

Perceptions of drinking water management and safety: A public survey of U.S. residents

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```
Warning: package 'modelsummary' was built under R version 4.3.3
```

```
`modelsummary` 2.0.0 now uses `tinytable` as its default table-drawing  
backend. Learn more at: https://vincentarelbundock.github.io/tinytable/
```

```
Revert to `kableExtra` for one session:
```

```
options(modelsummary_factory_default = 'kableExtra')
```

```
Change the default backend persistently:
```

```
config_modelsummary(factory_default = 'gt')
```

```
Silence this message forever:
```

```
config_modelsummary(startup_message = FALSE)
```

```
Loading required package: grid
```

```
Loading required package: Matrix
```

```
Loading required package: survival
```

```
Attaching package: 'survey'
```

```
The following object is masked from 'package:graphics':
```

```
dotchart
```

```
— Attaching core tidyverse packages ————— tidyverse 2.0.0
—
✓ dplyr      1.1.4    ✓ readr      2.1.5
✓ forcats    1.0.0    ✓ stringr    1.5.1
✓ ggplot2    3.5.0    ✓ tibble     3.2.1
✓ lubridate  1.9.3    ✓ tidyr      1.3.1
✓ purrr      1.0.2
— Conflicts ————— tidyverse_conflicts()
—
* tidyr::expand() masks Matrix::expand()
* dplyr::filter() masks stats::filter()
* dplyr::lag()     masks stats::lag()
* tidyr::pack()    masks Matrix::pack()
* tidyr::unpack() masks Matrix::unpack()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all
conflicts to become errors
```

