Public Perceptions of Water Shortages, Conservation Behaviors, and Support for Water Reuse in the U.S.

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ABSTRACT

Reclaimed water programs treat wastewater to remove hazardous compounds, pathogens, and organic matter and provide reclaimed water for non-potable applications. Reusing water may significantly reduce demands on freshwater resources and provide sustainable water management strategies. Though production of reclaimed water is highly regulated, public acceptability has historically hindered the implementation of successful reclaimed water systems. The public generally opposes the use of reclaimed water due to the "yuck factor", which is the instinctive disgust associated with the idea of recycling sewage and the fear that exposure to reclaimed water is unsafe. This paper reports the results of an extensive survey that was conducted to evaluate the potential acceptability of reclaimed water use. A total of 2,800 respondents across the U.S. participated in the survey. Results demonstrate that a small percentage of the population is concerned about water shortages, the majority of the population practices some level of water conservation, and a substantial percentage of the population supports the use of reclaimed water. Climate, demographic variables, and financial incentives were tested for influence on attitudes and behaviors regarding water, including awareness, conservation, and support for water reuse. Sex, age, last monthly water bill, and location (as EPA region) showed no significant effect on the acceptance of water reuse, while ethnicity, education level, metro/non metro, and income showed significant effects. Drought conditions do not have a statistically significant effect on the number of reclaimed water supporters, but increase the number of respondents who are water concerned, the number of respondents who are the most active water conservers, and the number of respondents who limit their use of water for lawn and garden watering. Financial incentives influence the willingness of respondents to participate in water reuse programs, and a decrease in the monthly water bills increased the

likelihood that respondents would participate in a reclaimed water program. Support for the use of reclaimed water for various applications ranked positively, on average, except for the application of water reuse for food crop irrigation and use of reclaimed water at respondents' own residences. Results and conclusions of the survey can provide insight for implementing successful reclaimed water programs.

Keywords: public opinion; water conservation; water reuse; water shortage; yuck factor; survey

1 INTRODUCTION

The security and sustainability of the U.S. water supply is a growing concern. Recent trends in national water use indicate that moderate decreases in water withdrawal may be expected due to increases in irrigation efficiency, optimized industrial processes, and the penetration of water-efficient appliances and practices (Georgakakos et al. 2014). Anticipated population growth and climate change are expected to continue to stress freshwater resources, however. The U.S. population is projected to increase 30% by 2060 (US Census Bureau 2014), and climate-based water use projections show dramatic increases due to rising temperatures, localized decreases in precipitation, and elevated potential evapotranspiration (Brown et al. 2013).

Reusing, recycling, and reclaiming wastewater effluent provides a sustainable alternative to pressing water demands. Reclaimed water is the end product of wastewater reclamation that meets water quality requirements for biodegradable materials, suspended matter, and pathogens (Levine and Asano 2004) and can be used for irrigation, industrial, residential, and direct consumption, based on the satisfaction of targeted water quality standards (USEPA 2012). Water reuse reduces withdrawals from fresh water systems and alleviates the volume of wastewater and associated nutrient and pollutant loads that are discharged into fresh water bodies. Reusing water may also provide a more energy efficient management strategy than alternative water supply strategies, such as water desalination and inter-basin transfers. As a result, water reuse programs can reduce CO_2 emissions and impacts on the global environment (Dolnicar and Schäfer 2009).

In spite of their technological promise, however, the widespread implementation of water reclamation programs is limited by the social acceptability of reusing wastewater effluent. Public resistance to water reuse may be the result of a lack of knowledge about reclaimed water and the perception of risks associated to health hazards. "Physiological repugnance" (Bruvold and Ward 1972) or the "yuck factor" (Russell and Lux 2009), which is defined as emotional discomfort generated from close contact with certain unpleasant stimuli (Angyal 1941), contributes to the opposition of water reuse programs. Uses that involve high human exposure are typically less acceptable than uses that involve low levels of contact, even though the technology required to treat wastewater and convert it to reusable water that surpasses drinking water standards is currently available (Bixio et al. 2005). For example, reverse osmosis may be used to treat wastewater effluent and achieve water quality that exceeds the quality of most tap and bottled water (Dolnicar and Schäfe, 2009). Ready availability and accessibility of information about public attitudes toward water reuse is crucial for decision-makers to consider water reuse projects and select appropriate and sustainable resource management strategies (Sheikh and Crook 2013).

The goal of this research is to explore the factors that affect underlying public reluctance toward using reclaimed water. We look at this question with two data sets. First, we rely on the results of a national survey that was conducted to evaluate public perceptions about reclaimed water. Analysis of results allows us to identify the level of awareness about water shortages, water conservation behaviors, and attitudes about the use of reclaimed water. Based on the analysis, three outcomes are defined by participant responses: salience, behavior, and attitudes. These outcomes are paired with demographics and socioeconomic indicators to help explain responses to reclaimed water. Second, we incorporate an additional data set of external factors to identify the influence of geographic location, climate, and local drought conditions on outcomes. The influences of demographic and socio-economic factors on salience, behavior, and attitudes are also assessed. Results show outcomes are heavily influenced by local climate and socio-economic status. Support for water reuse depends on the intended end use and decreases with the level of direct exposure.

2 MATERIALS AND METHODS

2.1 Water And Municipal Systems National Survey

Previous research on public attitudes toward recycled water, perceived risks, and demographic and socioeconomic drivers of acceptability has been limited by restricted regional scales, a narrow scope, and small sample sizes. Several surveys have been conducted to assess the attitudes of residents of communities in Australia (Dolnicar and Schäfer 2009; Hurliman 2008; Marks et al. 2006; Miller and Buys 2008), California (Bruvold et al. 1981; Bruvold 1988; Bruvold and Ward 1972), Arizona (Rock et al. 2012), and Turkey (Buyukkamaci and Alkan 2013). Other studies sampled residents of specific cities (Gu et al. 2015; Browning-Aiken et al. 2011; Haddad et al. 2009), visitors to individual facilities (Hills et al 2002), university students (Vedachalam and Manci 2012), and a four-county metropolitan area in the southeast U.S. (Robinson et al. 2005). These studies conducted surveys for a range of sample sizes, up to 408 respondents. The exception is a survey of visitors to the "Millenium Dome" in London, England, which included 1,055 respondents and could be conducted more readily than surveys that are conducted to sample geographically dispersed residents in a community or region.

