Student support and perceptions of urine source separation in a university community

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Abstract

Urine source separation, i.e., the collection and treatment of human urine as a separate waste stream, has the potential to improve many aspects of water resource management and wastewater treatment. However, social considerations must be taken into consideration for successful implementation of this alternative wastewater system. This work evaluated the perceptions of urine source separation held by students living on-campus at a major university in the Southeastern region of the United States. Perceptions were evaluated in the context of the Theory of Planned Behavior. The survey population represents one group within a community type (universities) that is expected to be an excellent testbed for urine source separation. Overall, respondents reported high levels of support for urine source separation after watching a video on expected benefits and risks, e.g., 84% indicated that they would vote in favor of urine source separation in residence halls. Support was less apparent when measured by willingness to pay, as 33% of respondents were unwilling to pay for the implementation of urine source separation and 40% were only willing to pay \$1 to \$10 per semester. Water conservation was largely identified as the most important benefit of urine source separation and there was little concern reported about the use of urine-based fertilizers. Statistical analyses showed that one's environmental attitude, environmental behavior, perceptions of support within the university community, and belief that student opinions have an impact on university decision makers were significantly correlated with one's support for urine source separation. This work helps identify community characteristics that lend themselves to acceptance of urine source separation, such as those related to environmental attitudes/behaviors and perceptions of behavioral control and subjective norm. Critical aspects of these alternative wastewater systems that require attention in order to

foster public acceptance after implementation are also highlighted, such as convenient and aesthetically pleasing methods for waterless toilet paper disposal.

Keywords

Wastewater treatment; urine source separation; survey; public acceptance; public perception; Theory of Planned Behavior

1. Introduction

The drawbacks of conventional wastewater treatment have become increasingly apparent largely due to stringent regulatory requirements for effluent quality (Foley et al. 2009), a desire to improve the energy and cost efficiency of operations (Gao et al. 2014), and acknowledgement of valuable resources in wastewater (Guest et al. 2009, Leverenz et al. 2011, Mo and Zhang 2013, Huggins et al. 2016). An alternative approach is urine source separation, which involves the collection and treatment of urine as a separate waste stream through the use of urine-diverting toilets and urinals (Larsen et al. 2009, Larsen and Gujer 1996). The expected benefits of urine source separation include targeted removal of nutrients and micropollutants to minimize environmental discharge (Lienert et al. 2007, Udert and Wachter 2012, O'Neal and Boyer 2013, Zollig et al. 2015), improved recovery of nutrients from urine for reuse as fertilizer (Larsen et al. 2009), reduced use of potable water (the water resource itself and associated treatment) as toilet flush water (Ishii and Boyer 2015), and simplified centralized treatment of the remaining (non-urine) wastewater (Wilsenach and Loosdrecht 2006). These benefits largely stem from the fact that urine typically contributes less than 1% of the influent volumetric flow to a municipal wastewater treatment plant, yet greater than 50% of the influent phosphorus load and 80% of the influent nitrogen load (Wilsenach and Loosdrecht 2006).

The successful implementation of urine source separation requires a strong understanding of both technical and social implications in order to minimize maintenance problems, avoid public health concerns, and enable user acceptance. Public acceptance and use of source separating fixtures is certainly key to realizing the benefits of the system. Accordingly, several researchers have used survey methods to quantify public perceptions of source separating technologies in a hypothetical sense and post-implementation. The aim of previous work is generally to better understand aspects of the system needing improvement, as well as the type of educational information that should be shared with users. Survey results have often suggested high levels of public support. Lienert and Larsen (2010) stated that “urine source separation and nutrient recycling is appealing to lay people and their willingness to support the NoMix bathroom innovation is large” in a comparative analysis of 38 studies across seven Northern and Central European countries. Pahl-Wostl et al. (2003) found that focus group members were not only willing to have a urine diverting toilet in their home, but also willing to eat food crops that had been fertilized with urine. Expert stakeholders in China expressed acceptance of urine source separation and expected that the implementation of such technologies would increase over the next 20 years (Medilanski et al. 2006). In the United States, Lamichhane and Babcock (2013) similarly reported that respondents from a survey sample at the University of Hawaii were highly accepting of urine source separation, e.g. 80% were willing to install a urine diverting toilet in their home, however, the majority of respondents had no knowledge of urine source separation prior to the survey.

Previous studies have also identified potential social barriers to the implementation of urine source separation. Acceptance of urine source separation consistently decreases when willingness to pay is included as a measure of acceptance (Lamichhane and Babcock 2013,

Lienert and Larsen 2010, Pahl-Wostl et al. 2003). Pahl-Wostl et al. (2003) concluded that focus group members (Swiss citizens) were highly accepting of urine source separation and showed evidence of strong environmental awareness, yet they were unwilling to incur additional costs or efforts in order to implement the alternative system. Respondents have also been less accepting of urine source separation if they were required to take personal responsibility for maintenance issues, i.e., respondents are more critical of implementing urine source separation at home than at work or in public buildings (Lienert and Larsen 2006, 2010). Additionally, even if overall acceptance of urine source separation is high, some source separating toilet designs require behavior that is difficult to impart on users. For example, necessitating that users sit on the toilet seat while urinating in order to activate a valve that enables separate collection of urine may be a challenge for male users and/or all users in public settings. Potential barriers to public acceptance of urine source separation are important to identify because they help inform implementation and management strategies. For example, Blume and Winker (2011) found that German users of source separating toilets were more likely to comply with sitting on toilet seats for separate collection of urine if a disinfection spray were made available.

