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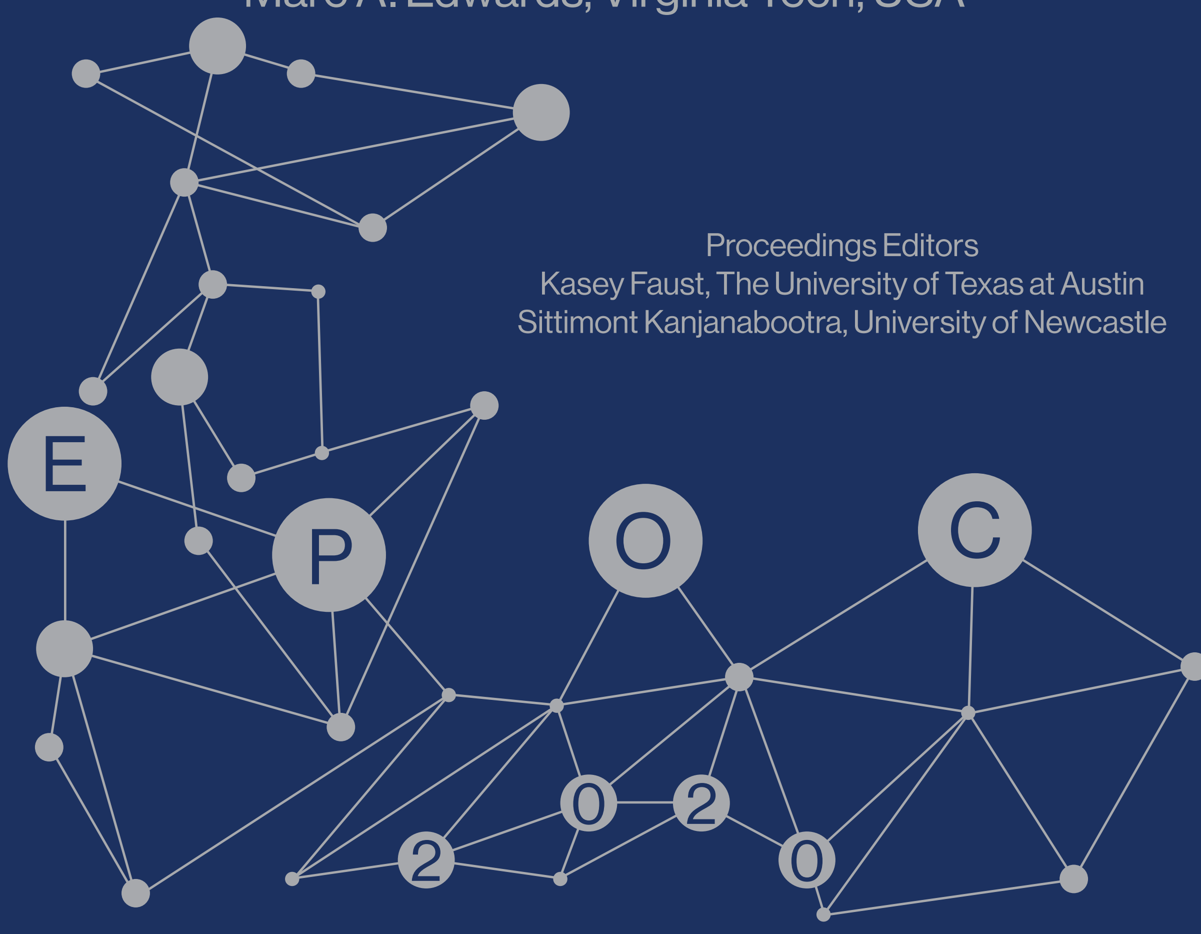

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Do Water Contamination Events Impact Willingness to Pay for Improved Water Quality in Shrinking Cities?