Research in this area has not demonstrated nationwide attitudes through a survey of a representative sample of the U.S. population.

The Water and Municipal Water Systems Survey was conducted in May 2013, and responses were collected from 2,800 respondents who completed more than two thirds of the survey. The respondents reflect a representative sample of U.S. demographics and were recruited by GfK Knowledge Networks, who also administered the survey. The research was funded by the U.S. National Science Foundation (Grant No. CMMI-1233197). The survey consisted of 22 questions, with a number of sub-questions, that cover a range of topics related to water use and reclaimed water. Questions focused on the following topics as respondents indicated:

a) *interest* in governmental issues, politics, science and technology, environmental issues and health and medicine,
b) *knowledge* of scientific topics and environmental issues,
c) *views* on the governmental role in public policy and participatory processes,
d) *knowledge* of water issues and water management,
e) *use* of water conservation measures in the past and *likelihood* of adoption in the future if asked to do so by different actors,
f) *knowledge* of reclaimed water,
g) *acceptance* and *perception* of community acceptance of water reuse for alternative end uses,
h) *likelihood to adopt* the use of reclaimed water under alternative financial incentive scenarios, and
i) *involvement* in community activities, community ties, political affiliation, and religious affiliation.

Questions were presented in alternative formats, including open-ended, closed-ended, and ranking questions. The survey data also included demographic and socioeconomic information for each respondent, including age, biological sex, race/ethnicity, marital status, number and age of children, highest level of education achieved, geographical location, metropolitan or rural residency, type of household, household income, home ownership status, household head status, and household size.

2.2 Outcomes: Concern for Water Shortages, Water Conservation Behaviors, and Support For Water Reuse

Survey results were explored to test the factors that may affect concern for water shortages, conservation behaviors, and support for the use of reclaimed water. The analysis explored responses to three questions, which are selected from categories *b, e* and *g,* as listed above, about *knowledge*, *adoption* of conservation measures, and *acceptance* of water reuse, respectively.

The first question (asked in form of Questions 1a and 1b in the Appendix) asked respondents to select the most important environmental problem for the U.S. The question was presented in two different formats. In the closed-ended format, each respondent selected from a pre-defined list of ten options: air pollution, chemicals and pesticides, water shortages, water pollution, nuclear waste, domestic waste disposal, climate change, genetically modified foods, using up our natural resources, and none of these. In the open-ended format, respondents selected an environmental problem without a prompt. Respondents were labeled as Water Concerned or Water Unconcerned based on their responses. Those who selected water shortages or named "water" or "water shortages" were defined as Water Concerned respondents. All other respondents were classified as Water Unconcerned. In both cases, participants that chose or named water pollution as the most important problem were not included in the Water Concerned classification because the major driver for water reuse programs is water scarcity and shortages. Water quality and water pollution problems may arise in a water-rich basin, and these issues were not assessed for their influence on perceptions toward water conservation and water reclamation in the analysis reported here.

In the second question (Question 2 in the Appendix), respondents were asked which water conservation measures had they engaged in at their residence in the past two years from a list of four actions - limit lawn and garden watering, turn the faucet off when washing dishes or brushing teeth, limit the length of showers, and modify the toilet to use less water. Those who had adopted three or four conservation measures in the past two years were classified as Water Conservers. Those who adopted two or fewer conservation measures were classified as Non-conservers.

In the third question (Question 3 in the Appendix), participants were asked to rank their support for the use of reclaimed water at their residence on a scale from one to seven, where 1 = strongly support, and 7 = strongly oppose. Respondents who selected 1, 2, or 3 were defined as Reclaimed Water Supporters; respondents who selected 4 were classified as Reclaimed Water Neutral; and those who selected 5, 6, or 7, as Reclaimed Water Opponents.

2.3 Independent Variables: Climate, Demographic, and Socioeconomic Factors

The location of each respondent was reported as the state of residence and as it lies within the ten EPA regions: New England, New York and New Jersey, Mid Atlantic, Southeast, Great Lakes, South Central, Midwest, Mountains and Plains, Pacific Southwest, and Pacific Northwest (Table 1).

The Palmer Drought Severity Index (PDSI) was used as an indicator of climatic conditions relevant to water scarcity related tendencies (Table 2). The PDSI measures the departure of the moisture supply from average conditions and calculates precipitation deficit at specific locations (Palmer 1965). It is based on a supply-and-demand model of soil moisture based on precipitation and temperature data. The PDSI is used as a drought-monitoring tool and has been used to trigger actions associated with drought contingency plans (Willeke et al. 1994). As an estimator of relative dryness, regions with lower PDSI values have drier climates and are prone to drought (Dai et al. 2014). PDSI data were collected for each state and each month of the period May 2012 to May 2013, corresponding to the 13 months prior to the month the survey was conducted, from the U.S. Drought Portal (www.drought.gov). This period was selected to include the summer preceding the survey, when water shortages are more likely to occur. Each respondent reported his or her state of residence, and each respondent was assigned a corresponding time series of PDSI values.