```
Warning: package 'tinytable' was built under R version 4.3.3
```

```
Hoisted 7 variants:
Manrope Bold
Manrope ExtraBold
Manrope ExtraLight
Manrope Light
Manrope Medium
Manrope Regular
Manrope SemiBold
```

Methodology

Survey Instrument

The online survey was administered and distributed through the Qualtrics online panel in April 2023. Panels were recruited using gender, age, and race/ethnicity quotas to obtain approximately representative samples of the U.S. population. Panels were continuously sampled until a representative sample was obtained, with a total sample size of 1,100 respondent and estimated $\pm 3\%$ margin of error at 95% confidence (Dillman, 2011). Quality checks, performed by Qualtrics, excluded responses that failed attention or speed checks, IP address checks, or failed to meet representative demographic criteria. All participants were provided and agreed to a written informed consent agreement. The Texas A&M University Institutional Review Board reviewed the study protocol prior to distribution and deemed the study exempt from formal review.

We sought to characterize (1) choice in primary drinking water source; (2) problems experienced with drinking water; (3) concern about drinking water contamination; (4) perceptions of trust and safety in drinking

water quality and associated management entities; and (5) how people receive information about drinking water quality. Participants were asked for their main source of household tap water (municipal public supply, public rural water district, private ground or surface water, private rainwater collection) and their main source of drinking water (unfiltered tap, filtered tap, bottled/prepackaged, or other). We also asked if they had experienced any of 12 different potential drinking water issues. To characterize concerns about contamination sources, we also asked how concerned they were about 10 different potential sources of contamination on a five point scale from “*not at all concerned*” to “*extremely concerned*.”

Levels of responsibility and trust in different entities involved in drinking water management were assessed with 2 questions. First, participants were asked what level of responsibility (on a five point scale from “*no responsibility*” to “*full responsibility*”) they believed each of six different entities had for ensuring drinking water is safe. We also asked what the participants level of trust was in each of those