There is a need to build upon these previous studies and include communities that lend themselves to urine source separation due to factors such as existing infrastructure organization (e.g., high toilet density, compact wastewater collection system), the need to protect sensitive receiving waters, and a community culture that is accepting of new technologies. Thus, the overall goal of this study was to provide insight into the pathways and barriers to acceptance of urine source separation by students in a university community. The selected survey population represents an important group (on-campus residents) within a community type (universities) that is expected to be a suitable demonstration site for urine source separation due to high density

residence halls, shared identity among pertinent stakeholders, and accessibility to users/data. University communities offer a unique opportunity to evaluate alternative wastewater paradigms (e.g., source separation versus centralized treatment of combined wastewater) because wastewater production, treatment, and potential nutrient reuse are oftentimes all within very close proximity to each other. To the authors' knowledge, only one survey study has been previously conducted regarding acceptance of urine source separation in the United States, which was administered at the University of Hawaii (Lamichhane and Babcock 2013).

The work presented here builds upon this previous study by comparing support for and perceptions of urine source separation as a function of several factors and in the context of the Theory of Planned Behavior (see Figure 1). In the Theory of Planned Behavior (Ajzen 1991), one's likelihood of executing a certain behavior (i.e., articulating support for urine source separation) is determined by intention, which is in turn influenced by attitude toward the behavior, subjective norm, and perceived behavioral control. Attitude toward the behavior is defined as "the degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question"; subjective norm is defined as "social pressure to perform or not to perform the behavior"; perceived behavioral control is defined as "perceived ease or difficulty of performing the behavior and it is assumed to reflect past experience as well as anticipated impediments and obstacles." The insights gained from this study are expected to help characterize community types that would be accepting of urine source separation, as well as highlight aspects of the urine source separation system that are critical for facilitating public acceptance pre- and post-implementation. The findings from this research also contribute to the broader issue of public understanding of water including water supply, water use, and resource recovery.

Figure 1. Adaptation of a structural diagram showing the form of the Theory of Planned Behavior. The dashed line indicates that “perceived behavioral control” can only influence the likelihood of executing a behavior if there is also actual behavioral control over doing so (Ajzen, 1991).

2. Methodology

2.1. Survey Distribution

All on-campus residents at the University of Florida (UF), including approximately 7,500 residents in undergraduate residence halls and 1,300 residents in graduate and family housing facilities, were invited to participate in an anonymous online survey. All survey related materials were sent from the authors to a contact person within the UF Department of Housing and Residence Education who distributed materials by email to the undergraduate and graduate housing list serves. Communications began with a pre-notice email to all residents on March 19, 2014, which included information about the timing and content of the upcoming survey. On March 26, 2014, a second email was distributed with an invitation and link to the online survey. The survey remained open from March 26, 2014 to April 29, 2014 and three reminder emails were sent out during this timeframe to encourage participation (April 9, 15, and 23). A \$5 gift certificate to a coffee establishment was offered to the first 30 respondents to participate in the survey after the April 15 reminder email was delivered. In addition to emails, the survey was

advertised outside of four undergraduate residence halls and one graduate and family housing facility, which were selected based on their high occupancies. The online survey, distributed emails, and overall survey protocol were reviewed and approved by the UF Institutional Review Board prior to the commencement of the study. The multiple and varied contacts, e.g., advertising events outside of residence halls and emails, were based on web survey implementation guidelines by Dillman et al. (2008), and were expected to increase resident awareness of the study and to appeal to respondents in different ways.

2.2. Overall Survey Design

A brief overview of the survey design is provided here. A detailed description of the survey design, as well as a reproduction of the online survey, can be found in Supplementary Materials (Section S1). The online survey was constructed and distributed using Qualtrics Survey Software. Overall, the survey was designed to identify and measure each respondent's perceptions and support for the implementation of urine source separation in UF residence halls. Furthermore, survey questions were designed to explore one's support for urine source separation in the context of the Theory of Planned Behavior (Figure 1).

The survey began with requests for basic demographic information, such as the respondent's age, gender, residence hall, and major field of study. Subsequent questions pertained to the respondent's environmental attitude and behavior, i.e., "attitude toward the behavior" in Figure 1. Environmental attitude was measured using the New Ecological Paradigm Scale (NEP) (Dunlap et al. 2000) and quantification of environmental behavior was based on the frequency at which respondents reported engaging in several activities over the last year (Whitmarsh and O'Neill 2010). NEP statements pertained to five hypothesized facets of an ecological worldview; listed environmental behaviors pertained to four behavioral domains and

were limited to activities deemed feasible for on-campus residents. Responses to questions pertaining to environmental attitudes (Q9 through Q11) were coded such that the most pro-NEP answer corresponds to a value of 5 and the most anti-NEP answer corresponds to a value of 1. Responses to questions pertaining to environmental behavior (Q12) were coded such that the most pro-environmental behavior answer (highest frequency) corresponds to a value of 5 and the most anti-environmental behavior answer (lowest frequency) corresponds to a value of 1.

