Drinking Water and Environmental Justice in Post-Flint America: How Water Tests Increase Public Welfare

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ABSTRACT

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In 2016, Flint, Michigan declared a State of Emergency due to high levels of lead in the city's drinking water. Flint is predominantly black or African-American and the average income is significantly below the U.S. average. Extensive media coverage about these events may have adversely affected water quality perceptions in similarly disadvantaged communities but whose public drinking water systems have no outstanding violations. We conducted experiments in such a community to explore how individuals perceive their own drinking water and tests the effectiveness of two water quality treatments (water test kit and professional laboratory test). After collecting water samples from each participants home, these experiments revealed that the average willingness-to-accept to drink three ounces of their own water was $9.57. After treatment, their average willingness-to-accept was as low as $2.88. We show that inexpensive water test kits can be leveraged to rebuild trust in public water systems and enhance the welfare of disadvantaged communities.

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Introduction

Millions of Americans live in communities in which the public water system is in violation of the Safe Drinking Water Act (SDWA) (Fedinick et al., 2017; Allaire et al., 2018; Langin, 2018). In Flint, Michigan, negligence led to one of the largest drinking water crises in recent United States history when, in 2014, Flint switched its drinking water supply from the Detroit system, which draws water from the Great Lakes, to the more-polluted Flint River to reduce costs. The pollution in the river water hastened corrosion of aging lead pipes, and in January 2016 Flint declared a State of Emergency due to dangerously high levels of lead in the drinking water supply (State of Michigan, 2016). More recently (August 2018), the city of Detroit, Michigan, shut off the water supply at all 106 of its public schools due to high levels of lead and/or copper detected at 24 of the schools (Detroit Public Schools Community District, 2018).

The significance of these events goes well beyond Flint as they may have contributed to an overall decline in trust in drinking water utilities in the United States. This may be particularly true for those communities that are similarly disadvantaged in terms of their socio-economic character – evidence from previous research found that people of color and low-income have been disproportionately subjected to environmental and health risks in their neighborhoods and workplaces (Zimmerman, 1993; Bullard & Johnson, 2000; Brulle & Pellow, 2006; Martuzzi et al., 2010).

Our study uses field experiments to examine individuals' perceptions of drinking water. We conducted this study in a neighborhood that is similar to Flint in terms of income and race (see Figures 1 and 2). This neighborhood also has suffered from environmental injustices, including numerous Superfund sites, contaminated areas, and vulnerability to storm surges and sea level rise (see Appendix A, Figure A1). The neighborhood, known as Southbridge, is located in South Wilmington, Delaware, in the U.S. mid-Atlantic and receives its drinking water from a public system that had no outstanding violations of the SDWA at the time of the experiment (Delaware Health and Social Services, 2018). We analyzed participants' willingness to accept (WTA) monetary compensation to drink unfiltered tap water collected from their own kitchen faucet.

Water quality over all has improved since the establishment of the Clean Water Act of 1972 and the SDWA of 1974 in the United States, and the benefits likely exceed the large cost of these regulations (Keiser et al., 2018; Keiser & Shapiro, 2018; Muller et al., 2011). In fact, the Environmental Protection Agency (EPA) reports that drinking water regulations have reduced the detrimental effects of contamination on water users largely through protection of human health, but also through aesthetic (improved taste/odor) and material (reduced corrosion/build-up) effects (EPA, 2002). Despite these great improvements in drinking water quality and safety, widely covered events, such as the Flint crises, may have severely impacted the perception of water quality in the United States.

A frequent issue in mitigating public overreaction to safe drinking water[1] involves access to information – water quality information and drinking water standards are public information that

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[1] The vast majority of Americans are not drinking water that can lead to the health effects that impacted Flint (EPA, 2016).

can be accessed per the SDWA (EPA, 2002). However, this information is frequently difficult to access and difficult to understand, as it is not necessarily prepared for the general public. Additionally, people with less education are less likely to agree with the findings of scientific studies (Drummond and Fischoff, 2017). Furthermore, the public water systems in the United States are old and often in need of maintenance and modernization. Nearly a third of U.S. water systems utilize service lines that contain lead and it is not always known where these lead pipes are within a system (Cornwell et al., 2016). Contaminants like lead are closely monitored under the SDWA, and typically maintained through corrosion control methods such as chemical treatment. Despite inherent reasons to be concerned about drinking water quality and incipient stages of stricter standards for water quality or additional requirements for emerging contaminants; it holds that drinking water in the United States is generally safe (Ebenstein, 2012; Greenstone and Hanna, 2014; USEPA, 2016). One potential way to address these negative perceptions of public drinking water, particularly in disadvantaged communities, is by involving these individuals in the testing of their own household drinking water.