entities (on a five point scale from “*do not trust at all*” to “*fully trust*”). To assess the public’s perceived safety of drinking water, we asked participants to rate their drinking water safety on an ordinal scale from 0 through 10. We assessed sources of drinking water quality information by asking how often (five point scale from “*never*” to “*always*”) each of 11 different sources were used to get information about drinking water quality. **create supplementary info with survey questions**

Analysis

Survey responses were weighted to match marginal sex/gender, age group, race/ethnicity, and education proportions to national level benchmarks from the 5-year 2021 American Community Survey (ACS). We chose to weight gender using “male” and “non-male” binary responses because the ACS only provides binary responses for sex. This approach groups “female” and “other” respondents under the same marginal weight. Race and ethnicity were recoded at white or Caucasian and non-white categories due to small sub-population sample sizes. Weights were developed by poststratification raking using the American National Election Study (ANES) weighting algorithm implemented in the *anesrake* R package (DeBell & Krosnick, 2009; Pasek, 2018). Weighted summary statistics were calculated using the *survey* R package (Lumley, 2004).

Models

We explored factors associated with changes in (1) primary drinking water source, (2) perceived safety of drinking water, and (3) perception of drinking water safety using regression-based approaches. Prior research provides evidence that age, gender, perceptions of drinking water safety, category of water supplier, and dissatisfaction with taste/color are commonly associated with the higher likelihoods of bottled water usage (Doria, 2006; Gorelick et al., 2011; Hu et al., 2011). We modeled choice of primary drinking water source (unfiltered tap water, filtered tap water, or bottled water) using demographic variables (**?@tbl-weights**), source of household tap water, and experience with any of (1) odd taste, (2) odd smell, (3) discolored water, or (4) cloudy water.