After all questions on environmental attitudes and behaviors, respondents were asked about their preexisting knowledge related to urine source separation and then randomly provided with one of four information treatment videos. The purpose of the information treatment was to ensure that all respondents had been introduced to the concept of urine source separation and to test the influence of providing different levels of detailed information. Information treatments are further discussed in Section 2.3

The final section of the survey included questions related to perceptions and support for urine source separation. Support for urine source separation was quantified using four different questions. Female respondents were also asked about their willingness to dispose of urine-soiled toilet paper in a trashcan in order to enable water savings. In addition to support questions, respondents were asked about their perceptions of potential risks and benefits associated with urine source separation, including economic, environmental, and social impacts.

Lastly, respondents were asked to share their opinions on how various groups at UF, e.g., undergraduate students, graduate students, faculty, administration, and staff, would feel about urine source separation and its implementation in residence halls. These questions helped reveal how respondents perceived urine source separation to be received by their surrounding community, i.e., “subjective norm” in Figure 1. Respondents were also asked if votes from on-

campus residents regarding the implementation of urine source separation had the power to influence decision makers at UF, thus speaking to one's perceived level of "behavioral control" (Figure 1). The survey concluded with additional demographics questions.

2.3. Information Treatments

All survey respondents were randomly provided with one of four information treatment videos prior to questions on support and perceptions of urine source separation. The information treatment was provided in the form of a website link within the survey, which directed respondents to a new browser window with a YouTube video. All four information treatment videos began by describing current wastewater practices and then introducing urine source separation as a potential alternative. The form and function of urine-diverting toilets were explained, e.g., a front bowl/small flush for the collection/conveyance of urine and a back bowl/large flush for the collection/conveyance of feces and other solids. Several potential costs and benefits associated with the implementation of urine source separation were also covered in all four videos. The costs or potential risks that were discussed included the new infrastructure that would be required, e.g., urine-diverting toilets, pipes, and storage tanks; potential for precipitation and clogging in urine-diverting toilets and urine pipes; chemical inputs required to produce struvite fertilizer from source separated urine; the risk of community refusal to use fertilizers produced from urine; the possibility of dissatisfied users due to urine-diverting toilet malfunction or unsightly urine storage tanks. Benefits covered in the information treatment videos included reduced potable water use in urine-diverting toilets and the associated reduced water/wastewater treatment requirements; the nutrient content of urine and the potential to reuse those nutrients in agriculture as an alternative fertilizer; reduced nutrient contamination of the

environment resulting from the separation, recovery, and reuse of urine nutrients; the potential for advancement of water/wastewater knowledge and interdisciplinary research opportunities.

The four information treatments differed in the level of detail that was provided for each expected impact. Information Treatment #1 provided only qualitative information about potential benefits and risks, and effort was made to describe urine source separation in a general sense. Information Treatment #2 also only included qualitative information, but this information was put in the context of UF and the city of Gainesville, Florida, USA. In Information Treatment #3 and Information Treatment #4, the UF/Gainesville context was maintained and quantitative life cycle assessment information about urine source separation in UF residence halls was added. Information Treatment #3 included life cycle inventory data from a study conducted by Ishii and Boyer (2015), e.g., pounds of plastic needed for urine pipes and storage tanks, while Information Treatment #4 included life cycle impact assessment data from a study conducted by Ishii and Boyer (2015), e.g., global warming and eutrophication potential resulting from urine source separation system inputs. Links to all four information treatment videos are provided in the Supplementary Materials (Section S2).

2.4. Data Analysis

Survey responses were deemed valid based on completion time (>20% of the median response time), respondent confirmation that they watched the information treatment video, and provision of an answer to Q29 (the last survey question before final demographics questions).

Support for urine source separation was quantified based on respondent answers to four questions in the online survey (Q18, Q19, Q21, Q27), as well as Q22 for female respondents. The responses to each of these questions are discussed individually below. The results for these indicators of support were also normalized and aggregated to create two different aggregated

support terms for each individual survey respondent, one term including Q18, Q19, and Q21, the other also including Q27 (willingness to pay). Respondent willingness to dispose of urine-soiled toilet paper in a nearby trashcan was not included in the aggregated support terms because it only applied to female respondents. A respondent's aggregated support terms were calculated by normalizing their response to an individual question to a range of 0 to 1 and then averaging normalized response values. Responses to individual questions were normalized using the following equation: $[1 / (\text{Number of answer choices} - 1)] \times (\text{Numeric answer choice} - 1)$.

JMP (statistical discovery software from SAS) was used for all statistical analyses. Cronbach's alpha test, a measure of inter-correlation among items, was used to evaluate internal consistency across an individual respondent's answers to questions designed to measure support for urine source separation. Cronbach's alpha test was also used to evaluate the consistency of one's responses related to environmental attitude and environmental behavior (Bland and Altman 1997). Effects Tests utilizing the F statistic were used to evaluate the differences in mean responses given by those in various groups, e.g., separated by gender, information treatment, or environmental attitude. Nonparametric evaluations with Spearman's ρ correlation coefficient, a measure of how well the relationship between two variables can be described with a monotonic function, were used to quantify the relationship between various explanatory variables and one's aggregated support term for urine source separation, as well as the relationships between select explanatory variables.