This research contributes to understanding how socio-economically disadvantaged communities in the United States perceive tap water provided by a public water system with no outstanding violations of primary drinking water standards. We find that simple inexpensive water tests can be an effective tool in mitigating public distrust in the safety of their drinking water, providing evidence that a science-based solution (objective testing) can significantly alleviate those concerns and increase social welfare. Specifically, our primary experimental results indicate that participants are concerned about their tap water and require, on average, $9.57 to drink three ounces of it. However, water testing can significantly reduce this concern by roughly 70%

($2.88). This is particularly important in low-income communities facing difficult financial decisions about the safety of their drinking water and potentially considering purchasing bottled water. Disadvantaged communities may have stronger dependencies on public drinking water systems than wealthier communities that can potentially afford to upgrade their water systems or purchase bottled water. Objective testing using low-cost water test kits can demonstrate water safety and thereby improve communities' trust in drinking water systems that have no outstanding violations of the primary drinking water standards. Note, our findings revealed that none of the tested household drinking water samples were in violation of the SDWA (for tested measures) – making this community different from Flint, MI where dangerous levels of lead were found in the drinking water. Our results are meaningful to many communities in the U.S., specifically socio-economically disadvantaged ones, that receive their drinking water from public drinking water systems that have no outstanding violations but may be suffering from an unduly negative public perception. To our knowledge, no previous study has quantified these behaviors through revealed preference research methods or provided evidence of potentially cost-effective large-scale mitigation approaches to destigmatizing public drinking water systems that comply with the regulations.
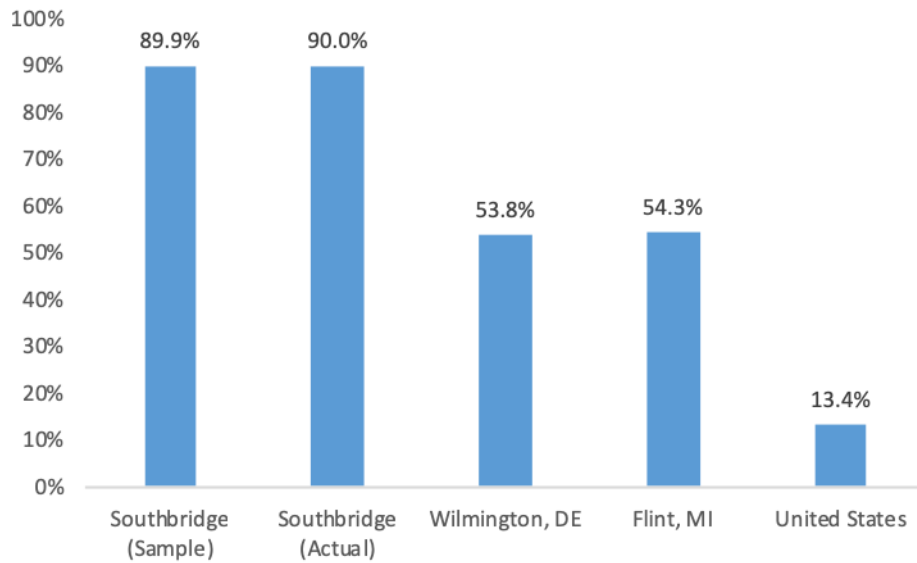
Figure 1. Average annual household incomes
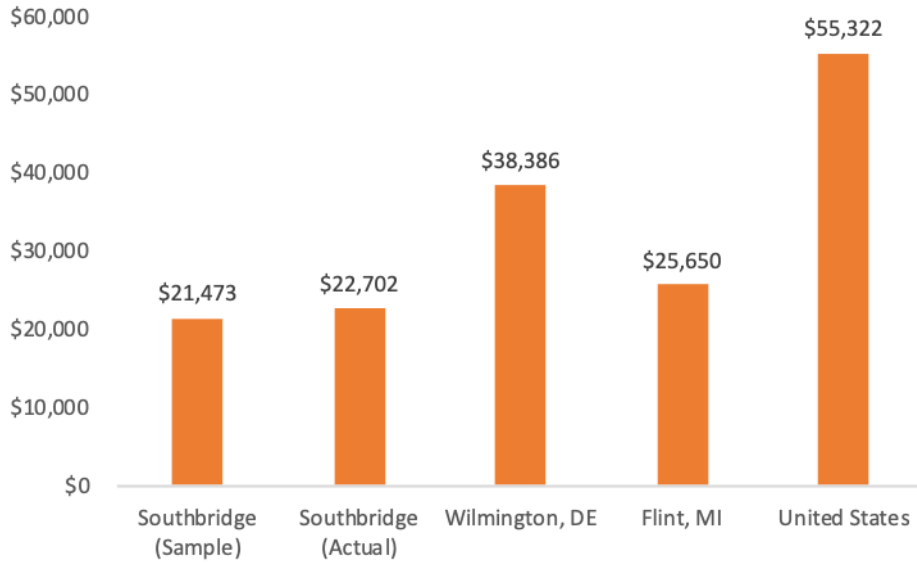
Note: Data for Southbridge Actual and Wilmington DE came from the Center for Energy and Environmental Policy (CEEP, 2005; CEEP, 2014); data for Flint MI and the United States came from the U.S. Census Bureau (USCB, 2017).