Survey questions were posed to provide data about socioeconomic and demographic factors. Respondents reported their biological sex, the location of residence as metro or non-metro, and their role as household head. Respondents reported age in years (recoded within four categories: 0-30, 30-45, 45-60, and > 60), race/ethnicity (categorized as white non-Hispanic, black non-Hispanic, other non-Hispanic, Hispanic, and two or more races non-Hispanic), education (categorized as none through 12th but no diploma, High School Graduates or GED holders, Some College or Associate's degree, and College Graduates BS, MS or PhD) and annual household income (recoded into five categories: $0-15,000; $15,000-35,000; $35,000-60,000; $60,000-100,000; and >$100,000). In addition, participants were asked how much they paid on their water bill the previous month and were classified accordingly into five categories ($0-50, $50-100, $100-150, $150-200, and >$200).

Participants were asked to rank their willingness to participate in a water reuse program under alternative financial scenarios (Question 6 in the Appendix). These scenarios included incentives such as a one-time rebate of $30 or $60, a reduction of $10 in a monthly water bill, or a surcharge of $0.25 or $0.50 in the unit cost of water. Combinations of these options, including no incentive and no surcharge, resulted in eighteen different scenarios. Each participant was presented with one program scenario to rank his or her willingness to participate in using reclaimed water.

2.4 Statistical Analysis

Two sets of statistical test were conducted to assess and interpret survey results. A Pearson's Chi Square test of independence was performed to determine the existence of a relationship between the different outcome categories and the demographic variables. This test evaluated the probability of that a relationship is due to random chance. If the probability was low, the hypothesis was rejected, and the observation of a relationship is a statistically significant finding. Statistical significance was evaluated at a significance level of $p < 0.05$. Goodness of fit is established through probability theory and the assumption that the sample is normally distributed.

Linear regression was conducted to determine the relationship between decreasing values of PDSI associated with each state (indicating increasing drought conditions) and the percentage of respondents in each state that identify as Water Concerned, Water Conservers, and Reclaimed Water Supporters. Linear regression was also conducted to establish correlation between PDSI values and specific conservation behaviors.

3 RESULTS AND DISCUSSION

3.1 Outcome Categories

Results show that only a small percentage of participants, 6.5% (183), are Water Concerned; 51% (1417) of participants are Water Conservers; and 43% (1211) of participants are Reclaimed Water Supporters. Each respondent falls within one class for each outcome, and Fig. 1 represents the distribution of respondents within all categories. For example, 2% of all respondents are Water Concerned, Water Conserver, and Reclaimed Water Supporter (WC/C/RWS in Fig. 1). In contrast, 14% of all respondents are Water Unconcerned, Non-conserver, and Reclaimed Water Opponent (WU/NC/RWO in Fig. 1).

The conservation measure that was most widely reported by respondents is turning off the faucet when washing dishes or brushing teeth (76.8% of respondents), followed by limiting yard watering (56.2%) and limiting showering time (54.7%). Modifying the toilet to use less water was the measure least adopted (40.3%). Results are consistent with recent research that shows that Americans, when asked for the most effective strategy they could implement to conserve water in their lives, mentioned curtailment (taking shorter showers, turning off the water while brushing teeth) rather than efficiency improvements (replacing toilets, retrofitting washers) (Attari 2014). Modifications to the toilet require an active role and capital investment by participants, whereas other measures require a behavioral change alone.

3.2 Influence of Demographic and Socio-Economic Factors

A number of regional, demographic, and socioeconomic factors were tested for significant relationships with behavioral categories, defined above as Water Concerned/Water Unconcerned, Water Conservers/Non-conservers, and Reclaimed Water Supporters/Neutral/Opponents. A summary of statistical significance is shown in Table 3.

Pearson's Chi square tests of independence were performed to test relationships between variables, and detailed results are provided in Table 4. Descriptions of the significant relationships are provided as follows.

Analysis of survey results show that sex is related to the awareness of water shortages. Nearly two-thirds (62.8%) of male respondents are Water Concerned, compared to half (49.1%) of women who are Water Concerned. No statistical significance was found between sex and other outcomes; these results show a difference between the acceptability of water reuse between male and female respondents only for $p < 0.20$. The research to date about the influence of sex on the acceptance of water reuse has been contested. Bruvold (1979), Po et al. (2005), and Miller and Buys (2008) found sex differences in the acceptance of water reuse, while others (Hurlimann 2006, 2008; Hills et al. 2002; Robinson et al. 2005; Rock et al. 2012; Buyukkamaci and Alkan 2013; Gu et al. 2015) found no significant difference in the level of acceptability between male and female responses. These results have led researchers to conclude that that sociodemographic factors may not account for variations in risk perceptions, and that attitudinal and contextual factors may have more prominent effects on perceptions (Po et al. 2003; Hurlimann 2008). While some socio-demographic associations were proposed in the 1970s and 1980s, these assumptions may not be valid today (Marks 2003). The findings here show no difference in acceptance of water reuse based on sex, based on a large national survey of 2,800 respondents, which is representative of the U.S. population. More recent surveys that show that sex has an influence are based on small surveys or local populations: 93 participants were surveyed from eight suburbs around Perth, Australia (Po. et al. 2005), and 408 participants were surveyed from the northern Brisbane region of South-East Queensland, Australia (Miller and Buys 2008).

Results show that age influences both Water Concerned/Unconcerned and Water Conserver/Non-conserver status. Both concern for water shortages and water conservation increase with age, as the highest percentage of Water Concerned respondents is reported within the age group 45-60, and the highest percentage of Water Conservers is reported within the age group >60 (Table 4). No relationship was found between age and support for water reuse. Past research results have been inconsistent in the effects of sociodemographic variables: few studies (Hurlimann and McKay 2003; Gu et al. 2015) did not find a significant relationship between acceptability of reclaimed water and age, while Donicar and Schäfer (2009) found that the acceptability of water reuse increases with age.

Race and ethnicity influence water awareness, and Hispanics participants had the highest percentage of Water Concerned respondents (8.8%), followed by white non-Hispanic participants (7.1%). Correlation between race and support for reclaimed water use was also found. 45.4% of white non-Hispanic participants were Reclaimed Water Supporters, 44.7% of other non-Hispanic, 55.8% of 2+ races non-Hispanic, 35.0% of Hispanics, and 27.4% of black non-Hispanic.