We used a multinomial logistic regression model (Agresti, 2002) to explore variables associated with the public’s choice of drinking water source (unfiltered tap water, filtered tap water, bottled water, or other). We used proportional odds models (Agresti, 2002; McCullagh, 1980) to explore factors associated (1) trust in entities responsible for drinking water safety, and (2) perceptions of drinking water safety. Multinomial logistic regressions were fit using the *svyVGAM* R package (Lumley, 2023) and proportional odds models were fit using the *survey* R package (Lumley, 2004). We calculated the generalized variance inflation factor (GVIF) to

evaluate potential impacts of multi-collinearity among model predictors on our interpretation of the models (Fox & Monette, 1992). We report our model results as odds-ratios.

Primary choice in drinking water

Prior research provides evidence that age, gender, perceptions of drinking water safety, category of water supplier, and dissatisfaction with taste/color are commonly associated with the higher likelihoods of bottled water usage (Doria, 2006; Gorelick et al., 2011; Hu et al., 2011). We modeled choice of primary drinking water source (unfiltered tap water, filtered tap water, or bottled water) using demographic variables (**?@tbl-weights**), source of household tap water, and experience with any of (1) odd taste, (2) odd smell, (3) discolored water, or (4) cloudy water. We hypothesize that ...

Levels of trust

Although public trust in government institutions is at historically low levels (Pew Research Center, 2022), there is evidence that the public may have higher trust in local public water utilities relative to other state, local, and federal institutions (Weisner et al., 2020). However, this effect might be confounded by experience with specific local drinking water problems. We modeled the level of trust participants had in their local water provider using demographic variables, household tap water source, and experience with any of (1) odd taste, (2) odd smell, (3) discolored water, or (4) cloudy water.

Perception of drinking water safety

We explored factors associated with perceived safety in drinking water using a proportional odds model relating sex/gender, age, race/ethnicity, education, home ownership, and household tap water supply to self-reported rating (on scale 1-10) of drinking water safety.

Results

Sources of drinking water and drinking water problems