Figure 2. Percentage of black and African American citizens in each community

Note: Data for Southbridge Actual and Wilmington DE came from the Center for Energy and Environmental Policy (CEEP, 2005; CEEP, 2014); data for Flint MI and the United States came from the U.S. Census Bureau (USCB, 2017).

Experimental Design

General Setup

Following protocols approved by our university's Institutional Review Board (IRB), we sampled 241[2] participants from the Southbridge neighborhood of Wilmington, Delaware. Participants were split into two separate experiments, A and B (see Figure 3). In Experiment A, participants took part in a baseline group, which was primarily setup to test if repeating the same decision over time would impact behavior (Plott & Zeiler, 2005). The focus of Experiment B was to test the effectiveness of two different types of water testing. Participants took part in either Experiment A or Experiment B, but not both. In both experiments participants made two decisions, specifically, we used a WTA-version of the Becker-DeGroot-Marschak (BDM) mechanism (Becker et al., 1964) to elicit and quantify participants' WTA monetary compensation to drink tap water, which originated from a public water system (additional details are provided in Appendix B). The WTA-version of the BDM mechanism has been shown to be both incentive compatible and demand revealing (Messer et al. 2010). In this mechanism, a utility maximizing individual (i) offers the lowest amount money they would accept (O_{ii}) to drink tap water (j), such that the utility derived from O_{ii} is larger or equal to the status quo. To ensure incentive compatibility, a randomly drawn number (P_{ii}) determines the outcome. If $P_{ii} \geq O_{ij}$, the participant drinks the tap water and receives P_{ii}; if $P_{ii} < O_{ij}$, the participant does not drink the water nor receives any payment. All decisions were made on tablet computers that were placed to ensure privacy for the participants. In addition to the possible incentive pay in the

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[2] After removing participants who had previously taken part in our university's research and those participants who failed to return for round two of the experiments, 167 participants remained for the data analysis. Each participant made two decisions in the experiments, resulting in a total of n=334 observations.

BDM mechanism, all participants received $15.00 for their time, for each time they came to the community center to participate in these experiments. Additionally, all participants were extensively trained on how to make offers, including a video containing multiple examples of different offers, different randomly determined compensations, and corresponding outcomes.

Figure 3. Road map showing the experimental design.