The most influential factor affecting water awareness, water conservation, and adoption of water reuse is the educational level. The highest level of education (BS, MS, or PhD) corresponds to the highest percentage of Water Concerned respondents and Reclaimed Water Supporters. The level of support for water reuse shows an increase in the percentage of respondents who are Reclaimed Water Supporters, from 28.9% for individuals with some schooling to 55.2% for individuals with a college degree. This is consistent with previous studies that found education to be an important factor driving attitudes towards water reuse and risk perception (Bruvold 1979; Robinson and Robinson 2005; Po et al. 2005; Hartley 2006;

Hurlimann 2008; Donicar and Shäfer 2009; Gu et al. 2015). The highest percentage of water conservers is reported in the group “Some college/Associate degree”.

There was no significant relationship between residents of metropolitan and residents of rural areas and their status as Water Concerned/Water Unconcerned or Water Conserver/Non-conserver. However, there was a significant relationship between community type and support of the use of reclaimed water, where 44.7% of residents of metropolitan areas are reported as Reclaimed Water Supporters, 28.5% are Reclaimed Water Neutral, and 26.4% are Reclaimed Water Opponents. A relationship was found between household head status and water awareness, conservation, and support for water reuse. Household head status indicates a greater concern for the three water issues. Household income showed correlation with the three dependent variables. The highest income categories ($60,000-100,000 and >$100,00) show the highest percentage of Water Concerned. The income group $60,000-100,000 reports the highest percentage of Water Conservers, and the income group >$100,000 reports the highest percentage of Reclaimed Water Supporters. Previously conducted research demonstrates that income influences the acceptability of water reuse (Bruvold 1979; Hurliman 2008; Hanke and Athanasiou 1970; Hills et al. 2002; Hurliman 2008). The value of the last monthly water bill influenced only water conservation behaviors, and the highest percentage of respondents who are Water Conserver were found in Group 2 ($50-100).

3.3 Influence of Location and Climate on Outcomes

The location of respondents showed some influence on outcome categories. The percent of respondents who are Water Concerned is highest for EPA Regions 6, 8, and 9 (Table 4). The percent of respondents who are Reclaimed Water Supporters is highest for EPA Regions 7, 8, 9 and 10. Except for the Pacific Northwest Region 10, these regions include states with average monthly PDSI values during the period of study less than -2.0, indicating the occurrence of moderate, severe or extreme droughts (Table 5). There was no significant correlation between EPA region and water conservation behavioral categories (Water Conserver/Non-conserver).

The effect of drought on the outcomes was assessed through linear regression analysis. For each state, the average PDSI value is calculated over the 13-month period (twelve-month period prior to the survey and the month the survey was conducted). The 13-month period corresponds to a drought period, with monthly PDSI values ranging from -6.0 to 3.2. The relationship between the occurrence of drought, represented by the average PDSI, and the percentage of respondents categorized as Water Concerned is shown as statistically significant ($p < 0.05$) (Table 6). These results indicate that increasing dry periods (decreasing values for PDSI) increase the number of respondents who identify water shortages as an important environmental problem.

The effect of drought on the water conservation behaviors of respondents is also tested (Table 6). There is, however, no statistically significant effect of PDSI on the number of Water Conservers. The survey question concerning conservation was posed to consider the previous two-year time period for the adoption of conservation measures, and climatic conditions of the previous year may only partially account for the adoption of water conservation behaviors. Though the severity of droughts influences the likelihood that respondents recognize water shortages as the most important environmental problem in the U.S., this awareness may not lead to taking an active role to alleviate the problem. Similarly, being unaware of water shortage problems may not prevent participants from adopting water conservation measures. These findings are consistent with previous studies. For example, the San Diego County Water Authority polled residents about the use and conservation of water. Results from a 2012 survey showed that though 46% of respondents felt that reducing water was 'the right thing to do', only 25% of respondents had reduced their household water usage (San Diego County Water Authority 2012).

PDSI values were used to evaluate the effect of drought on the number of conservation measures used by respondents. Results show that the percentage of respondents in each state adopting four conservation measures in the most recent two years increases with a decreasing average PDSI value, taken over the 13-month period (Table 6). The percentage of respondents in each state limiting lawn and garden watering also increases with decreasing values of the 13-month average PDSI. Other conservation measures do not show a significant relationship to the PDSI. Outdoor water conservation may be more influenced by climatic conditions than other conservation measures.

The effect of drought on the support of reclaimed water is also evaluated (Table 6). Regression tests the hypothesis that residents of drier climates and respondents that experience more severe droughts are more willing to use reclaimed water in their households than respondents who experienced moderate droughts. This hypothesis is not supported by the analysis, as there is no statistical significance between PDSI values and the percentage of Reclaimed Water Supporters.

3.4 Influence of Financial Incentives

The likelihood to sign up for a reclaimed water program under the different eighteen financial and subsidy scenarios (Question 6 in the Appendix) is evaluated based on the average ranking from respondents (1= Not at all likely, 4 = Somewhat likely, 7=Extremely likely), shown as the mean and standard deviation of responses in Table 7. Each participant was randomly assigned to view one scenario, which is characterized by settings for a surcharge, a rebate, or reduction in the monthly water bill, to provide an incentive for participating in a reclaimed water program. The number of participants who responded to each scenario is shown as *N* in Table 7. For example, for scenarios 1 3, 7, 11, and 13, the average of responses is less than 4.0, which corresponds to the response "Somewhat likely". These scenarios correspond to limited incentives and a monthly surcharge that is imposed for using the reclaimed water system.