The majority of respondents lived in homes with a municipal public water supply (56%, 1.6% SE) with 13.3% using some type of private water supply (Table 1). A relatively high percentage of respondents stated they did not know what the source of their tap water was (13.3%, 1.2% SE). The majority of respondents (65.5%) used unfiltered or filtered tap water as their main source of drinking water (Table 1). Bottled or pre-packaged water was the primary drinking water sources for 34.2% (1.6% SE) of respondents. Only 3.1% (0.6% SE) of respondents stated that they had not experienced any issues with their tap water (Table 2). Odd taste (27.5%, 1.4% SE), hardness or scale buildup (20.3%, 1.3% SE), and odd smell (18.8%, 1.3% SE) were the most common issues. Notably, 14.9% (1.1% SE) of respondent stated they have experienced a boil water notice.

Table 1: The proportion of respondents with the specified household water source and drinking water source.

Response	Proportion	SE
What is the source of your household tap water?		
Public supply - municipal	0.561	0.016
Public supply - rural water district	0.163	0.012
Private supply - well, river, pond	0.114	0.01
Private supply - rainwater harvest system	0.019	0.004
I don't know	0.139	0.012
Other	0.004	0.002
What is your main source of drinking water?		
Unfiltered tap water	0.28	0.015
Filtered tap water	0.375	0.015
Bottled/prepackaged water	0.341	0.016
Other	0.003	0.001

Table 2: Proportion of respondents that have experienced specified issues with their drinking water.

Issue	Proportion	SE
Odd taste	0.274	0.014
Odd smell	0.187	0.013
Discolored water	0.117	0.01
Cloudy water	0.148	0.011
Staining of clothes, teeth, or skin	0.055	0.007
High salt content	0.031	0.005
Hardness or scale buildup	0.202	0.013
Corrosion of pipes or water fixtures	0.081	0.009
Boil water notice	0.149	0.011
Water shortage	0.094	0.009
None of the above	0.031	0.006
Other	0.031	0.006

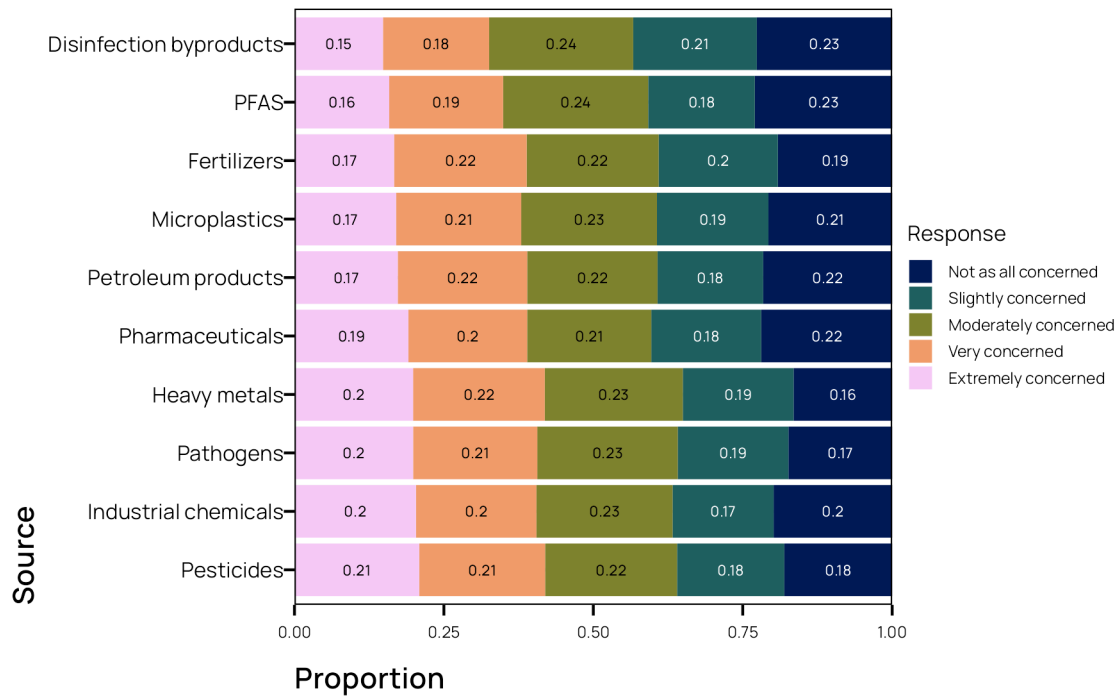


Figure 1: Contaminants of concern

We did not observe strong differences among response levels between different contaminants of potential concern (Figure 1). Pesticides (*extremely concerned* = 21%, 1.3% SE; *very concerned* = 21.1%, 1.3% SE), industrial chemicals (*extremely concerned* = 20.3%, 1.3% SE; *very concerned* = 20.1%, 1.3% SE), pathogens (*extremely concerned* = 19.9%, 1.3% SE; *very concerned* = 20.8%, 1.3% SE), and heavy metals (*extremely concerned* = 19.8%, 1.3% SE; *very concerned* = 22.0%, 1.3% SE) are sources that elicited the highest levels of concern across all respondents. Disinfection byproducts (*Not at all concerned* = 22.6%, 1.4% SE; *slightly concerned* = 20.7%, 1.3% SE) and PFAS (*not at all concerned* = 23.0%, 1.4% SE; *slightly concerned* = 17.8%, 1.2% SE) were sources of least concern.