EXPERIMENT ROAD MAP
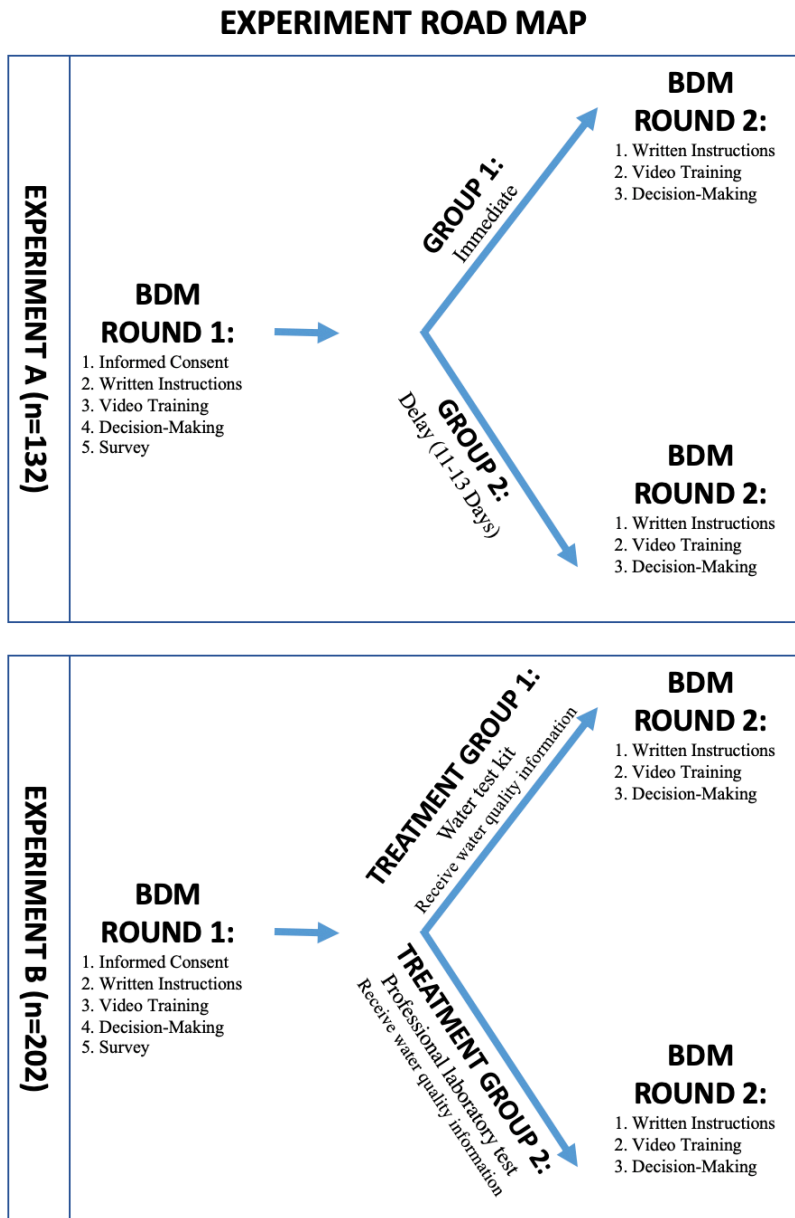
Experiment A

This research was announced in the community through fliers. Adult individuals were invited to participate in our study, which was conducted at the Southbridge Neighborhood House (a local community center). Participants were randomly assigned to one of two groups - an *immediate*

Round 2 group or an 11-13-day *delayed* Round 2 group. After participants signed the informed consent forms, read the experimental instruction and received the video training on the BDM, they placed WTA offers that presented the lowest amount of money they would accept to drink three ounces of the public tap water. All offers placed had to be in the interval $[\$0, \$50]$. If participants did not want to drink the water for $50 or less, they could check a box indicting this preference and would not be subjected to drinking the water nor receive any payment other than the time compensation. Participants in the *immediate* Round 2 group went through the BDM mechanism twice (back-to-back), whereas the *delayed* Round 2 group returned after 11-13-days to submit offers for Round 2. The purpose of both of these groups was to test the impact of time on offering behavior in the BDM mechanism, and, to a lesser degree, to test if participants in the neighborhood perceived the water collected from a public tap in the community differently compared to their own home's tap water (explained in Experiment B). The *immediate* Round 2 and *delayed* Round 2 groups allowed us to analyze participants' behavior in the BDM over time - learning may impact offering behavior in BDMs and other auctions (Plott & Zeiler, 2005; Noussair et al., 2003; Lusk & Shogren, 2007). In Experiment B we asked participants to return after 11-13 days (the time required by one of the treatments) to make another round of offers. Hence, Experiment A offers insight into potential participant learning and the impacts of time on offering behavior.