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ABSTRACT

Chronic population decline experienced by shrinking cities results in the underutilization of water infrastructure systems, that can lead to technical (e.g., increased water age) and financial challenges (e.g., reduced revenues from a smaller customer base) for utilities. Due to the high fixed costs associated with water infrastructure, the per capita costs charged to end-users correspondingly increase. Conflicting shrinking cities literature indicates that if poverty rates are >40% or more, residents cannot afford the high service costs, whereas other studies have found that a willingness to pay (WTP) increased rates for services if a value added is perceived. Here, we explore the influence of water contamination events on WTP for improved water quality in shrinking cities. Enabling this study is a survey distributed to 21 U.S. shrinking cities in 2019 (*n*=521). Statistical inferencing and qualitative analyses were used to explore the association between residents' WTP and residents witnessing water contamination events in their city or being aware of contamination events in other cities. Respondents who witnessed events in their city had the highest WTP with an average of 15.4% increase of their current bills. When looking into respondents' awareness of water contamination events, the qualitative analysis revealed that the most referenced events by residents were "Do Not Drink" advisories and chemical-related contamination events. Unsurprisingly, the 2016 Flint Water Crisis—which occurred in a shrinking city— received a great deal of attention when respondents identified contamination events in other cities. Understanding the influence of water contamination events on residents' WTP may assist utilities to define opportunistic times of support to increase utility rates, aligning with residents' stated preferences. Even a small rate increase can provide valuable additional resources to these utilities in shrinking cities that are frequently facing financial constraints.

KEYWORDS: shrinking cities, willingness to pay, water contamination events, water infrastructure, water quality

1. INTRODUCTION

In recent decades there has been a worldwide trend of population growth in some cities (U.N., 2014), and a converse trend of urban population decline in other urban areas referred to as "shrinking cities") (Bontje, 2004; Richardson and Nam, 2014). Shrinking cities here refer to medium or large cities (with a peak population of approximately 100,000 or more) that have experienced chronic population decline since their peak in 2010 or earlier U.S. Census (U.S. Census Bureau, 2011). Different from urbanization, local authorities and utilities in shrinking cities face challenges related to economic growth, increased residential vacancy, a decrease in demand of infrastructure services, causing existing infrastructure to be larger than once needed and often underutilized (Faust et al., 2016). This is particularly relevant to water infrastructure, as underutilization has public health and environmental consequences (Yang and Faust, 2019a). For instance, declining water infrastructure demands can lead to decreased water quality due to increased water age or stagnant water (Elfland et al., 2010; Faust et al., 2016; Rink et al., 2010).

The reduction in use of urban water infrastructure services has both technical impacts on the water infrastructure system, as well as financial implications on the utilities. Due to the high fixed costs of water infrastructure (~75-80%; Hummer and Lux, 2007), as the customer base declines, the per capita costs of services increase (Faust et al., 2017; Hummer and Lux, 2007). Important to note, in shrinking cities, poverty rates are often much higher than the national average, reaching upwards of 40% or more (e.g., Flint Michigan—41.2% as compared to the U.S. national average—15.1%; U.S. Census Bureau, 2010). Given this, utilities must balance the maintenance and operation of existing water infrastructure with the financial vulnerability of residents.

Increasing rates to consumers is one method often proposed to generate additional revenue for water utilities (Faust et al., 2016). A method used in the literature to evaluate how much water infrastructure rates may be increased is the contingent valuation or stated preference (e.g., Faust et al., 2018; Hensher et al., 2005; Osman et al., 2019). This method directly asks how much more respondents are willing to pay for improved water quality. A limitation to the stated preference method is the method of accounting for respondents reporting a zero willingness to pay (WTP). Notably, in this study, WTP refers to the willingness to pay *more* for water service relative to what the respondent is currently paying. Some respondents may be willing to pay nothing additional as they perceive no value regarding the incremental improvement of service, while others may report a zero WTP in the form of protest toward the service (Tentes and Damigos, 2015). Further, respondents' stated WTP may differ from the actual amount as revealed through behaviors (Rollins et al., 1997). However, understanding residents' stated preference provides insight regarding where the public attitude stands. As such, sources of opposition may be identified in advance without having to wait to capture residents' revealed behaviors.

There is a limited understanding of the influence that high profile water contamination events may have on WTP. Are people willing to pay more as they become aware of vulnerabilities in the system? Does the public perceive that the ability to manage such contamination events should be encompassed in their current rates? Or is the public simply happy with the service as is? As such, this study has three objectives: (1) to assess the WTP for improved water quality received at the tap in shrinking cities, (2) to test the association between WTP for improved water quality received at the tap and the awareness of water contamination events, and (3) to analyze the type of water contamination events witnessed that residents refer to when asked to consider these events. A better understanding of how water contamination events—such as the Flint Water Crisis—can influence WTP, allows utilities to implement policies at times of most acceptance.