3. Results and Discussion

Although four information treatments were used in this study, the results presented below are for all respondents together. Results are not separated based on the provided information treatment because there were no significant differences between the responses given by each

information treatment group. Recent work by Fielding and Roiko (2014) suggests that the provision of any information likely improved respondent acceptance of urine source separation, whereas further analysis of Fielding and Roiko's (2014) data by de Koster and Achterberg (2015) suggests that the provided information may have further polarized those that would have initially been accepting or unaccepting of the new technology. In this work, it is proposed that there was no significant difference between the respondents who received each information treatment because the concept of urine source separation was overwhelmingly new (89% reported no previous knowledge of urine source separation) and the information treatments were too similarly detailed in terms of listed risks and benefits for such an unfamiliar topic.

Polarization trends observed by Koster and Achterberg (2015) may become evident as familiarity with urine source separation increases, such as through the installation of a urine source separation demonstration facility or quantification of required costs per student. However, at this stage, the lack of significant differences between the four information treatment groups is important because it implies that one does not require an information treatment video with quantitative data and/or a community specific message to introduce the concept of urine source separation to a university community. Information Treatment #1 provided only qualitative information about potential benefits and risks, and effort was made to describe urine source separation in a general sense; Information Treatment #4 was more complex, with quantitative life cycle assessment information about urine source separation presented in the context of UF/Gainesville. The increased level of effort and detail that went into Information Treatment #4 as compared with Information Treatment #1 did not significantly impact reported support for urine source separation.

3.1. Survey Sample Characterization

A survey sample including 570 valid survey responses out of the 1,069 responses collected was identified. As previously discussed, the validation process involved filtering out survey responses with insufficient completion times, failure to indicate viewing of the information treatment video, and/or no provision of an answer to the last survey question before final demographics questions. It is expected that this high rate of attrition may have been reduced through the use of a shorter survey tool and/or direct compensation for adequate participation. The 570 valid responses represent a 6.5% response rate for all on-campus residents at UF. Overall characteristics of the survey sample are presented in Supplementary Information (Section S3). Due to the fact that survey respondents were not forced to answer every question, n values are given for each question, as they may be slightly less than 570.

The majority of respondents (80%) indicated that they had never heard of urine source separation, urine-diverting toilets, or NoMix toilets prior to receiving information about this survey. Similar results were found in another urine source separation survey distributed to groups at the University of Hawaii. Lamichhane and Babcock (2013) reported that 80% of the survey sample answered “No” when asked if they had ever heard of urine diversion toilets. In this work, 11% of the total survey sample reported that they had previously heard of urine source separation, 13% had heard of urine-diverting toilets, and 8% had heard of NoMix toilets. The survey sample’s overall lack of prior urine source separation knowledge suggests that the information treatments included in this survey served as the first introduction to urine source separation for the majority of respondents.

3.2. Perceived Benefits and Risks of Urine Source Separation

Respondents were provided with a randomly ordered list of seven potential benefits associated with urine source separation (Q25). All of the listed benefits were discussed in the

four information treatment videos, except the role of pharmaceuticals in urine source separation. Respondents were asked to rearrange the list in order of perceived importance such that the most important benefit was listed at the top (rank #1) and the least important benefit was listed at the bottom (Rank #7). Figure 2, part A, shows the average ranking of each listed benefit. *Conservation of drinking water* had the strongest average ranking, followed by *reduced discharge of nutrients into the environment* and *reduced drinking water costs*. *Positive publicity for the University of Florida* was ranked as the weakest benefit of urine source separation. An alternative representation of the benefit rankings is shown in Figure 2, part B, in which the distribution of rankings for each listed benefit is given. These findings agree with previous reports of the public's general support and positive view of water conservation (Dolnicar et al. 2011, Flack and Greenberg 1987, Gilbertson et al. 2011). Furthermore, the suggestion that water conservation and reduced nutrient pollution are perceived as the primary benefits of urine source separation aligns well with literature pertaining to water reuse, in which public acceptance of water reuse in the US tends to be higher when water conservation and environmental protection are clear benefits (Hartley 2006). It should be noted, however, that water conservation was the first benefit presented in all four information treatment videos, which may have prompted students to list water conservation as the most important benefit of urine source separation. Although benefits and risk were randomly ordered in the online survey, future studies are recommended to also change the order in which benefits/risks are presented in information treatments.

Figure 2. Perceived importance of various benefits associated with urine source separation (n=531). A) Average ranking of listed benefits with rank #1 being the most important benefit and rank #7 being the least important benefit (arranged in order of increasing average ranking), and B) distribution of rankings for each listed benefit with rank #1 being the most important and rank #7 being the least important (arranged in order of decreasing rank #1 designations).