Experiment B

Once again, the research was announced through fliers in the community. However, this time, participants met the researchers at the community center, who walked them back to their residence, where participant filled multiple vials with tap water from their kitchen faucet. The

participants and researchers then returned to the community center, where each participant was randomly placed into one of two treatment groups that involved different types of testing of the just-collected tap water: an inexpensive home water test kit (Treatment Group 1) such as one that can be conveniently purchased at a hardware store or online, or an independent professional laboratory test (Treatment Group 2) that is more expensive but more precise. Just like in Experiment A, participants received experimental instructions and video training on how to place offers in the BDM mechanism.

Prior to any water testing, all participants participated in a first round of the BDM mechanism concerning the lowest amount of money they would be willing to accept to drink three ounces of their own tap water they had just collected – participants could place offers in the interval $[\$0, \$50]$.

All participants were then asked to return 11-13 days (the time required by the independent laboratory to complete the tests) to participate in Round 2 of the experiment. They received the same BDM instructions and training as in Round 1. Depending on the participant's treatment group, they then received the test results from the professional laboratory or the home water test kit. Both tests included the same common water quality measures: lead, bacteria, chlorine, nitrate, nitrite, hardness, and pH - these parameters were chosen as they are typically included in common water quality tests. All participants received the same summary sheet of water quality results (see Appendix B). Additionally, below the summary sheet, participants received the tests results as reported by either the professional laboratory or the water test kit. After participants examined their water test results, they made another offer for the lowest amount of money they

would accept to drink three ounces of their own tap water (other than the test results, Round 1 and Round 2 of Experiment B were identical).

BDM Mechanism Outcome

The functionality of the computer program that determined the outcome of both Experiment A and Experiment B were identical. For each of the participants' two offers, the computer determined the random price against which the participants' offers were compared. At the end of the experiment, participants were asked to return the tablet computer, and the last screen entailed the outcome for each participant. If the computer determined that the random price was greater or equal to the participant's offer $\left(P_{ii} \geq O_{ii}\right)$, then the participant would drink three ounces of tap water and receive P_{ii} (privacy was ensured for the drinking of the water and the payment); if the computer determined that the random number was smaller than the participant's offer $\left(P_{ii} < O_{ii}\right)$, then the participant would receive her time compensation and not drink the tap water.

Results

Despite previously reported widespread concerns in the neighborhood about the quality of their drinking water (Perez & Egan, 2016), and participants' (stated) concern in this study (78% of participants reported as being concerned about their drinking water quality in an accompanying survey), none of the tested water samples were found to be in violation of the United States Environmental Protection Agency's (USEPA) Primary Drinking Water Standards for tested measures. This suggests that participants' negative perception may not be warranted - at least

with respect to the tested parameters in this study. Figure 4 provides a street-level overview of the tested area.

Figure 4. GIS map of tested area in the Southbridge neighborhood

HOUSEHOLDS TESTED IN SOUTHBRIDGE NEIGHBORHOOD

This map provides a street-level overview of the tested area, however, in order to maintain participant confidentiality, we do not identify tested households but rather the street on which we tested. The number inside each marker identifies how many households we tested on the particular street.

Given our experimental design, which allowed for offers of $0 to $50, we analyzed the data using a Tobit model to account for censoring. Additionally, we clustered the error terms by the

individual participant. The Tobit regression model has the following functional form (see, for example, Cameron & Trivedi, 2010):

$$y_i^* = \mathbf{x'}_i \beta + \varepsilon_i, i = 1, \dots, N$$

where, $\varepsilon_i \sim N(0, \sigma^2)$ and $\mathbf{x'}_i$ denotes the vector of independent observations. In this particular case, we place an upper censor, *UC*, at 50.01 that accounts for the unobserved variables such that

$$y = \begin{cases} y^* & \text{if } y^* < UC \\ UC & \text{if } y^* \geq UC \end{cases}$$

where *y* is the observed bid and y^* is the underlying value.