2. LITERATURE REVIEW

Previous studies have found that residents' WTP for improved water service is influenced by geographic and socio-demographic attributes, local context and culture, and external factors, such as policy and proximity events (Brody et al., 2008; Faust et al., 2018; Tanellari et al., 2015). Further, how much residents are willing to pay can be influenced by experiences relating to physical water infrastructure failures (e.g., leaks, water service interruptions; Hensher et al., 2005; Griffin and Mjelde, 2000). For instance, a study conducted in Washington D.C. in 2007 found that consumers had a greater WTP if they had negative perceptions of or experiences with their water system, such as pinhole leaks (Tanellari et al., 2015). Concerning the influence of the local context, previous work has identified geographic and socio-demographic attributes influencing respondents' WTP. An example of this is a survey implemented in Rethymno, Greece, between November 2004 and January 2005, that analyzed the public's WTP for improved water quality and quantity (Genius et al., 2008). Results found that female respondents, high-income families, families with children, and households that did not drink tap water had a higher WTP. Respondents with high water bills, those affected with water cuts, and, interestingly, those who thought water quality was important had a lower WTP. The authors speculate that this might be due to the discontent of respondents toward their situation rather than their actual valuation of water quality (Genius et al., 2008). Similarly, Wang et al. (2010) assessed consumer WTP for improvements in China's household water services in 2006. Results showed that households with higher incomes, urban households, and male respondents were generally willing to pay more. Relevant to this study, previous work explored WTP, specifically in U.S. shrinking cities, as well (Faust et al., 2016; Faust et al., 2018; Osman et al., 2019). Faust et al. (2016) found that despite high poverty levels in shrinking cities, residents were still willing to pay more for improved water services. Osman et al. (2019) evaluated the temporal dynamics of WTP for improved water and wastewater services finding that there are significant shifts in WTP over time.

The impact of water contamination events on already aging water infrastructure has been a longstanding concern for researchers, policymakers, and utility managers (Morckel, 2020). Previous work has examined the causes and impacts of these events on water distribution networks to help utility managers with preparation and response—e.g., localization of the water contamination event in the network (Sankary and Ostfeld, 2019), or mitigation strategies (Shafiee and Berglund, 2017). However, the impact of water contamination events has been primarily focused on technical metrics related to the water network, such as water flow and quality (Clark and Buchberger, 2004; Khanal et al., 2006), location of the event (Sankary and Ostfield, 2019), or spatial structure of the network (Davis and Janke, 2015). For example, Sankary and Ostfield (2019) used probabilistic approaches (Bayesian methods) to localize the point source of water contamination events in the distribution network. Similarly, Davis and Janke (2015) studied the influence of the level of details of water network models on the analysis to quantify the impact of water contamination events. The authors found that decreased network details resulted in lower accuracy when estimating the adverse effects of such water contamination events. The work from Shafiee and Berglund (2017) went beyond using purely technical network metrics and proposed a framework combining usage behaviors of residents with network attributes to evaluate public health consequences of water contamination events.

In summary, the existing literature has explored residents' WTP as a form of potential revenue for water utilities. Water contamination events have primarily focused on the impacts on technical network attributes. Although studies have discussed a potential association between water contamination events and residents' WTP, these have been speculative. This work is aimed at better understanding the influence of water contamination events on residents' WTP.

3. METHODS

Enabling this study is a survey deployed throughout U.S. shrinking cities to assess public WTP for improved water quality. To leverage insights from the survey data, quantitative and qualitative methods were used. Specifically, statistical inferencing tested for association of WTP with (1) witnessing (or not) water contamination events and (2) awareness of water contamination events in *other* cities than where respondents currently resided, and qualitative analyses were used to understand the type and location of water contamination events residents are aware of within and beyond city boundaries.