Results show that for the same surcharge and rebate scenario, the likelihood of signing up for a reclaimed water program increases in all cases where a $10 reduction in the monthly water bill is included, except for scenarios 9 and 10, which include a $0.25/month surcharge and a one-time rebate of $30, respectively. Respondents were most likely to participate in a water reuse program under scenario 8 ($0.25 surcharge, no rebate, and a $10 reduction in the water monthly bill) and least likely to participate under scenario 13, which has no incentive and the greatest financial burden to the consumer ($0.50/month surcharge, no rebate, and no variation in the water monthly bill).

Results reported here indicate that a reduced water bill increases the willingness to adopt the use of reclaimed water. Previous research identified that the costs and benefits experienced by residents can affect public acceptability of water reuse (Marks et al., 2002). Demand for reclaimed water has been inhibited by artificially low and subsidized water prices (Woolston and Jaffer 2005). Low reclaimed water rates could encourage its use and help meet re-use and demand management targets (Woolston and Jaffer 2005). In addition, the willingness to pay for recycled water increases with limited supply alternatives and uncertainty in water security. Capital costs and operational costs of retrofitting existing communities with reclaimed water infrastructure can be considerable, when compared to the costs of expanding existing freshwater supply sources or other water management alternatives. By planning dual distribution systems in areas of new development, the cost of including water reuse in an existing water supply portfolio may become competitive with other supply alternatives. The cost for reclaimed water treatment and distribution may be offset by costs that are delayed or avoided to construct new water infrastructure, purchase water through inter-basin transfers, or mitigate excessive nutrient loading of wastewater effluent.

3.5 Acceptability of End Uses

The acceptability of alternative end uses of reclaimed water was assessed using Question 5 in the Appendix, which poses "How acceptable do you think the following uses of reclaimed water would be in your community?" The alternative uses are listed in Table 8. Results are shown as the mean of responses (1 = Completely unacceptable, 4 = Neither acceptable nor unacceptable, 7 = Completely acceptable) and demonstrate that all proposed uses of reclaimed water are acceptable, except for food crop irrigation with an average ranking of 3.62 (Table 8).

Support for the use of reclaimed water within the respondent's own household, without specification of the intended use (Question 3 in the Appendix), was ranked at an average of 3.34 (SD=1.76), indicating low acceptability. Acceptability is inversely proportional to the level of direct exposure, which is consistent with results from previous research (Marks 2003; Po et al. 2005; Hartley 2006; Hurliman 2007, Friedler et al. 2006; Dolnicar and Shäfer 2009; Marks et al. 2008; Miller and Buys 2008; Browning-Aiken et al. 2011)

Potential fresh water savings achieved through the use of reclaimed water, even if applied for selected end uses, may be significant. For example, Schmidt et al. (2014) used these same data to analyze tradeoffs between public acceptance and the potential reduction of water stress in Wake County, North Carolina. Public acceptance was estimated using the results of this survey and water stress reduction was calculated based on the reduction of potable water demand through the Water Stress Index (WSI). This indicator quantifies the state of regional water resources, and it is calculated as the ratio of anthropogenic freshwater withdrawals to the local freshwater supply (Sabo et al. 2010). An area withdrawing more than 40% of the regional supply (WSI > 0.40) is considered water stressed. Results showed a decrease of the WSI for Wake County from 0.54 to 0.39 if reclaimed water was used for all irrigation needs except food crop irrigation. This framework can be applied for counties across the U.S to evaluate reclaimed water use potential. Tradeoffs will vary according to local and regional land use characteristics and climate conditions, and new analysis should include the cost of new infrastructure and the impacts of financial incentives on acceptability.

4 CONCLUSIONS

This research reports on a national survey, and results demonstrate that a small percentage of the population is concerned about water shortages, the majority of the population conserves water, and 43% of the population supports the use of reclaimed water. Through analysis of the survey, this research identifies that climate, education, and economic status can influence attitudes and behaviors regarding water, including awareness, conservation, and support for water reuse. Sex, age, last monthly water bill, and location (as EPA region) showed no significant effect on the acceptance of water reuse, while ethnicity, education level, metro/non metro, and income showed significant effects. Droughts were found to have some effect on survey responses. The highest percentage of water concerned respondents and reclaimed water supporters reside in regions that experienced drought conditions in the 13-month period prior to the survey. Increasing dry periods increase the number of respondents who are water concerned, the number of respondents who are the most active water conservers (adopted four conservation measures in the two years before the survey was conducted), and the number of respondents who limit their use of water for lawn and garden watering.

Results demonstrate that financial incentives influence the willingness of respondents to participate in water reuse programs, and a decrease in the monthly cost of water increased the likelihood that respondents would participate in a reclaimed water program. Support for the use of reclaimed water for various applications ranked positively, on average, except for the application of water reuse for food crop irrigation and use of reclaimed water at respondents' own residences. These results demonstrate that the public is still somewhat reluctant to use recycled water for applications with an elevated degree of direct exposure. This suggests that the 'yuck' factor and the perception of risks may affect the willingness to participate in water reuse programs.

To address increasing water demands, urban water resources can be diversified through water reuse programs as a sustainable solution to water shortages. Decision-makers need available and accessible information about public attitudes toward water reuse to select appropriate and sustainable resource management strategies. Implementation of reclaimed infrastructure should focus initially on applications with greater social acceptability, such as street cleaning, car washing, irrigation of parks and athletic fields or toilet flushing. Acceptance of the use of recycled water for other end uses and applications, such as food crop irrigation and watering of residential lawns may increase as public knowledge of the system develops. As citizens become more familiar with the technology and general understanding of the associated benefits of water reuse increases, officials, planners, and managers may experience diminished opposition to additional applications and achieve greater water savings through widespread implementation of water reuse programs.

AKNOWLEDGMENTS

This research was possible thanks to the support of the National Science Foundation, Grant Number 1233197. Opinions and findings are those of the authors and do not necessarily reflect views of the funding agency. Thanks to two anonymous reviewers for their input.

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Appendix

Questions from the Water and Municipal Water Systems Survey that were used to conduct the research reported here are listed as follows.