In addition to a list of potential benefits associated with urine source separation, respondents were also presented with a randomly ordered list of seven potential risks (Q26). All of the listed risks were discussed in the four information treatment videos, except the role of pharmaceuticals in urine source separation. Respondents were asked to rearrange the list of potential risks in the online survey in order of importance such that the most important risk was at the top of the list (rank #1) and the least important risk was at the bottom (rank #7). Figure 3, part A, shows the average ranking of each listed risk. Unlike the listed benefits, there was not one risk in particular that stood out as being perceived as the most important. The four risks with the strongest rankings had average rankings that were very similar in magnitude: *Infrastructure costs*, *negative publicity for the University of Florida*, *operation and maintenance costs*, and *malfunction of urine-diverting toilets and urinals*. One risk, however, did stand out as being perceived as the least important: *Increased maintenance requirements*. There was also little concern expressed regarding the reuse of nutrients from urine agriculture, as *Community refusal to use urine-based fertilizers* and *pharmaceutical contamination of urine-based fertilizers* were

5th and 6th in terms of average ranking. A comparative analysis of survey studies in Europe also found that the public was very accepting of urine-based fertilizers in agriculture (Lienert and Larsen 2010). Figure 3, part B, shows that the highest proportion of respondents ranked *infrastructure costs* (25.8%) and *negative publicity for the University of Florida* (23.9%) as the most important risks (#1 rank) associated with urine source separation out the seven risks listed in the online survey. Similarly, previous studies related to water reuse have found costs and the potential for negative perceptions to be identified by the public as risks of water reuse (Baggett et al. 2006).

Figure 3. Perceived importance of various risks associated with urine source separation (n=523). A) Average ranking of listed risks with rank #1 being the most important risk and rank #7 being the least important risk (arranged in order of increasing average ranking), and B) distribution of rankings for each listed risk with rank #1 being the most important and rank #7 being the least important (arranged in order of decreasing rank #1 designations).

3.3. Overall Support for Urine Source Separation

3.3.1. Individual Support Metrics

Overall, the total survey sample reported high levels of support for urine source separation as measured by various questions. 74% of respondents were in agreement with urine source separation being a good idea for society and 84% reported that they would vote in favor of implementing urine source separation in on-campus housing at UF (Figure 4, parts A and B).

When presented with the scenario of entering a bathroom in UF Housing with an available conventional toilet and an available urine-diverting toilet, 82% of respondents indicated that they either had no preference or that they would preferentially use the urine-diverting toilet (Figure 4, part C).

Figure 4. Respondent support for urine source separation as indicated by three separate questions. A) Agreement that urine source separation is a good idea for society (n=570), B) expected voting behavior related to the implementation of urine source separation in UF housing facilities (n=569), and C) toilet preference in a bathroom with an available conventional toilet and an available urine-diverting toilet (n=568).

Support for urine source separation was less apparent, however, when analyzing results for willingness to change behavior and willingness to pay. 35% of female respondents were unwilling to dispose of urine-soiled toilet paper in a nearby trashcan despite mentioning the need to do so in the information treatment videos as a water conservation method. Only female respondents were asked this question about urine-soiled toilet paper disposal because they are the users that are expected to use toilet paper at each urination event and thus would require one small flush and one large flush per urination event if toilet paper was disposed of via back bowl flushing. This finding is interesting because water conservation was most frequently indicated as the most important benefit of urine source separation, as discussed in Section 3.2. Respondents across multiple survey studies conducted in Europe also felt that disposing of urine-soiled toilet

paper in a trashcan or the back bowl of a urine-diverting toilet without flushing was the most challenging requirement for its intended use (Lienert and Larsen 2010). These results suggest that there is potential for strengthening understanding of the link between water conservation, flush water use, and toilet paper disposal, as well as the need to ensure easy, aesthetically pleasing, and culturally acceptable non-flush disposal options in urine source separation systems. Toilet paper disposal units should be within arm's reach of the urine diverting toilet, as well as minimize odor emissions and the ability for users to see the bin's contents.. Future survey and demonstration efforts should also consider how toilet paper disposal and overall urine source separation operations will be perceived by housekeeping staff. The majority of respondents were also not willing to pay for the implementation of urine source separation in UF Housing (33% reported \$0 per semester) or were only willing to pay a minimal amount (40% reported \$1 to \$10 per semester). Lamichhane and Babcock (2013) also saw high levels of declared support for urine source separation in combination with a low willingness to pay for the technology in their University of Hawaii survey. Lamichhane and Babcock (2013) found that the majority of respondents (80%) were willing to install a urine-diverting toilet in their home if there was no associated cost, but the proportion of respondents willing to install decreased to 61% when a \$50 charge was associated with the new fixture.

Figure 5. Respondent willingness to change behavior and willingness to pay for urine source separation. A) Willingness of female respondents to dispose of urine-soiled toilet paper in a nearby trashcan (n=388), and B) amount that respondents are willing to pay per semester while living on-campus in order to fund the implementation of urine source separation in UF Housing (n=570).

A Cronbach's alpha value was calculated for four of the previously discussed questions designed to measure one's support for urine source separation: agreement level with urine source separation being a good idea for society, expected voting behavior regarding the implementation of urine source separation in UF Housing, toilet preference, and willingness to pay. A relatively strong Cronbach's alpha value of 0.663 resulted from the analysis and exclusion of any of the four questions did not result in a higher consistency rating. Typically, Cronbach's alpha values greater than 0.70 are considered indicative of high consistency. Responses to all four questions measuring support for urine source separation were also significantly correlated with one another (Spearman ρ , $p < 0.0001$), with toilet preference and voting behavior showing the strongest correlation (Spearman's $\rho = 0.45$). It is expected that toilet preference and voting behavior demonstrated the strongest correlation because these measures of support relate to decisions that directly affect one's own bathroom regimen, yet do not extend into inquiries of payment. A visual representation of the correlation between toilet preference and expected voting behavior is shown in Figure 6. Figure 6 shows that respondents who would choose to use a conventional

toilet are more likely to vote against the implementation of urine source separation in UF Housing than both respondents with no toilet preference and respondents with a preference for a urine-diverting toilet.