3.1 Survey Development and Deployment

An online survey was deployed using the web-based software Qualtrics (Qualtrics, 2016) in December 2019 to 21 U.S. shrinking cities. These are medium and large cities that required large infrastructure to provide services at the peak of the population that has since declined, as discussed by Faust et al. (2016). Prior to deployment, the survey was determined exempt by the University of Texas at Austin Institutional Review Board and underwent content and expert validation. Participation was voluntary; all respondents were 18 years or older. Table 1 shows the frequency of survey responses included in this study, while Table 2 summarizes descriptive statistics of sociodemographic attributes from the survey respondents.

Table 1. U.S. shrinking cities considered in this study

City	Frequency of responses	Percentage (%)
Akron, Ohio	24	4.6%
Baltimore, Maryland	25	4.8%
Birmingham, Alabama	40	7.7%
Buffalo, New York	24	4.6%
Camden, New Jersey	21	4.0%
Canton, Ohio	24	4.6%
Cincinnati, Ohio	25	4.8%
Cleveland, Ohio	25	4.8%
Dayton, Ohio	25	4.8%
Detroit, Michigan	24	4.6%
Flint, Michigan	24	4.6%
Gary, Indiana	23	4.4%
Niagara Falls, New York	25	4.8%
Pittsburgh, Pennsylvania	24	4.6%
Rochester, New York	25	4.8%
Saginaw, Michigan	22	4.2%
Scranton, Pennsylvania	25	4.8%
St. Louis, Missouri	25	4.8%
Syracuse, New York	24	4.6%
Trenton, New Jersey	24	4.6%
Youngstown, Ohio	23	4.4%
Total	521	100%

Table 2. Descriptive statistics of select parameters

Unless otherwise indicated (1 if yes, otherwise 0)	**Min/Max**	**Average**
Individual characteristics		
Female	0/1	0.67
Responsible for paying all or a portion of water bill	0/1	0.78
Witnessed no water contamination events in the past 10 years	0/1	0.45
Witnessed <5 water contamination events in the past 10 years	0/1	0.32
Witnessed 5-10 water contamination events in the past 10 years	0/1	0.13
Witnessed >10 water contamination events in the past 10 years	0/1	0.10
Aware of past water contamination events in other cities	0/1	0.62
Willingness to pay more for improved quality of water (%)	0/100	14.31
Length of time lived in your city (years)	0/87	34.25
Household characteristics		
Number of people in household (people)	1/7	2.39
No household income	0/1	0.03
Household income is between 0 and $19,999	0/1	0.16
Household income between $20,000 and $34,999	0/1	0.17
Household income between $35,000 and $49,999	0/1	0.15
Household income between $50,000 and $74,999	0/1	0.18
Household income between $75,000 and $99,999	0/1	0.13
Household income $100,000 or greater	0/1	0.18

The following are survey questions of interest relevant to this study.

1. How much more are you willing to pay for improved quality (defined as clean water with an adequate smell and taste) of your water service? (%)
2. How many water contamination events has your city witnessed in the past 10 years? (I do not know/zero/less than five/between five and 10/more than 10)
3. What type of contamination events has your city witnessed? (open-ended)
4. Are you aware of any events of water contamination that have occurred in other cities? (Yes/No)
5. Can you specify the location of the events of water contamination that occurred outside of your city? (open-ended)

3.2 Statistical Inferencing

Chi-square tests of independence (Washington et al., 2010) were used to assess for an association between WTP for improved water quality with (1) witnessing contamination events in respondent's city, and (2) awareness of water contamination events in other cities. "I do not know" responses were not included. Responses to WTP in both cases were categorized by zero WTP or a WTP greater than zero on current water rates.

3.3 Qualitative Analysis

Open-ended questions underwent qualitative analyses (Saldaña, 2013). By identifying emerging themes, insight into residents' awareness of types of water contamination events in their city, as well as the location of water contamination events outside of their city emerged. All valid responses were iteratively coded (see Tables 3 and 4). Inter-coder reliability checks were conducted to ensure the consistency and replicability of the results (Saldaña, 2013).

