water compared to Latinx Caucasian adults, which may reflect this group's disproportionate exposure to racial discrimination in water and housing policy in the US (Meehan *et al.* 2020b; Wilson *et al.* 2022).

US nativity did not influence tap water perceptions, despite findings from previous investigations in which the prevalence and odds of mistrusting tap water were greater in foreign-born individuals (Pierce & Gonzalez 2017; Javidi & Pierce 2018). The current findings could be related to a relatively small percentage of foreign-born participants (8.1%). In comparison, 19.2% of the total Phoenix, AZ population is foreign-born (United States Census Bureau 2021). Tap water mistrust in foreign-born Latinx adults was hypothesized to be related to experiences with poor water quality in their home countries (Pierce & Gonzalez 2017). A significant interaction between nativity and prior experiences with tap water was not observed in the present investigation. However, the country of origin was not reported by foreign-born participants in the present study. Differences in various factors such as tap water regulations, trust, and violations across all Latinx countries could impact comparisons made between US-born and foreign-born participants. For example, foreign-born Latino mothers from Central

American countries have reported a greater prevalence of trust in tap water in their home countries than in the US (Colón-Ramos *et al.* 2017; McCarley *et al.* 2021).

Organoleptic characteristics of water have commonly been associated with safety perceptions. This is supported by our findings in which the odds of tap water mistrust increased with each additional negative home tap water experience. Mistrust was more common among Latinx adults who had experienced hard water/mineral deposits, unpleasant taste, unpleasant smell, and other contaminants in their home tap water in the previous year. The prevalence of mistrust was not different among adults with and without sediment or rusty color in their home tap water. Additionally, the odds of mistrust were significantly greater for each additional water quality acceptability score, where a higher score indicates worse water quality and acceptability. While organoleptic characteristics of water are not dependable indicators of health risk (Napier & Kodner 2008), it appears Latinx adults may associate undesirable perceptions with a lack of safety. The present findings are supported by previous focus groups and interviews in which Latinx adults reported believing their tap water was not safe due to unpleasant taste, discoloration, unpleasant smell, and presence of chlorine or other minerals that cause tap water to taste unpleasant (Scherzer *et al.* 2010; Hess *et al.* 2019).

Bottled water was purchased by about half of this sample as their primary source of drinking water. The prevalence of tap water mistrust was greater in those purchasing bottled water but lower in those using the public supply (municipal and rural) as their primary source. Accordingly, the odds of mistrust were significantly lower in those who rely on the public supply (municipal). Those who mistrust their tap water appear to rely on alternatives or modifications to the home drinking water system. Specifically, there was significantly greater prevalence of mistrust among those who are not satisfied with their current drinking water (piped in house) and the odds of mistrust increased with each additional alternative and/or modification employed. Mistrust was significantly more prevalent in those who purchase $\geq$1-gallon containers for drinking water, who often use bottled water for drinking water purposes, and whose drinking water is separate from their water supply system. Thus, Latinx adults who mistrust their tap water are most likely to rely on alternatives to their home drinking water system rather than modifications (i.e., water softener or water treatment system).

Hispanic households have been observed to be significantly less likely to rely on tap water (unfiltered and filtered) over bottled water compared to NH White households (Javidi & Pierce 2018). Additionally, the use of home water treatment devices was significantly less prevalent among Hispanic adults compared to NH White adults (Rosinger *et al.* 2018). It is possible that filtered or treated water may not be perceived as safe, even if it is perceived more favorably than unfiltered or untreated water. Florida residents who consumed municipal water believed that water filters could combat organoleptic concerns, such as unpleasant-tasting water. However, they still preferred bottled water for what they considered to be more serious concerns (i.e., safety, contamination, and health risk) (Triplett *et al.* 2019). Additionally, among Latinx parents participating in a water filter intervention, tap water consumption increased despite mixed perceptions of filtered water. Specifically, some perceived their water to be safer when using a water filter pitcher, while others maintained their distrust and still preferred bottled water (Reese *et al.* 2022; Santillán-Vázquez *et al.* 2022). Similarly, tap water mistrust in the present sample was prevalent among those with perceptions that bottled water tastes and smells better (62.2%), is of higher quality (60.9%), and is safer (61.7%) than tap water. Moreover, the odds of mistrusting tap water were significantly greater with each favorable perception of bottled water compared to tap water. In comparison, previous investigations have observed 34.1% (Onufrak *et al.* 2012) and 64.7% (Park *et al.* 2019) of Hispanic adults to perceive bottled water to be safer than tap water. Adults who believe bottled water is safer than tap water are significantly less likely to primarily consume tap water (van Erp *et al.* 2014). Similarly, beliefs that bottled water is cleaner and tastes better than tap have been associated with significantly greater odds of primarily consuming bottled water (Gorelick *et al.* 2011).