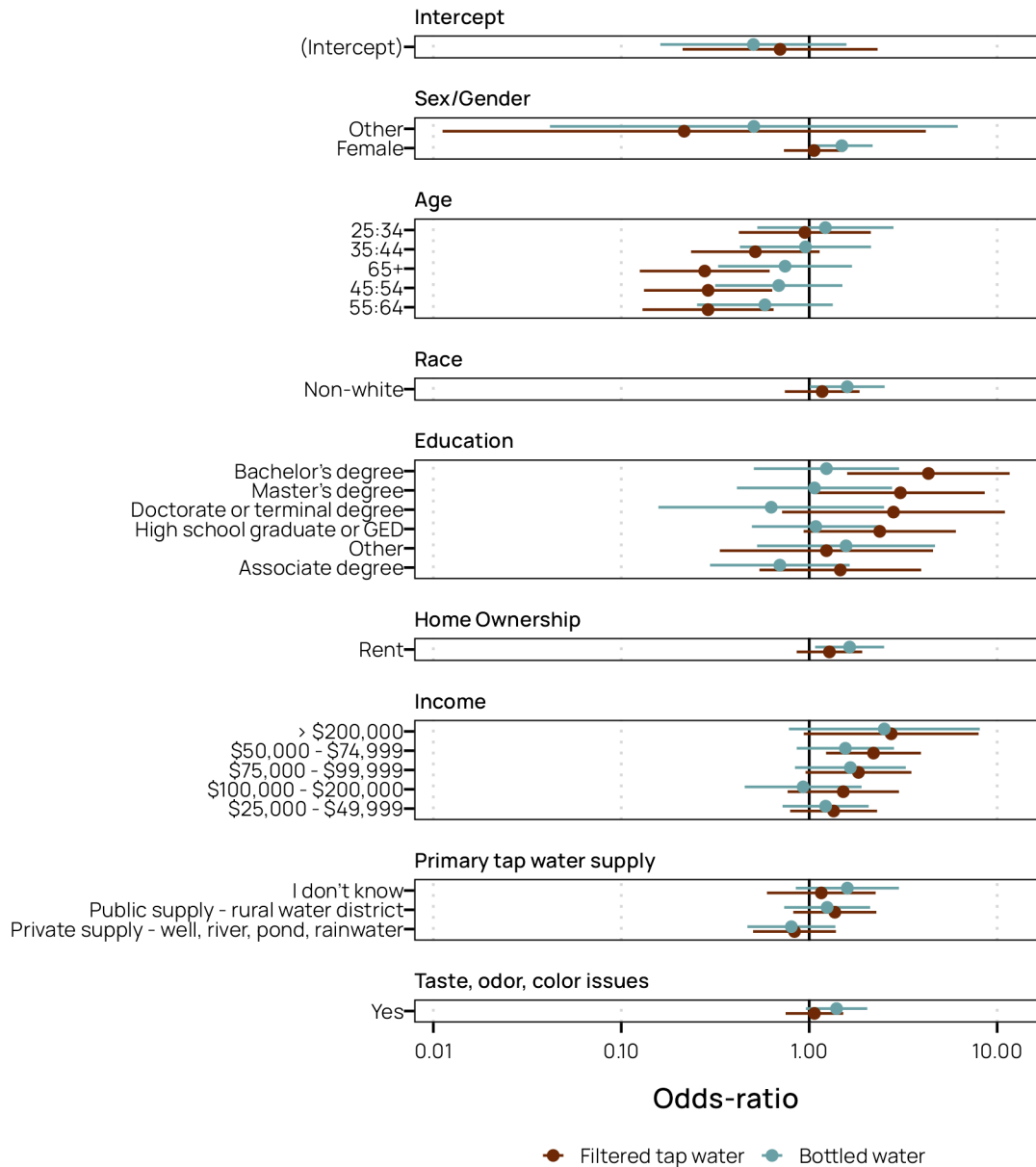


Figure 2: Primary drinking water model coefficients (odds-ratios) and 95% CIs. Odd-ratios are relative to unfiltered tap water.

Based on the multinomial regression model, we found limited effects of demographic variables, drinking water sources, and experience with odd taste, color, or smell on the odds of using bottled drinking water compared to unfiltered drinking water. Notably, females had 1.49 times the odds (95% CI [1.02, 2.17]) of using bottled drinking water instead of unfiltered tap water compared to males. Non-whites had 1.59 times the odds (95% CI [1.01, 2.52]) of using bottled drinking water instead of unfiltered drinking water compared to white respondents. Renters had 1.64 times the odds (95% CI [1.07, 2.50]) compared to homeowners.

Conversely, older respondents were more likely to use unfiltered drinking water compared to filtered water (45:54 age group: OR = 0.29, 95% CI [0.132, 9.636]; 55:64 age group: OR = 0.29, 95% CI [0.130, 0.647]; 65+ age group: OR = 0.278, 95% CI [0.002, 1.25]) but there was not strong evidence for differences in odds between bottled water and unfiltered drinking water among any of the age groups. Education also showed strong effects on the use of filtered drinking water. Having a bachelor's degree resulted in 4.31 times the odds of using filtered drinking water compared to those not graduating high school. A master's degree had a similarly large effect (OR = 3.06, 95% CI [1.09, 8.59]).

Sources of information

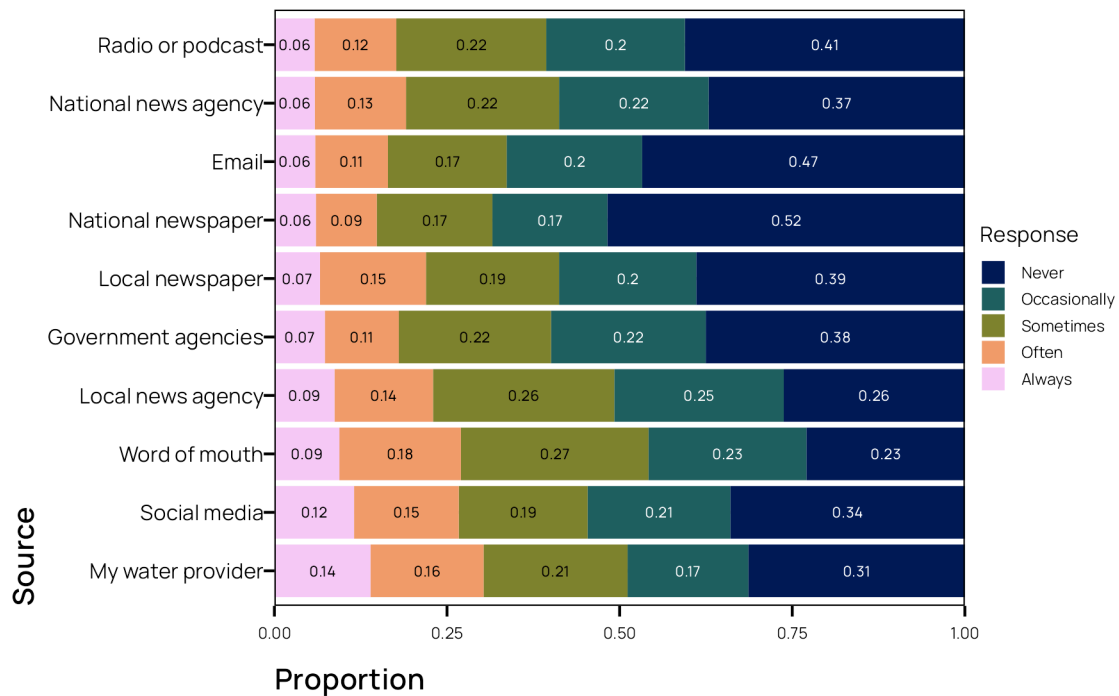


Figure 3: Sources of drinking water quality information.

Water providers appear to be the most relied upon source for information on drinking water with 13.9% (1.1% SE) and 16.4% (1.2% SE) of responses indicating water providers are *always* or *often* used as a source of information (Figure 3). Both social media (*always* = 11.5%, $\pm 1\%$ SE; *often* = 15.2%, $\pm 1.1\%$ SE) and word-of-mouth (*always* = 9.4%, $\pm 1\%$ SE; *often* = 17.6%, $\pm 1.2\%$ SE) are also frequent sources of information with similar or higher usage than local news agencies (*always* = 8.7%, $\pm 0.9\%$ SE; *often* = 14.3%, $\pm 1.1\%$ SE) or local newspapers (*always* = 6.6%, $\pm 0.8\%$ SE; *often* = 15.3%, $\pm 1.1\%$ SE). Some of the least utilized sources included radio or podcasts (*never* = 40.5%, $\pm 1.6\%$ SE; *occasionally* = 20.1%, $\pm 1.3\%$ SE), email (*never* = 46.7%, $\pm 1.6\%$ SE; *occasionally* = 19.6%, $\pm 1.3\%$ SE), national newspapers (*never* = 51.8%, $\pm 1.6\%$ SE; *occasionally* = 16.7%, $\pm 1.2\%$ SE), and government agencies (*never* = 37.5%, $\pm 1.6\%$ SE; *occasionally* = 22.4%, $\pm 1.4\%$ SE).