Table 3. Coding dictionary for type of water contamination events

Codes	Definition	Quotation Examples
Responses relating physical water infrastructure failures as causes of contamination events		
Water main breaks	Responses indicating water main breaks as cause of water contamination	"pipeline breaks"
Sewage intrusion	Responses indicating sewage intrusion	"sewage intrusion"
Other	Responses indicating misc. failures as cause of water contamination	"dam damage"
Responses related to specific types of contamination events		
Chemical	Responses indicating chemical contamination events	"lead" or "too much disinfection chemicals"
Biological	Responses indicating biological contamination events	"city water has an issue with algae"
Physical	Responses indicating physical contamination events	"muddy water" "cloudy murky smelly water"
Radiological	Responses indicating radiological contamination events	"radiation"
Not specified	Responses did not specify the type of contamination event	"contamination" "possible contamination"
Responses related to contamination advisories		
Boil advisory	Responses indicating boil advisories	"boil advisory" "boil alert"
Do Not Drink advisory	Responses stating "do not drink" advisories	"do not drink"
Responses related to knowledge of contamination events, but type not specified		
Unsure of event specifics	Responses indicating lack of knowledge of type of events witnessed	"I don't remember" "not sure"
Responses related to no knowledge of events		
No known events	Response indicating that no contamination events were witnessed	"None"

Table 4. Event location that occurred outside city's respondents

Codes	Examples of cities referred by respondents
Northeast	
New Jersey	Lawrenceville, Gloucester City, Newark
New York	Syracuse, Dewitt, New York City
Pennsylvania	Pittsburgh, Philadelphia
Midwest	
Michigan	Flint, Detroit, Lansing
Ohio	Akron, Dayton, Cleveland
Missouri	St. Louis, Clayton
Illinois	Chicago, Columbia
Indiana	Gary, Griffith
South	
Alabama	Jasper, Fairfield
Texas	Houston
West Virginia	Charleston
Florida	Naples
Mississippi	Meridian
Georgia	Georgia
North Carolina	Wrightsville Beach
West	
Colorado	Brighton
California	Campbell

3.4. Limitations

The data collected is cross-sectional, while public perceptions are dynamic and change with new information and experiences. Hypotheses tests provide evidence related to the presence or lack of association between two variables; however, these tests cannot provide evidence about the type of relationship. Responses to the open-ended questions capture respondents' awareness, not the objective impact of the water contamination event. Lastly, as respondents were from 21 medium and large U.S. shrinking cities, our results may not be transferable for cities outside this city classification.

4. RESULTS

A large percentage of responses regarding WTP for improved water quality (152 responses or 29% of the sample) reported a value of zero (Figure 1), consistent with other studies (Faust et al., 2018; Osman et al., 2019). The average percentage of willingness to pay across residents was 14.3% more than their current bills (including the reported zeros). The average WTP for respondents when excluding zeros was a 20.2% increase in the respondent's current bill. A WTP for improved water quality was associated with respondents who witnessed water contamination events in their city (p=0.002) or who were aware of water contamination events (p=0.021) in other cities.

Additional information was gathered regarding personal experience with water contamination events or knowledge of such events in other cities (Table 5). The frequency of responses from the qualitative analysis is also reported (Table 6 and 7).