Figure 6. Visual representation of the correlation between support for urine source separation as indicated by toilet preference and expected voting behavior (n=567).

3.3.2. Aggregated Support Terms

In order to investigate the impact of various factors, e.g., gender, environmental orientation, subjective norm, on one's support for urine source separation, an aggregated support term was calculated for each respondent. Two aggregated support terms were considered: the first term includes only one's agreement level with urine source separation being a good idea for society, voting behavior, and toilet preference; the second term includes all of these measures of support for urine source separation in addition to one's willingness to pay. For both aggregated support terms, a higher value is indicative of stronger support for urine source separation. Figure S1 (Supplementary Information) shows the distribution of both aggregated support terms with the majority of respondents falling in the range of 0.75 to <1 when willingness to pay is excluded (part A) and in the range of 0.5 to <0.75 when willingness to pay is included (part B). These results further confirm previous discussion of the disagreement between one's declared support

for urine source separation and one's willingness to pay. Similar results were reported by Attari (2014), in which survey participants felt that behavioral changes that required no economic investment (e.g., shorter showers) were the most effective water conservation actions for themselves, while efficiency improvements that do require economic investment (e.g., water fixture replacements and upgrades) were the best option for others. Survey results for this study suggest that participants support urine source separation (which requires an economic investment), but that they are not personally willing to be an investor. Inclusion of responses to the question regarding willingness to pay notably shifts the distribution of aggregated support terms to lower values (less support).

3.4. Factors Influencing Support for Urine Source Separation

In two separate Effects Tests with the F statistic, each aggregated support term was set as the response variable and the effects of several potential explanatory variables were explored: gender, residence hall type (undergraduate vs. graduate), spending the majority of one's life in the United States (yes/no), previous knowledge of urine source separation (yes/no), the information treatment received (1, 2, 3, or 4), thinking that votes have the power to convince the University to implement urine source separation (yes/no), average environmental attitude, average environmental behavior frequency, and subjective norm. In order to evaluate results in the context of the Theory of Planned Behavior (Figure 1), a respondent's subjective norm was described using two calculated factors based on responses to Q28 and Q29. The first subjective norm factor was the average level of agreement one perceived all groups at UF to have with urine source separation being a good idea for society, hereafter referred to as averaged perceived agreement. The second subjective norm factor was the average level of likelihood one perceived

all groups at UF to have regarding voting in favor for the implementation of urine source separation in residence halls, hereafter referred to as averaged perceived likelihood.

Results of the Effects Tests using the aggregated support term that excludes willingness to pay showed that average environmental attitude, average perceived agreement, average perceived likelihood, and thinking that votes have the power to convince had significant impact on support for urine source separation ($p < 0.05$). Conducting the same analysis using the aggregated support term with willingness to pay showed that all of the same factors had significant effects, in addition to average environmental behavior frequency ($p < 0.05$). For both tests, average environmental attitude had the most significant effect ($p < 0.0001$). Additional nonparametric analyses using Spearman's ρ correlation coefficient showed that all factors deemed significant in the Effects Tests also resulted in significant positive Spearman's ρ values ($p < 0.0001$), with the strongest correlations belonging to the two subjective norm factors: average perceived agreement and average perceived likelihood. Thus, the more that one perceived other groups at UF to agree with urine source separation being a good idea for society or the more likely one perceived these groups to vote in favor of its implementation, the higher one's own declared support for urine source separation. It should be noted that there was no significant difference between the support levels of respondents separated by the Information Treatment they received.

Further discussion of the factors that showed significant correlation with support for urine source separation is provided in Sections 3.4.1–3.4.3. A modified reproduction of the structural diagram showing the form of the Theory of Planned Behavior is shown in Figure 7. Modifications are based on the results discussed here and their alignment with the influencing factors included in the Theory of Planned Behavior.

Figure 7. Modified adaptation of the structural diagram showing the form of the Theory of Planned Behavior (Ajzen 1991). Modifications are based on survey results, which show environmental orientation, perceptions of support in the surrounding community, and belief that voting can impact decision makers as predictors of support for urine source separation.

3.4.1. Attitude toward the Behavior: Environmental Orientation

When evaluating the consistency of each respondent's agreement with the 15 NEP statements, a Cronbach's alpha value of 0.858 was determined. This high (>0.70) Cronbach's alpha value supports the argument that the 15 NEP statements reliably assess the same construct: environmental attitude. Results pertaining to this survey sample's overall NEP characterization are summarized in the Supplementary Materials (Table S2). The average NEP score for all respondents across all statements was 3.58. This average NEP score is within the range of scores reported by Johnson and Bowker (2004) for randomly selected residents of the United States. Johnson and Bowker (2004) analyzed $>3,500$ responses to a telephone survey and found that depending on ethnicity average NEP scores ranged from 3.31 ("Foreign-born Latino") to 3.74 ("Asian") depending on ethnicity. Effects Tests using the F statistic of survey results for this study showed that female respondents had a significantly higher average NEP score than male respondents (3.64 vs. 3.45, $p<0.05$), which was also reported by Johnson and Bowker (2004).