While participants have changed their minds about environmental issues in response to various sources of information, differences in the prevalence of mistrust were not observed for any source. However, newspapers, television, and friends and family were the most common sources of water quality information. The news, advertising, and friends have previously been identified as prevalent information sources, with family being a significantly more common source for Latinx parents compared to NH White parents (Gorelick *et al.* 2011). Additionally, 70.3% of participants received information from health care providers and the prevalence of mistrust was greater for those who receive water quality information from a health care provider (54.6%) compared to those who do not (43.2%). Previously, only ~35% of participants were observed to receive information from their physicians (Gorelick *et al.* 2011). However, receiving information from health professionals is believed to have minimal to no influence on perceptions (Doria 2009), as supported by the present data (OR = 0.97, 95% CI = 0.50,1.89, P = 0.93).

Unsurprisingly, consumer confidence reports were the least common source of water quality information. While the EPA utilizes these reports to communicate with citizens about the quality of their local water, they do not meet national readability standards and are considered difficult to understand (Roy *et al.* 2015). The low prevalence of these reports as a source of information in the present study may also have been impacted by terminology used in the survey question. While participants were asked about consumer confidence reports in the survey, the reports in Phoenix, AZ are marketed as a water quality report. Therefore, it is possible that some participants were not aware that their water quality reports qualified as consumer confidence reports. Latinx mistrust in tap water safety has also been hypothesized to be related to distrust in the government (Scherzer *et al.* 2010). However, receiving water quality information from government sources and non-government sources was not a significant predictor of tap water mistrust in this investigation. Additionally, 68.4% of adults believe some level of government (federal, state, or local) should be responsible for protecting water quality in the community. Mistrust was greatest in those who believe local government should be responsible and lowest in those who believe individual citizens should be responsible. Ultimately, education about water quality does not appear to be an effective way to address tap water mistrust in Latinx adults. Contrarily, favorable perceptions of and reliance on bottled water in this sample support previous beliefs that water-related perceptions and behaviors are influenced by bottled water advertisements and marketing (Doria 2006; Pierce & Gonzalez 2017). In particular, bottled water marketing campaigns appear to capitalize on perceived associations between organoleptic perceptions, health, and risk through utilizing labels such as pure, pristine, natural, and healthy (Doria 2006; Wilk 2006). Bottled water marketing and advertising campaigns also have a history of targeting minorities (Javidi & Pierce 2018). Unfortunately, few promotional campaigns for tap water currently exist.

Limitations

A high prevalence of survey responses included straight-lined data and were excluded from data analysis. This may have been influenced by various aspects of the online survey design, including the use of matrix questions, presenting more than one question per page, and the overall length of the survey. The statistical analysis utilized could have introduced type one error due to multiple comparisons. The sample was highly educated, with 92.9% of participants having completed at least some college, and was not evenly distributed across sexes (62.6% male). Participants were only recruited from Phoenix, AZ, so these results are not generalizable to other geographical areas. While participants with a wide range of ages (18–75 years) were recruited, 93.5% of the sample was $<$40 years (median age of 26 years). As mentioned previously, participants' residential tap water quality was not tested. Accordingly, it is possible that some perceptions of mistrust in tap water safety are valid. The Adapted Survey of Water Issues in Arizona did not include bottled water marketing or advertising as a source of information about water. Future investigations should evaluate these sources of information as potential predictors of tap water perceptions. Finally, there is unmeasured error associated with all forms of public opinion research. As is commonly the case with self-reported data, we were not able to verify the accuracy of responses. Specifically, we could not verify whether individuals were Latinx or residents of the greater Phoenix, AZ area.

CONCLUSION

Overall, Latinx mistrust in tap water safety is very prevalent in Phoenix, AZ, and appears to be related to organoleptic perceptions of home tap water and reliance on alternatives to their home drinking water system, such as purchasing bottled water and $\geq$1-gallon containers for drinking water. The majority of this sample perceives local sources of water positively and appears to trust their government to regulate municipal water. Accordingly, public policy and/or interventions differentiating quality and sensory characteristics (e.g., taste and smell) from safety seem warranted. Onetime or regular volunteer activities related to water may be effective means for reaching this population.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

S.A.K. is a scientific consultant for Hyduro Inc. and has served as a scientific consultant for Danone Research. He also has active grants with Danone Research and Standard Process.

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