Results Experiment A

Figure 5 shows mean and median offers. While mean offers decreased between Round 1 and both immediate and delayed Round 2, the median offers appeared less responsive between Round 1 and Round 2, which might indicate that there is no systematic behavior change between Round 1 and both of the *immediate* and *delayed* versions of Round 2. Furthermore, the regression results provided in Table 1 did not reveal any significant behavior changes in participants - neither offers in the *immediate* Round 2 BDM nor the *delayed* Round 2 were significantly different. Plott and Zeiler (2005) argued that sufficient training can reduce overbidding in auctions (such as BDMs) and our video practice may have generally achieved this. These findings also imply that any treatment effects reported on in Experiment B, were not driven by time delays, but were the results of the underlying treatment.

Figure 5. Mean and median offers in Experiment A
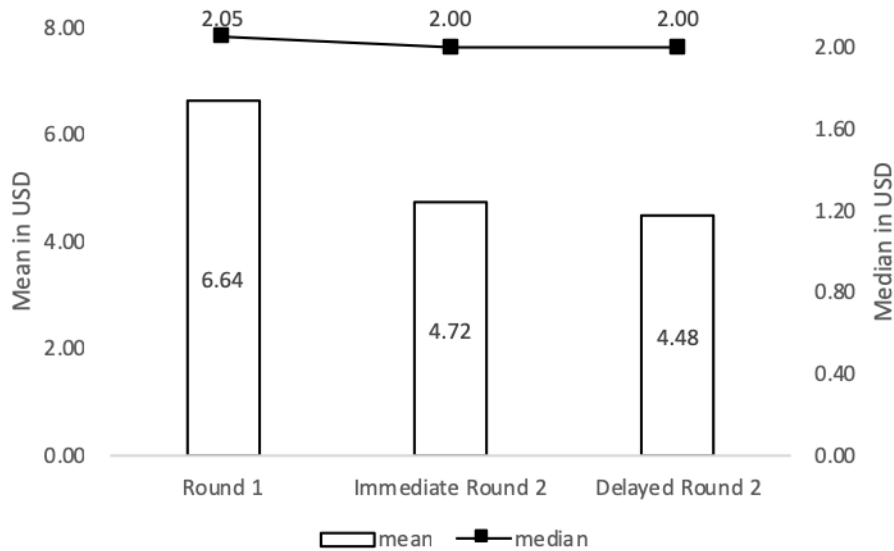
Table 1. Experiment A regression results – no significant differences in WTA

| Offer	M1: Combined Immediate and Delayed BDM (n=132)			M2: Immediate Round 2 (n=40)			M3: Delayed Round 2 (n=92)		
	Coef.	Std.	p-Value	Coef.	Std. Err.	p-Value	Coef.	Std. Err.	p-Value
Immediate Rnd 2	-3.331	2.156	0.125	-3.407	2.709	0.216	-2.493	2.702	0.359
Delayed Rnd 2	-2.521	2.344	0.284						
Round 1		(Omitted)			(Omitted)			(Omitted)	
Constant	8.054	1.755	0.000	8.13	2.964	0.009	8.032	2.193	0.000
Sigma	11.928	1.533		10.581	2.409		12.501	1.944	
Pseudo R2	0.0018			0.0034			0.0013		
Log pseud. likelih.	-508.3			-151.3			-356.4		

Note: Tobit regression model with clustered error terms and upper censoring at 50.01. There were three censored observation in M1 (zero in M2 and three in M3). The covariates are consistent between the models, and the deviations in the significance levels between M1 and M2, and M1 and M3 are due to the decreased variation in the explanatory variables and sample size.

Results Experiment B

Figure 6 shows mean and median offers in Experiment B, in which participants bid on tap water drawn from their homes and were provided with the results of objective testing of the water's

quality in a treatment prior to their second-round decisions. On average, participants in Round 1 required $7.78 to drink the tap water. In the post-treatment Round 2, participants in the water test kit treatment required only $2.87 and participants in the professional laboratory analysis treatment required only $3.70. Decreases in the median responses were large as well, declining from $2.00 in Round 1 to $0.91 under the water test kit treatment and $1.00 under the professional laboratory treatment in Round 2.