Perceived responsibility, trust, and safety

Question: What level of responsibility should the following entities have for making sure drinking water is safe for consumption?

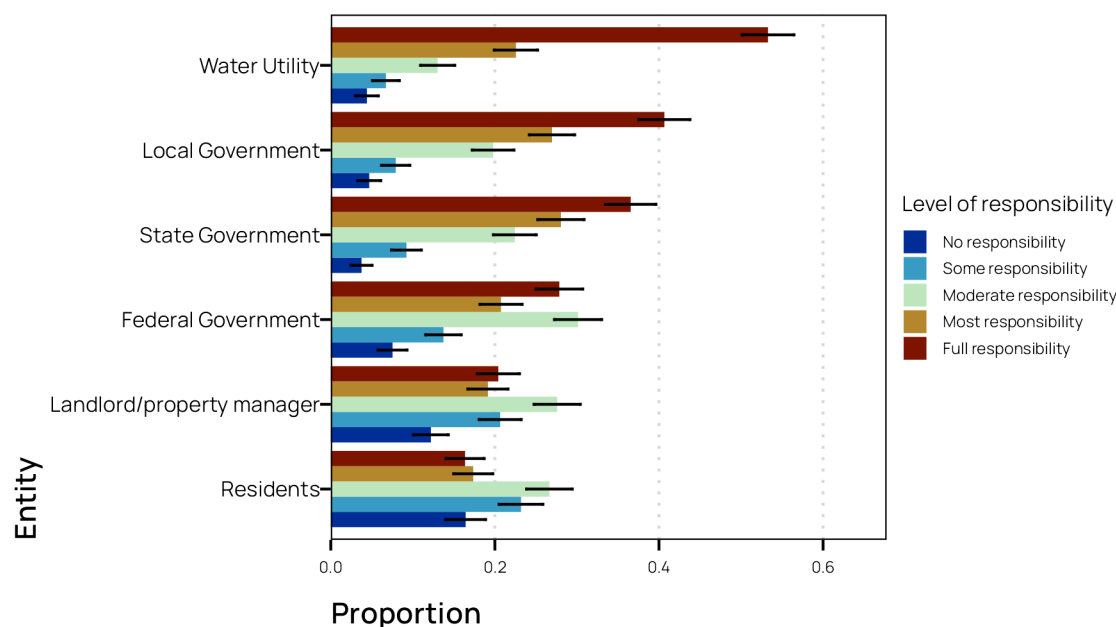


Figure 4: Weighted proportional responses for the level of responsibility people believe different entities have for ensuring drinking water safety. Bar lengths represent the mean proportional response with error bars representing the 95% confidence interval.

In general, higher proportions of survey respondents assigned water utilities (53.3%, 95% CI [50.1%, 56.5%]), local government (40.7%, 95% CI [37.5%, 43.8%]), and state government (36.6%, 95% CI [33.5%, 39.6%]) with the highest levels of responsibility for ensuring safety of drinking water (Figure 4). Moderate responsibility was the most common response for the level of responsibility attributed to household residents (26.6%, 95% CI [23.9%, 29.4%]) and landlords/property managers (27.6%, 95% CI [24.8%, 30.4%]). A relatively high proportion of responses indicated residents have no responsibility for drinking water quality (16.4%, 95% CI [14.0%, 18.9%]). Relative to other governmental institutions, fewer people felt the federal government had full responsibility (27.9%, 95% CI [25.0%, 30.7%]) for drinking water safety.

Question: What is your level of trust in the following entities for making sure drinking water is safe for consumption?

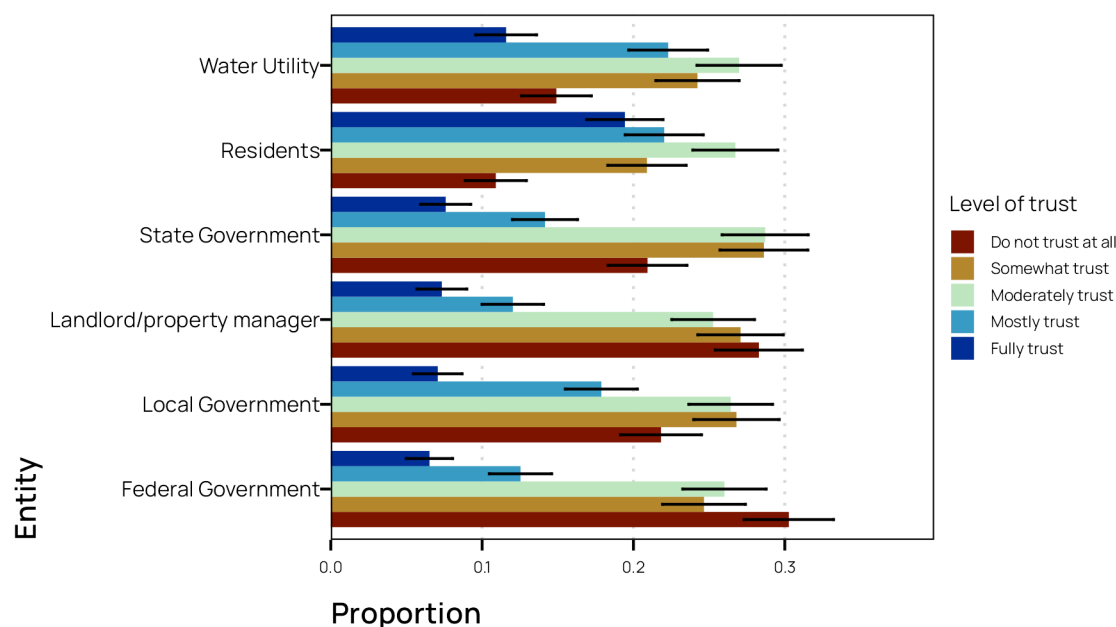


Figure 5: Weighted proportional responses for the level of trust people have in the entities responsible for ensuring drinking water safety. Bar lengths represent the mean proportional response with error bars representing the 95% confidence interval.

When asked for their level of trust in these entities for ensuring safety of drinking water, 30% (95% CI [27.3%, 33.2%]) of respondents expressed they do not trust the federal government at all (Figure 5). Only 6.5% (95% CI [4.9%, 8.1%]) indicated they fully trust the federal government for ensuring drinking water safety. State government fared slightly better, with 28.7% (95% CI [25.9%, 31.6%]) and 28.6% (95% CI [25.7%, 31.5%]) of respondents indicating they moderately trust or somewhat trust the state government for ensuring safety. Local and state government had rates of full trust (7.1%, 95% CI [5.5%, 8.7%]) and 7.6%, 95% CI [5.9%, 9.3%], respectively) comparable to the low rate observed for the federal government (6.5%, 95% CI [5.0%, 8.1%]).