Question 1a. Next, here is a list of some different environmental problems. Which one problem do you think is the most important for the U.S. as a whole?
1. Air pollution
2. Chemicals and pesticides
3. Water shortages
4. Water pollution
5. Nuclear waste
6. Domestic waste disposal
7. Climate change
8. Genetically modified foods
9. Using up our natural resources
10. None of these

Question 1b. Next, thinking of different environmental problems, which one problem do you think is the most important for the U.S. as a whole? Please write down the first problem that comes to mind.

Question 2. Which water conservation measures have you engaged in at your residence in the past two years?
a. Limited lawn and garden watering
b. Turned the faucet off when washing dishes or brushing teeth
c. Limited the length of showers
d. Modified the toilet to use less water

Introduction for Questions 3 and 4. As you may know, there are regions in the United States in which the demand for water exceeds the available supply. One possible solution to this problem is adopting the practice of reusing water for purposes unrelated to eating or drinking, such as watering lawns or flushing toilets. We are interested in knowing more about how you feel about this idea. For the purposes of the following questions, we define reclaimed water as sewage that is treated and filtered, then distributed back to people's homes directly from a treatment plant.

Question 3. Different people might have different opinions when it comes to using reclaimed water in their home. How about you? Would you support or oppose using reclaimed water at your residence?

Strongly support			Neither support nor oppose			Strongly oppose
1	2	3	4	5	6	7

Question 4. And what do you think about the majority of people in your community? Would they support or oppose using reclaimed water in their homes?

Strongly support			Neither support nor oppose			Strongly oppose
1	2	3	4	5	6	7

Question 5. How acceptable do you think the following uses of reclaimed water would be in your community?

Using reclaimed water to…
a. Irrigate food crops
b. Irrigate public parks or athletic fields
c. Clean streets
d. Wash vehicles at a car wash
e. Flush toilets in households
f. Water residential lawns

Completely unacceptable			Neither acceptable nor unacceptable			Completely acceptable
1	2	3	4	5	6	7

Introduction for Question 6. Imagine your community would like to build infrastructure to deliver reclaimed water to residents who are interested in using it. To pay for this water system, every household in the community would have to pay (no additional surcharge/an additional surcharge of $0.25/an additional surcharge of $0.50) in their monthly water bill. Each household that chooses to use reclaimed water would need to be hooked up to this new system. The water utility would do this for those people, and they would receive (no rebate/a one-time rebate of $30/a one-time rebate of $60) for signing up in the program. Finally, for those people who chose to use reclaimed water, their monthly water bill would (stay about the same/be reduced by about $10 per month).

Question 6. If it were offered to you today, how likely would you be to sign up for the reclaimed water program?

Not at all likely			Somewhat likely			Extremely likely
1	2	3	4	5	6	7

Question 7. How much did you pay for your water bill last month? Even if you can't remember the exact amount, please estimate to the nearest dollar.

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Table 1. EPA region classification

EPA REGION		States
1	New England	New Hampshire, Vermont, Maine, Massachusetts, Rhode Island, Connecticut
2	NY & NJ	New York, New Jersey
3	Mid Atlantic	Pennsylvania, Delaware, Maryland, Virginia, West Virginia
4	Southeast	Kentucky, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Tennessee, Florida
5	Great Lakes	Minnesota, Wisconsin, Michigan, Ohio, Indiana, Illinois
6	South Central	New Mexico, Texas, Oklahoma, Arkansas, Louisiana
7	Midwest	Nebraska, Iowa, Missouri, Kansas
8	Mountains & Plains	Montana, Wyoming, Utah, Colorado, North Dakota, South Dakota
9	Pacific Southwest	Nevada, Arizona, California
10	Pacific Northwest	Washington, Oregon, Idaho

Table 2. Palmer Drought Severity Index classification. Adapted from Palmer, 1965.

PDSI Classification	
4.0 or more	extremely wet
3.0 to 3.99	very wet
2.0 to 2.99	moderately wet
1.0 to 1.99	slightly wet
0.5 to 0.99	incipient wet spell
0.49 to -0.49	near normal
-0.5 to -0.99	incipient dry spell
-1.0 to -1.99	mild drought
-2.0 to -2.99	moderate drought
-3.0 to -3.99	severe drought
-4.0 or less	extreme drought

Table 3. Summary of statistically significant relationship between behavioral categories and demographic factors.

	Water Concerned/ Water Unconcerned	Water Conservers/ Non-conservers	Reclaimed Water Supporters/ Neutral/ Opponents
EPA Region	Yes	Yes	Yes
Sex	Yes	No	No
Age	Yes	Yes	No
Race/Ethnicity	Yes	No	Yes
Education	Yes	Yes	Yes
Metro/Non Metro	No	No	Yes
Household Head	Yes	Yes	Yes
Household Income	Yes	Yes	Yes
Last Water Bill	No	Yes	No

Table 4. Results for demographic and socio-economic factors.