Residents living in graduate and family housing had a higher average NEP score than those living in Undergraduate Housing, however, the F statistic within the Effects Test did not indicate that this was a significant difference.

Results suggest that one's level of support for urine source separation is significantly influenced by one's environmental attitude as measured by the NEP scale, with a pro-NEP orientation (i.e., higher NEP score) being indicative of stronger support. Figure 8 demonstrates the correlation between one's NEP score and one's support for urine source separation. Respondents were grouped based on their average NEP score and the distribution of expected urine source separation voting behavior was evaluated for each NEP group. The group with NEP scores ranging from 1.0 to 1.5 had zero members that would vote in favor of urine source separation, while 94% of the members in the group with NEP scores ranging from 4.5 to 5.0 indicated that they would vote in favor of urine source separation.

Figure 8. Respondent urine source separation voting behavior as a function of their calculated average “New Ecological Paradigm” (NEP) score, which is a measure of one’s environmental attitude.

Similarly, an individual’s responses should be relatively consistent over the 13 environmental behavior questions if these questions are all measuring the same construct. Indeed, the high Cronbach’s alpha value ($\alpha=0.776$) resulting from these 13 environmental

behavior questions demonstrates consistency. However, elimination of the first environmental behavior question (“*Walk, bike, or take public transport for short journeys (trips less than 3 miles)*”) results in a slightly higher Cronbach’s alpha value ($\alpha=0.777$), thus indicating that this question elicits the most inconsistent response when compared to the other 12 behaviors. Table S3 in the Supplementary Materials summarizes the reported frequencies at which survey respondents did various environmental behaviors within the past year. The average environmental behavior frequency for all respondents across all behaviors was 3.29, which falls between the frequency categories of *About half the time* and *Usually*. Effects Tests using the F statistic show that female respondents have a significantly higher average environmental behavior frequency than male respondents (3.32 vs. 3.22, $p<0.05$). Residents living in graduate and family housing had a higher average environmental behavior frequency than those living in undergraduate housing, but the difference was insignificant according to the results of the Effects Test. Environmental behavior was only a significant factor for predicting support for urine source separation when willingness to pay was included in the aggregated support term. It is hypothesized that this result is related to the fact that the environmental behaviors listed in this survey, as well as paying for the implementation of urine source separation, are all associated with some level of inconvenience in order to achieve an environmental benefit. Therefore, willingness to accept the inconvenience of environmental behaviors (e.g., higher frequencies of recycling, taking public transportation, participating in cleanups, etc.) is expected to be an indicator of willingness to pay. To further support this point, comparison of one’s willingness to pay against one’s average environmental behavior frequency results in a significant Spearman’s ρ correlation coefficient of 0.2974 ($p<0.0001$). Willingness to pay and average environmental attitude are also significantly correlated (Spearman’s $\rho=0.2475$, $p<0.0001$), but to a lesser extent.

3.4.2. Subjective Norm: Perceived Support for Urine Source Separation

Figure 9, part A, shows that the majority of respondents (54%–76%) felt that each group at UF would either agree or strongly agree that urine source separation is a good idea for society. The group that respondents most frequently indicated as agreeing or strongly agreeing with urine source separation being a good idea for society was graduate students, followed by faculty; this trend remained true regardless of whether the respondent group under consideration was undergraduate students or graduate students. Overall, the group that respondents most frequently indicated as disagreeing or strongly disagreeing with urine source separation being a good idea for society was staff. As previously mentioned, future evaluations of urine source separation perceptions and support should include additional stakeholder groups, such as those responsible for fixture maintenance, housekeeping on campus, and overall operations, as their acceptance is critical for the system's implementation and long-term operation. Similarly, Figure 9, part B, shows that the highest proportion of respondents felt that graduate students, followed by faculty, would be likely or very likely to vote in favor of implementing urine source separation in UF Housing, whereas the highest proportion of respondents felt that the group that would be unlikely or very unlikely to vote in favor was staff. Overall, respondents perceived that support for urine source separation would be higher in all groups if measured by agreement with the concept, as opposed to willingness to vote in favor for implementation on campus. For example, 76% of respondents felt that graduate students would agree or strongly agree with urine source separation being a good idea for society, but only 65% of respondents felt that graduate students would be likely or very likely to vote for its implementation in UF Housing (faculty: 67% vs.

59%; administration: 58% vs. 42%, undergraduate students: 55% vs. 46%, staff: 54% vs. 39%).

Figure 9. Respondent perceptions of support for urine source separation within the UF community. A) How strongly respondents felt each UF group would agree or disagree that urine source separation is a good idea for society (n=566–570), and B) how likely respondents felt each UF group was to vote in favor of implementing urine source separation in on-campus residence halls (n=568–570).

Figure 10 demonstrates the correlation between subjective norm and support for urine source separation. Respondents were grouped based on how likely they felt other groups at UF were to vote in favor of implementing urine source separation on campus and the distribution of expected urine source separation voting behavior was evaluated for each “perceived likelihood” group. The group with average “perceived likelihood” scores ranging from 0 to 0.2 had three members that would vote in favor of urine source separation, while 96% of the members in the group with scores ranging from 0.8 to 1.0 indicated that they would vote in favor of urine source separation. The Theory of Planned Behavior suggests that the more favorable one’s subjective norm, or “perceived social pressure to perform or not to perform the behavior”, toward a behavior, the stronger one’s intention is to perform the given behavior. In this case, subjective norm may be interpreted as one’s perception of how other groups within the UF community view urine source separation, which does indeed appear to impact one’s own support for the concept.