Water utilities appear to be more trusted by the public than other governmental institutions. While the proportion of responses indicating moderate trust (27.0%, 95% CI [24.2%, 29.8%]) and mostly trust (22.3%, 95% CI [19.7%, 24.9%]) are comparable to local, state, and federal government, much fewer people indicated that the “do not trust at all” the water utility (14.9%, 95% CI [12.6%, 17.2%]).

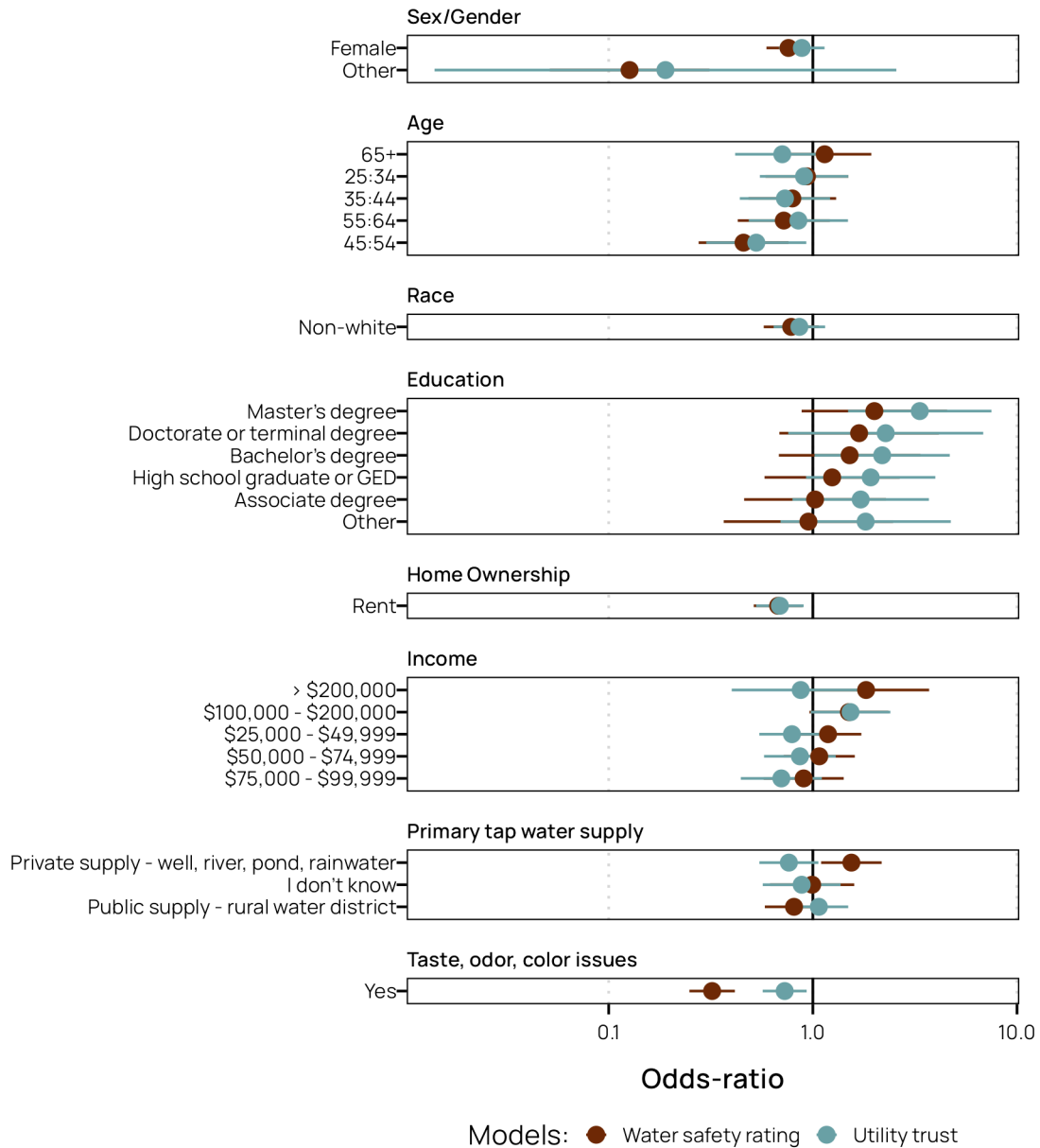


Figure 6: Estimated effect sizes (odds-ratios) and 95% confidence intervals of selected variables on (1) level of trust in drinking water utilities, and (2) perceived safety of drinking water.

The proportional odds model provides evidence that sex/gender, home ownership, household tap supply, and experience with taste/odor/color issues are associated with the perception of drinking water safety (Figure 6). Females were 1.32 times more likely to rate their drinking water less safe than males (OR = 0.76, 95% CI [0.59, 0.97]). Respondents identifying their gender as other had 7.69 times the odds (OR = 0.13, 95% CI [0.05, 0.32]) of rating their drinking water less safe than male respondents. Home ownership provided a strong signal with renters 1.49 times more likely to provide a lower drinking water safety ranking than homeowners (OR = 0.67, 95% CI [0.51, 0.89]). Respondents on private water supplies had 1.54 times that odds of

providing a higher drinking water safety rating than people on municipal supplies (OR = 1.54, 95% CI [1.10, 2.16]). People that experienced taste/odor/color issues with 3.12 times more likely to provide a lower safety rating than those that never experienced an issue (OR = 0.32, 95% CI [0.24, 0.41]).

We identified difference among some age groups, but a clear pattern was not evident. Respondents in the 45-54 age bracket were 2.22 times more likely to provide a lower drinking water safety rating than the 18-24 year old age group.

note- we could add a plot of differences in marginal probabilities, but I think there are too many levels in our factors, plus really long labels.

Discussion

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