Independent Variables	Frequency	%	Water Concerned (%)	Water Unconcerned (%)	Degrees of Freedom	*p* <	Water Conservers (%)	Non-conservers (%)	Degrees of Freedom	*p* <	RW Supporters	RW Neutral	RW Opponents	Degrees of Freedom	*p* <
	Dependent Variables														
Total	2800		6.6	93.5			49.4	50.6			43.5	29.2	27.3		
Sex					1	0.05			1	NS				2	NS
1 Male	1400	50.0	8.2	91.8			48.7	51.3			44.6	28.9	25.9		
2 Female	1400	50.0	4.9	95.1			50.1	49.9			41.9	29.3	28.4		
Age					3	0.05			3	0.05				6	NS
1 0-30	422	15.1	2.6	97.4			33.2	66.8			43.4	29.1	26.5		
2 30-45	626	22.4	6.1	93.9			44.7	55.3			41.4	30.5	27.5		
3 45-60	840	30.0	8.1	91.9			54.9	45.1			43.2	29.9	27.6		
4 >60	912	32.6	7.2	92.8			55.0	45.0			44.5	28.2	26.9		
Ethnicity					4	0.05			4	NS				8	0.05
1 White, Non-Hispanic	2132	76.1	7.1	92.9			50.0	50.0			45.4	27.7	26.5		
2 Black, Non-Hispanic	223	8.0	1.3	98.7			44.8	55.2			27.4	35.4	36.3		
3 Other, Non-Hispanic	85	3.4	4.7	95.3			57.6	42.4			44.7	32.9	22.4		
4 Hispanic	274	9.8	8.8	91.2			46.0	54.0			35.0	35.4	28.8		
5 2+ races, Non-Hispanic	86	3.1	1.2	98.8			48.8	51.2			55.8	23.3	20.9		
Educational Level					3	0.05			3	0.05				6	0.05
1 School	228	8.1	6.6	93.4			39.9	60.1			28.9	36.4	33.3		
2 HS Diploma/GED	831	29.7	5.7	94.3			48.1	51.9			35.4	32.9	30.9		
3 Some college/Associate degree	854	30.5	5.0	95.0			52.0	48.0			42.3	30.0	27.4		
4 BS, MS, PhD	887	31.7	8.8	91.2			50.5	49.5			55.2	22.8	21.9		
Metro/Non Metro					1	NS			1	NS				2	0.05
0 Metro	489	17.5	4.7	95.3			47.0	53.0			36.4	31.9	30.9		
1 Non Metro	2311	82.5	6.9	93.1			49.9	50.1			44.7	28.5	26.4		
Household Head					1	0.05			1	0.05				2	0.05
0 No	542	19.4	4.2	95.8			41.7	58.3			37.8	31.7	29.0		
1 Yes	2258	80.6	7.1	92.9			51.2	48.8			44.6	28.4	26.7		

Household Income					4	0.05			4	0.05				8	0.05
1 $0-15,000	224	8.00	4.5	95.5			42.0	58.0			29.5	37.1	33.0		
2 $15,000-35,000	430	15.4	3.7	96.3			44.2	55.8			37.4	31.4	30.7		
3 $35,000-60,000	495	17.7	7.1	92.9			47.3	52.7			40.0	28.5	30.5		
4 $60,000-100,000	721	25.8	7.4	92.6			52.6	47.4			43.7	30.1	26.1		
5 > $100,000	930	33.2	7.4	92.6			52.3	47.7			50.6	25.6	23.2		
Last Monthly Water Bill					4	NS			4	0.05				8	NS
1 $0-50	1589	56.8	5.6	94.4			44.5	55.5			43.4	29.1	27.1		
2 $50-100	770	27.5	7.7	92.3			59.7	40.3			46.5	26.6	26.5		
3 $100-150	197	7.1	7.6	92.4			54.3	45.7			39.6	33.0	26.4		
4 $150-200	64	2.3	10.9	89.1			53.1	46.9			45.3	25.0	29.7		
5 > $200	72	2.6	5.6	94.4			51.4	48.6			37.5	33.3	29.2		
EPA Region					9	0.05			9	0.05				18	NS
1 New England	141	5.0	4.3	95.7			49.7	50.4			36.9	39.0	24.1		
2 NY & NJ	242	8.6	3.7	96.3			43.4	56.6			39.7	31.8	28.5		
3 Mid Atlantic	305	10.9	2.6	97.4			55.1	44.9			40.7	25.2	33.4		
4 Southeast	572	20.4	4.0	96.0			50.7	49.3			41.3	28.5	29.2		
5 Great Lakes	483	17.3	5.4	94.6			44.1	55.9			39.5	31.1	29.2		
6 South Central	309	11.0	14.2	85.8			55.0	45.0			44.3	28.5	25.9		
7 Midwest	133	4.8	5.3	94.7			45.1	54.9			48.9	27.1	24.1		
8 Mountains & Plains	100	3.6	17.0	83.0			51.0	49.0			52.0	28.0	20.0		
9 Pacific Southwest	394	14.1	9.1	90.9			49.8	50.3			49.7	28.7	21.3		
10 Pacific Northwest	121	4.3	5.8	94.2			49.6	50.4			51.2	22.3	26.4		

* NS = no statistical significance

Table 5. States with lowest average PDSI values (May 2012-May 2013).

State (EPA Region)	Average PDSI
Colorado (8)	-4.87
Wyoming (8)	-4.52
New Mexico (6)	-4.31
Nebraska (7)	-3.56
Utah (8)	-3.53
Texas (6)	-2.95
South Dakota (8)	-2.65
Oklahoma (6)	-2.58
Kansas (7)	-2.57
Nevada (9)	-2.55
California (9)	-2.39
Arizona (9)	-2.16

Table 6. Relationship of 13-month average PDSI to percentage of respondents in categories.

Independent Variable	Dependent Variable	N (number of data points)	Regression Coefficient	R^2	p-level
PDSI	% Water Concerned by state	48	-0.031	0.299	< 0.05 (significant)
PDSI	% Reclaimed Water Supporters by state	48	-0.017	0.056	> 0.05 (not significant)
PDSI	% Water Conserver by state	48	-0.022	0.045	> 0.05 (not significant)
PDSI	% Adopted 4 conservation measures by state	48	-0.031	0.187	< 0.05 (significant)
PDSI	% Conserve water for lawn by state	48	-0.035	0.171	< 0.05 (significant)
PDSI	% Conserve water for faucet by state	48	-0.003	0.051	> 0.05 (not significant)
PDSI	% Conserve water for toilet by state	48	-0.00003	0.003	> 0.05 (not significant)
PDSI	% Conserve water for shower by state	48	-0.00027	0.012	> 0.05 (not significant)