Figure 6. Mean and median offers in Experiment B
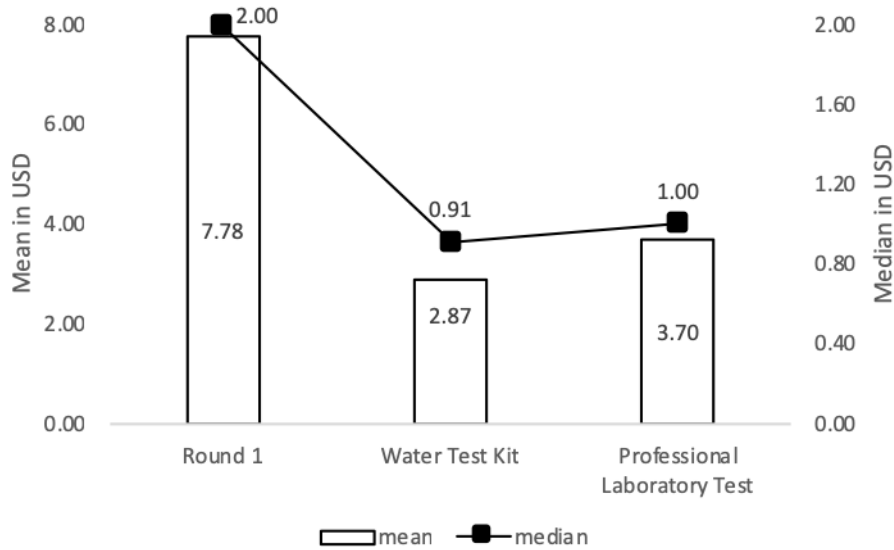
The results of the Tobit regression analysis, which are presented in Table 2, show a similar pattern. In the first auction, participants' mean WTA to drink three ounces of their own tap water was $9.57 (see Table 2, M4 Constant). However, after the treatments, participants' mean WTA had significantly decreased—by $6.69 ($p < 0.001$) in the water test kit treatment and $4.90

(p = 0.018) in the professional laboratory treatment.[3] These treatment effects remained when we included variables for the socio-demographic characteristics (Table 2, M5), though none of those descriptive parameters had a significant impact on participants' WTA. A Wald test identified no significant differences in behavior between the two treatments.

Our results show that (1) participants' perceptions of the quality of their water significantly improved after it was tested and therefore, (2) policymakers may leverage water testing to improve the public's perception of public water systems in a cost-effective way, by using relatively inexpensive water test kits. Of course, this approach is only desirable and would only increase public welfare if the utility in question does in fact provide safe drinking water.

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[3] Note, we used WTA measurements as a means to tease out behavioral differences pre- and post-treatment, i.e. before and after the water tests. We do not believe our experimental design allows us to draw conclusions about the amount of money people would be willing to accept for any amount of water, other than the three ounces tested in this research. For example, this research does not suggest that the derived willingness to accept for three ounces of household water can be proportionately upscaled to, say a day's worth or a year's worth of tap water consumption for the average individual. Instead, we believe that the strength of these findings lies in the effectiveness of simple and inexpensive water tests that may offer substantial welfare improvements of individuals who are socio-economically disadvantaged.

Table 2. Regression result Experiment B – water testing results in significant WTA reductions

Offer	M4: Treatments only (n=204)			M5: Treatments and descriptive variables (n=170)		
	Coef.	Std. Err.	p-Value	Coef.	Std. Err.	p-Value
Water Test Kit (Round 2)	-6.699	1.702	0.000	-6.349	1.876	0.001
Prof. Lab. Test (Round 2)	-4.901	2.054	0.018	-5.385	2.346	0.023
Pre-tested Water (Round 1)		(Omitted)			(Omitted)	
Age				-0.023	0.053	0.663
Female				1.191	2.013	0.555
Income				-3.839	3.511	0.276
Kids in Home				-0.052	0.551	0.925
Education				0.013	2.802	0.996
Water Concern				-4.820	3.248	0.140
Reverse Osmosis				-1.693	3.865	0.662
Previous Test				-1.716	6.013	0.776
Constant	9.571	1.586	0.000	16.847	6.035	0.006
Sigma	12.675	1.310		12.250	1.251	
Pseudo R2	0.0068			0.0131		
Log pseudolikelihood	-796.49			-658.13		

Note: Results of the Tobit regression model with clustered error terms and upper censoring at 50.01. There were five right-censored observations under treatments only and four under the treatments plus descriptive variables.