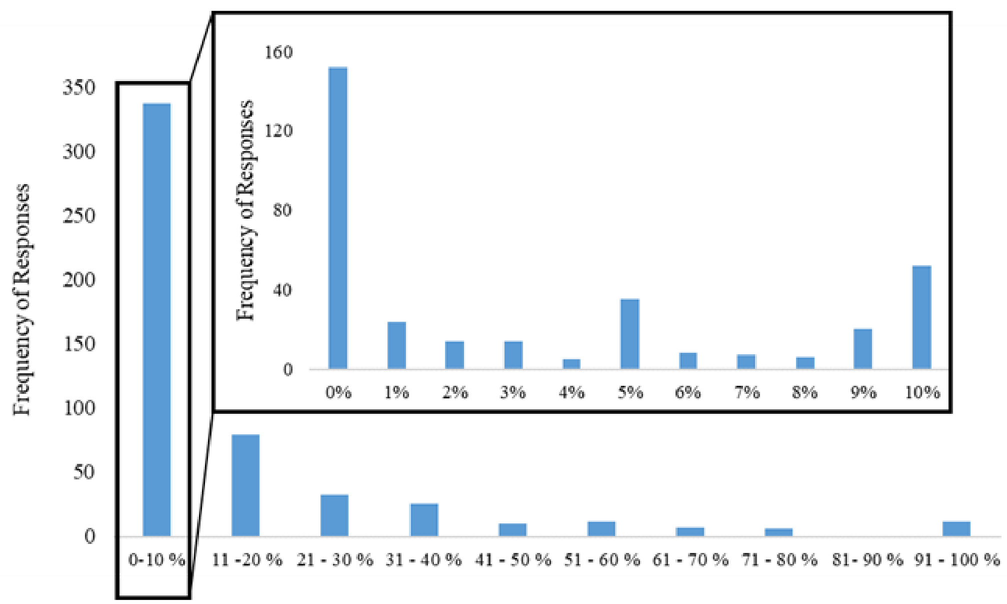

Figure 1. WTP more on current water bill for improved water quality

Table 5. WTP more on current water bill

WTP for improved quality (%)	Witnessed no events (frequency)	Witnessed at least one event (frequency)	Unaware of events in other cities (frequency)	Aware of events in other cities (frequency)
0-10 %	140	127	137	200
11 -20 %	17	36	19	60
21 - 30 %	4	21	14	19
31 - 40 %	4	12	5	20
41 - 50 %	3	5	6	4
51 - 60 %	2	4	6	6
61 - 70 %	0	6	2	5
71 - 80 %	3	1	3	3
81- 90 %	0	0	0	0
91 - 100 %	2	3	5	7
Total number of respondents	175	215	197	324
Average (%)	9.1	15.4	13.8	14.6

Table 6. Types of water contamination events witnessed

Categories	Total (Unique) Responses	Percentage
Physical water infrastructure	32 (32)	11.5%
Water main breaks	18	6.5%
Sewage intrusion	13	4.7%
Other	1	0.4%
Contamination	59 (58)	21.1%
Chemical	41	14.7%
Biological	8	2.9%
Physical	4	1.4%
Radiological	1	0.4%
Not specified	5	1.8%
Advisories	71 (62)	25.4%
Boil Advisory	30	10.8%
Do Not Drink Advisory	41	14.7%
Not sure of event type	16 (16)	5.7%
No known events	101 (101)	36.2%
Total	279 (249)	100.0%

Table 7. Water contamination event locations that occurred outside of respondents' city

Categories	Total (Unique) Responses	Percentage
Northeast	26 (26)	14.9%
New Jersey	9	5.2%
New York	12	6.9%
Pennsylvania	5	2.9%
Midwest	137 (134)	78.7%
Michigan	108	62.1%
Ohio	17	9.8%
Missouri	1	0.6%
Illinois	5	2.9%
Indiana	6	3.4%
South	9 (8)	5.2%
Alabama	2	1.1%
Texas	1	0.6%
West Virginia	1	0.6%
Florida	2	1.1%
Mississippi	1	0.6%
Georgia	1	0.6%
North Carolina	1	0.6%
West	2 (2)	1.1%
Colorado	1	0.6%
California	1	0.6%
Total	174 (162)	100%

5. DISCUSSION

On average, the respondents are WTP 14.3% more (including zeros) and 20.2% more (without considering zeros) for improved water quality compared to their current bills. Given the financial challenges often faced by water utilities in shrinking cities, capitalizing on this potential revenue source may directly benefit operations. Increasing funds for the maintenance of existing infrastructure and investment capabilities for new projects may assist utilities to improve the quality of the water provided to shrinking cities' residents. This context reinforces the importance that water utilities in shrinking cities should interact regularly with their users to gauge current attitudes. Namely, knowing how much more residents are willing to pay presents an opportunistic time of support to increase utility rates that align with residents' stated preferences. Otherwise, if utility rates are increased at a time without residents being willing to pay more for water quality, utilities may face opposition from the public, which can challenge the applicability of such rate increases (Faust et al., 2016). For example, in 2009, in the context of water infrastructure improvement, after consecutive years of water rate increases applied to residents of the city of San Diego, California, residents showed massive opposition to such increases by sending over 10,000 forms to the local authorities protesting the rate increase (City News Service, 2009). Notably, any increase in rates must consider equity and affordability for the current residents. As such, we do not necessarily suggest a uniform increase across all tiers in the rate structure.