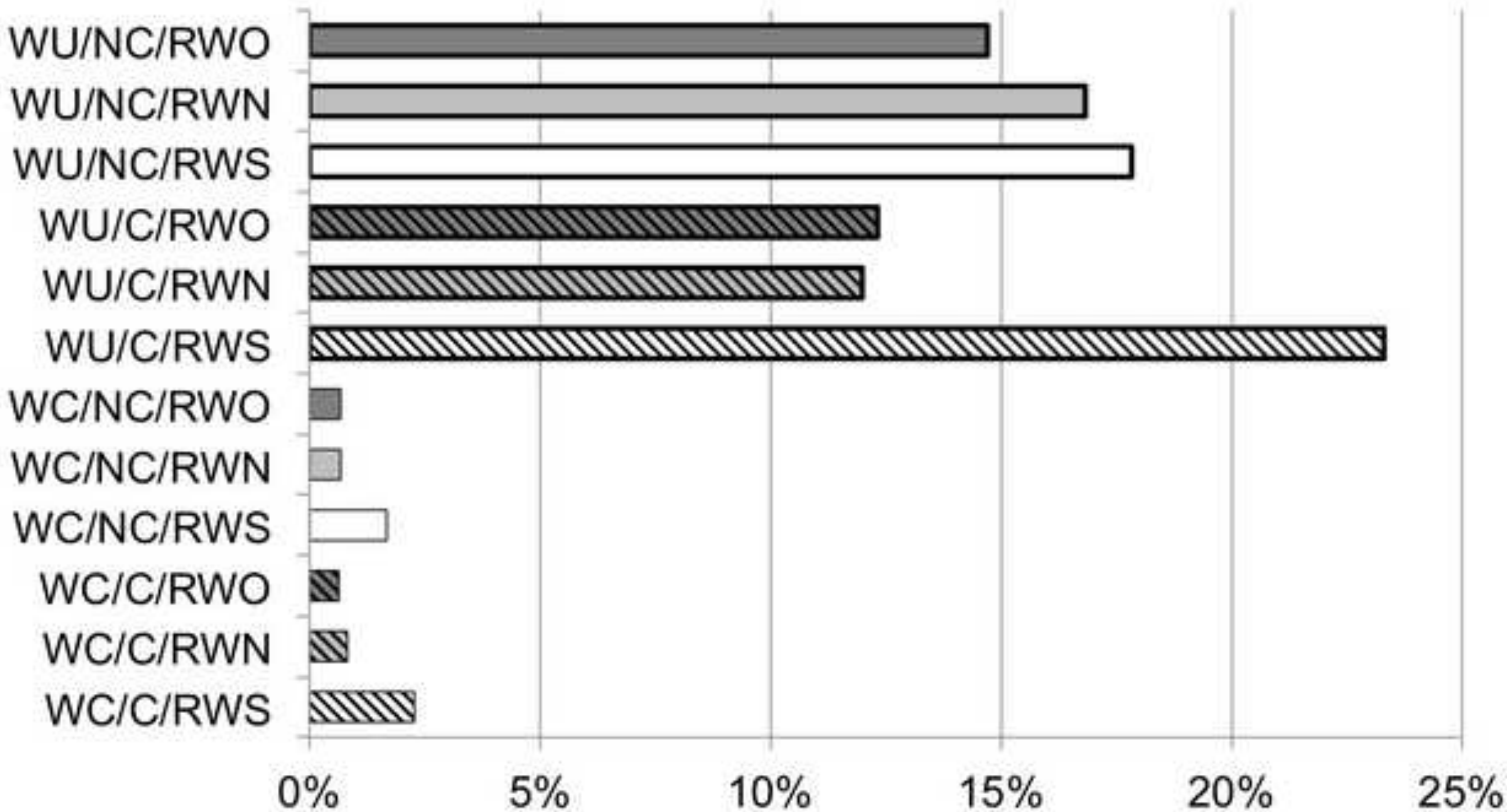
Table 7. Mean likelihood of adopting a reclaimed water program. SD indicates standard deviation. N indicates the number of participants who responded to the scenario.

Scenario	Surcharge	Rebate (One time)	Monthly Water Bill	N	Mean	SD
1	No	No	Same	151	3.80	1.98
2	No	No	- $10	162	4.39	1.93
3	No	$30	Same	146	3.78	1.94
4	No	$30	- $10	162	4.23	2.03
5	No	$60	Same	135	4.13	2.02
6	No	$60	- $10	161	4.28	2.04
7	$ 0.25/Month	No	Same	151	3.92	1.98
8	$ 0.25/Month	No	- $10	154	4.42	1.85
9	$ 0.25/Month	$30	Same	169	4.19	2.06
10	$ 0.25/Month	$30	- $10	134	4.14	1.98
11	$ 0.25/Month	$60	Same	156	3.72	2.09
12	$ 0.25/Month	$60	- $10	173	4.07	2.06
13	$ 0.50/Month	No	Same	142	3.53	1.90
14	$ 0.50/Month	No	- $10	141	4.04	2.10
15	$ 0.50/Month	$30	Same	158	4.09	1.93
16	$ 0.50/Month	$30	- $10	168	4.18	1.91
17	$ 0.50/Month	$60	Same	170	4.13	1.98
18	$ 0.50/Month	$60	- $10	142	4.13	2.07

Table 8. Mean acceptability of reclaimed water end uses. SD indicates standard deviation.

Reclaimed water end use	Mean Response	SD
Flush toilets in households	5.48	1.71
Clean streets	5.46	1.75
Water residential lawns	5.24	1.77
Wash vehicles at car wash	5.14	1.82
Irrigation of public parks or athletic fields	5.09	1.82
Irrigation of food crops	3.62	1.95

Figure(s)



WC - Water Concerned
WU - Water Unconcerned
C - Water Conserver
NC - Water Non-conserver
RWS - Reclaimed Water Supporter
RWN - Reclaimed Water Neutral
RWO - Reclaimed Water Opponent