Figure 10. Respondent urine source separation voting behavior as a function of their calculated average “perceived likelihood” score (i.e., how likely one feels others at UF are to vote in favor of urine source separation on campus), which is a measure of one’s subjective norm.

3.4.3. Perceived Behavioral Control: Expected Influence of Voting

Also in line with the Theory of Planned Behavior, believing that votes (regarding the implementation of urine source separation in residence halls) from on-campus residents had the power to convince university decision makers was significantly correlated with support, thus indicating some level of perceived behavior control over the situation. 63% of respondents felt that votes from residents of UF Housing did indeed have the power to convince the university to install urine source separation systems in residence halls. Notably, respondents who indicated that votes had the power to convince were significantly more likely to vote in favor of implementing urine source separation than those that felt votes did not have the power to convince (Effects Tests with F statistic, $p < 0.0001$). 89% of the respondents that indicated that votes from on-campus residents had the power to convince the university to install urine source separation systems indicated that they would vote in favor of implementing this system, as compared with 76% of the respondents that had little faith in the strength of resident votes.

3.5. Broader context of public perceptions about water

The survey findings presented here contribute to a larger collection of research on public perceptions about water quantity and quality. For example, water conservation was ranked as the most important benefit of urine source separation and water conservation is often ranked highly when various water resource management strategies are being evaluated (with intention to conserve water often aligning well with the Theory of Planned Behavior) (Boyer et al. 2012, Lam 1999, Trumbo and O'Keefe 2005). Related to water conservation are public perceptions about water use and how to use water more efficiently. Attari (2014) reported that individuals were more likely to recommend water efficiency improvements for other Americans while recommending curtailment at home. Attari (2014) explains that efficiency improvements require financial investment, which is why it is recommended for others but not oneself. This is similar to findings in this survey about the willingness to pay for urine diversion. The perceived importance of water conservation in combination with low willingness to pay for water conserving measures suggests that the water savings associated with urine source separation should be communicated to facilitate acceptance, and that users should be asked to make behavioral investments instead of economic investments (e.g., opting for trashcan disposal of urine-soiled toilet paper instead of flushing). Finally, many efforts have been dedicated to understanding public perceptions of (direct and indirect) potable reuse due to increasing emphasis on these systems as a means to address water stress and increasingly stringent wastewater standards (Millan et al. 2015). Similarities spanning public perceptions of resource recovery related to combined wastewater, source separated urine, and drinking water suggest that insights into messaging can be transferred across these areas.

4. Conclusions

The survey sample of on-campus residents at UF reported high levels of support for urine source separation, despite having minimal previous knowledge of this alternative wastewater system. Support was expressed in terms of urine source separation being a good idea for society and also favorability toward its implementation in residence halls on campus. However, female respondents expressed less favorability toward disposing of urine-soiled toilet paper in a trashcan and most respondents were unwilling or minimally willing to pay for urine source separation. The majority of survey respondents perceived that support for urine source separation was high in the surrounding community, with expected favorability decreasing in the order of graduate students > faculty > undergraduate students $\approx$ administration > staff. Conservation of drinking water was predominantly identified as the most important benefit associated with urine source separation. Little concern was expressed regarding the reuse of nutrients from urine as a fertilizer product. Statistical analyses showed that the following factors had significant and positive correlations with one's declared support for urine source separation, all of which fit well within the Theory of Planned Behavior:

- Subjective norm: The level of agreement one perceived groups at UF to have with urine source separation being a good idea for society; the level of likelihood one perceived UF groups to have regarding voting in favor for urine source separation in residence halls;
- Behavioral control: Belief as to whether or not votes from on-campus residents had the power to convince university decision makers to install urine source separation in residence halls;
- Environmental attitude: Average NEP-score including five hypothesized facets of an ecological worldview;

- Environmental behavior: The frequency at which various environmental behaviors were carried out over the past year.

Overall, these results suggest that although both environmental and economic impacts of urine source separation were discussed in the Information Treatment videos, the environmental benefits were more strongly communicated, thus making environmental orientation a significant predictor of support for urine source separation. The NEP scale and inquiries regarding the frequency of environmental behaviors may be used to measure environmental orientation and thus anticipated support for urine source separation. Furthermore, perceiving one's surrounding community as supportive of this alternative wastewater paradigm and perceiving one's opinion as important to community decision makers also leads to a higher likelihood of viewing urine source separation with favorability. Thus, community leaders should encourage discussion between the planners and the users, as well as empower users to make decisions regarding how urine source separation is implemented (e.g., phased construction versus an overhaul, toilet selection, treatment approach, etc.). Overall, these results highlight the need for demonstrations of urine source separation systems to target these types of communities, as well as to stress the associated environmental benefits of water savings and reduced nutrient discharges to the environment. Additionally, demonstrations should focus on ensuring the proper functioning of urine-diverting fixtures and minimizing behavior change required for their use in order to strengthen community support. Research-oriented groups (e.g., graduate students, faculty) are expected to be more accepting of urine source separation for initial demonstration and acclimation of additional groups.

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