We found that witnessing water contamination events, as well as being aware of water contamination events in other cities, are statistically associated with residents' WTP. Additionally, we disaggregated WTP based on whether respondents had witnessed water contamination events (or not), and whether respondents were aware of water contamination events in other cities (or were not) (see Table 5). We found a considerable difference in WTP when respondents witnessed water contamination events in their city. Respondents that witnessed at least one contamination event in their city were on average willing to pay 15.4% more as compared to respondents who witnessed no water contamination events, who were on average willing to pay 9.1% more. These results align with literature discussing the influence of water contamination events on public opinion and perceptions (e.g., Brody et al., 2008). When comparing the influence on awareness of water contamination events occurring in cities different from respondents, residents aware of water contamination events in other cities were willing to pay 14.6% more compared with residents unaware of events in other cities who were willing to pay 13.8% more. These results capture the influence of the geographic proximity to water contamination events in how these events are perceived by residents—i.e., in the city or outside the city. These results are in conversation with existing studies discussing the potential impact of the proximity of water-related events on public perceptions concerning water infrastructure issues (e.g., Osman et al., 2019; Tanellari et al., 2015).

The qualitative analyses revealed that the most frequent water contamination events identified by respondents were *Do Not Drink* advisories, capturing ~15% of the responses, and chemical contamination events with another ~15% of the responses (Table 6). Such advisories are typically communicated directly to the end-users, and as such, this might be expected. Open-ended responses regarding chemical-related water contamination events often referred to lead—e.g., “high lead levels” or “lead, chemical/oil spill, lack of clean water in lines.” Such awareness of lead contamination events may be related with the media attention surrounding the Flint Water Crisis, specifically to the high levels of lead found in Flint water and then in childrens’ blood (Dixon, 2016; Fonger, 2015; Hanna-Attisha et al., 2016; Pieper et al., 2018). However, despite the national attention surrounding the Flint Water Crisis, it is far from being an isolated occurrence of lead contamination in the United States. For instance, Reuters, Missouri, reported double the amount of lead poisoning rates as Flint throughout 3,000 areas, while Warren, Pennsylvania, reported high levels of lead poisoning in 36% of children (Pell and Schneyer, 2016). Similarly, in Newark, New Jersey, in 2016, about 25% of children under the age of six had measurable levels of lead in their blood, and by 2017, 22% of tested drinking-water samples exceeded the federal lead limit (Khazan, 2019).

When examining the respondents’ awareness of water contamination events outside of their city, Michigan, or more specifically, Flint, accounted for over 60% of the total responses (Table 7). Interesting to note, previous work has also discussed the influence of media attention on contamination events on residents’ perceptions and attitudes in shrinking cities. Yang and Faust (2019b) explored the interactions between shrinking cities’ residents and their water infrastructure in the household, finding that the unprecedented level of media attention given to the Flint Water Crisis has undoubtedly influenced the preference for bottled and filtered water instead of tap water. Our finding that WTP is associated with residents’ awareness of water contamination events presents water utilities with an opportunity to leverage this association and identify opportunistic times of support to increase utility rates and collect additional resources for financially constrained utilities in shrinking cities.

6. CONCLUSIONS

This study explored the influence of water contamination events on residents’ willingness to pay for improved water quality in shrinking cities. This study’s results were enabled by quantitative and qualitative analyses of responses to a survey deployed in 2019. Our results showed that residents witnessing and being aware of water contamination events were associated with residents' WTP. We found that residents witnessing water contamination events in their city as opposed to being aware of events in other cities resulted in a higher WTP for improved water quality. These results reveal the relevance that the geographic proximity to water contamination events may have on residents' WTP. The qualitative analysis showed a high awareness among shrinking cities' residents for advisory events (e.g., boil alerts, Do Not Drink advisories), which might be expected since residents typically receive these advisories directly from their local water utilities after water contamination events. When recognizing the specific location of water contamination events in other cities, most respondents referred to the region of Michigan, specifically to Flint. This result is likely due to the media attention surrounding the Flint Water Crisis (Dixon, 2016; Fonger, 2015).

As limited evidence exists that shrinking cities' residents are included in the management of water infrastructure, this study's findings may be used to encourage utilities in shrinking cities to regularly gauge resident's attitudes towards considering strategic timing to increase utility rates that align with residents' attitude toward WTP.

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