Another important step in the analysis is to verify that the treatment effects did not result from a few participants responding with very large reductions in their offers in Round 2. This potential was accounted for to some degree by use of clustered error terms in the Tobit model. However, additional insight can be gained by examining the number of participants who responded positively versus negatively to the treatments.

Under the water test kit treatment, nine participants increased their offers in Round 2, 16 did not change their offers, and 31 reduced their offers (were more willing to accept drinking the water). Under the professional laboratory treatment, 13 participants increased their offers in round 2, 15 did not change their offers, and 31 reduced their offers. Both sign and sign rank tests showed significant differences between the number of positive and negative changes in WTA

(p < 0.001). The median of positive offer differences minus the median of negative offer differences is likely positive, indicating that the number of participants who reduced their WTA in Round 2 was significantly greater than the number of participants who increased their offers. These results confirm that the treatment differences were not driven by a few participants whose WTA was substantially reduced after the treatment and, instead, reflect a general reduction in participants' WTA after receiving information about the quality of the water.

Though not statistically significant, a relatively large number of participants (22) increased the amount they required to drink the water after the treatment—the mean and median increase in offers for those participants were \$6.06 and \$2.87 respectively. For participants who decreased their offers (62), the mean and median reduction were \$14.56 and \$5.00. There were 31 participants whose offers did not change after the treatment. Potential motives for increasing the post-treatment offer include distrust in the researchers and a visceral rejection of the researchers' attempt to influence their decisions regarding their own drinking water. Several behavioral economic studies have found evidence of this type of behavior (Corbie-Smith et al., McEvily et al., 2012; Bertrand et al., 2004; Makri, 2017).

We also analyzed if any tested water-quality parameter was particularly concerning to participants. As previously noted, the tests revealed no violations of the USEPA's primary drinking water regulations for tested measures. Irrespective, even minor deviations from optimal levels theoretically could affect participants' behavior. Our analysis showed that none of the individual test parameters had a significant impact on participants' behavior (see Appendix C, Table C1), which suggests that the participants responded primarily to the overall test results

rather than to individual contaminants. This is important information for policymakers as it indicates that measures of individual contaminant levels likely do not play a substantial role in assuaging people's concerns as long as all are within the EPA standards. A single test of one or a few parameters may be sufficient to significantly increase trust in public drinking water systems (again, only for public water systems that have no outstanding violations). Lastly, we found no statistically significant differences in WTA water collected from a public tap in the community and participants' home tap water (see Appendix C, Table C2).

Conclusion

Our field experiment, conducted with 241 participants in a socio-economically challenged neighborhood in Delaware quantifies individuals' perceptions of their in-home drinking water. Their perceptions of the safety of their drinking water at the beginning of the experiment may have been affected by severe water crises such as the one in Flint, Michigan, in which improper treatment contaminated the water of predominantly black and low-income neighborhoods. Crises like the one in Flint can have significant, costly impacts in other communities, eroding their trust in their drinking water utilities despite such utilities being fully compliant with EPA's standards, as in the Southbridge neighborhood in Delaware.

Our tests of 122 samples of water from Southbridge found no violations of EPA's primary water standards (for the tested measures) at the household level, confirming previous tests conducted by the water utility (Delaware Health and Social Services, 2018). Yet we found that individuals in Southbridge were concerned about the quality of their drinking water, leading them to require $9.57 on average to drink a sample of the community's tap water. We further found that simple

water testing can significantly alleviate such concerns (reducing participants' WTA by $4.90 to $6.69) and that the inexpensive home water test kit could be a cost-effective way to restore communities' trust in their public water system. There was no significant difference in terms of assuaging community concerns about their drinking water between the expensive professional laboratory test ($150 per sample) and the water test kit ($20 per sample).

These findings are particularly relevant for policymakers working to enhance social welfare by restoring community trust in a water utility that has no actual outstanding water-quality violations. In a related study, Maertens et al. (2018) showed that free well water testing for arsenic in rural Bangladesh encouraged households to switch their water supply to safer alternatives. The results we presented in this study, show that simple and relatively inexpensive intervention would particularly benefit socio-economically challenged neighborhoods that likely have a much higher opportunity cost to replace their current drinking water supplies than wealthier communities that can afford to purchase bottled water.

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