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What do consumers think about recycling human urine as fertiliser? Perceptions and attitudes of a university community in South India

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ABSTRACT

Sanitation systems based on source separation and valorisation of human urine can improve the environmental sustainability of wastewater management. Yet, the social acceptability of such new, resource-oriented sanitation practices have not been assessed systematically. We attempt to address this research gap by reporting the findings of a survey conducted at a South Indian university that evaluated support for urine recycling among 1252 Indian consumers. We place our findings in the context of the Theory of Planned Behaviour, quantify consumer attitude to urine recycling through an exploratory numerical approach, and identify explanatory factors that shape consumer beliefs and perceptions. Overall, a moderately positive attitude was observed: 68% stated human urine should not be disposed but recycled, 55% considered it as fertiliser, but only 44% would consume food grown using it. While 65% believed using urine as crop fertiliser could pose a health risk, majority (80%) believed it could be treated so as to not pose a risk. The respondents' 'willingness to consume' urine-fertilised food was found to be strongly influenced by their willingness to pay. Consumer environmental attitudes, as evaluated using the New Ecological Paradigm scale, did not influence their attitude towards urine recycling behaviour. We thus believe that simply appealing to people's environmental sensitivities is not enough for introducing environmentally-friendly technologies like urine recycling, but that more targeted marketing messages are needed. We find sufficient support among our surveyed consumers for urine recycling but highlight that further research is needed to identify what information and agency will help translate positive attitudes into action and behaviour.

1. Introduction

In the sanitation sector, there is growing recognition that conventional systems in place today will not be able to fulfil the world's sustainability mandate (Guest et al., 2009). Several experts are convinced that the sector is in urgent need for a paradigm shift that transforms sanitation planning, functioning, and management by placing more emphasis on recycling human wastes (Langergraber and Muellegger, 2005; Guest et al., 2009; Larsen et al., 2013). Over the past few decades, *new sanitation* systems based on source separation and valorisation of various domestic wastewater fractions have started to attract research attention (Lens et al., 2001; Vinnerås and Jönsson, 2002; McConville et al., 2017; Poortvliet et al., 2018). Urine diverting toilets that separately collect human urine and faeces are in use in several parts of the world (von Münch and Winker, 2011; Okem et al., 2013; Cheng et al., 2017). In Northern Europe, source separating sanitation systems are being piloted across several cities such as Sneek (Netherlands), Helsingborg (Sweden), Ghent (Belgium), and Hamburg (Germany) (Skambraks et al., 2017). In many places, source separated toilet wastes are applied to soil as crop fertiliser (Jönsson et al., 2004; Langergraber and Muellegger, 2005).

It has been however been suggested that, people's perceptions and willingness to change their sanitation behaviour can be significantly affected by culture, traditions, and beliefs (Rosenquist,

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2005; Jewitt, 2011a, 2011b; Nawab et al., 2006; Simha et al., 2017). What people think of human excreta and how they manage it, varies both spatially and temporally (Rosenquist, 2005; Jewitt, 2011b). Jewitt (2011a; p. 765) in fact suggests that "… *deeply rooted emotions and taboos associated with human waste often occlude rational responses to its disposal, handling and reuse*". People's sanitation outlooks and behaviours do not rely solely on apparent logic or scientific knowledge, but may be affected by socio-demographical, cultural, and environmental factors (Black and Fawcett, 2010). These factors might include age, gender, religion, education, income, occupation, and surrounding environment, as well as people's necessities, circumstances, and aspirations. There is evidence that interventions aimed at improving sanitation tend to fail if they do not consider this social complexity (Black and Fawcett, 2010).

New sanitation systems based on urine diversion require wide behavioural changes, such as users familiarising themselves with diverting-type toilets at home and elsewhere; farmers adopting to new crop fertilisation practices; and, even consumers who are to purchase food grown using recycled toilet wastes as fertiliser (for an overview, see Lienert, 2013). Sociological studies investigating people's willingness to accept such new sanitation practices have been performed across different settings (Pahl-Wostl et al., 2003; Nawab et al., 2006; Lienert and Larsen, 2009; Mariwah and Drangert, 2011; Lamichhane and Babcock, 2013; Okem et al., 2013; Ishii and Boyer, 2016; Simha et al., 2017). Findings from these studies suggest that a myriad of factors interact and determine whether people/communities think favourably of source separation technologies, if they intend to change their sanitation behaviour, and what would motivate or discourage them to do so. In some studies, surveyed populations with common attributes were homogenous in their stated attitudes and beliefs. For instance, Mariwah and Drangert (2011) found that 84% of the peri-urban residents they surveyed in Ghana, at an agricultural community with little variation in demographic characteristics, agreed that human excreta is a waste, suitable only for disposal. Perhaps similarly, but with contrasting results, Lienert and Larsen's (2009) review of seven European countries revealed that a majority of the respondents liked the idea of using urine as a fertiliser. Situational and socio-economic aspects of sanitation behaviour are also more evident in some studies than others. For example, a stark contrast in willingness to pay for urine-diverting toilets was reported between residents in Pakistan (Nawab et al., 2006) and the United States (Lamichhane and Babcock, 2013; Ishii and Boyer, 2016).

Based on such findings in literature, it can be suggested that different attitudes to excreta/urine recycling exist in different settings. This is in line with Jewitt's (2011a,b) assertion of the existence of spatial-cultural differences in sanitation practices and also, in how taboos surrounding excreta are conceptualised. If that is indeed the case, findings of perceptions and attitudes to new sanitation systems from a particular setting may not hold true in another. Hence, further sociological research will be necessary to explore whether new sanitation practices will be socially sustainable in different places, and to support sanitation planning and decision-making with evidence-based case studies.

In 2014, the Government of India launched the Swachh Bharat Mission (SBM), its flagship campaign to promote cleanliness and achieve universal sanitation coverage. The campaign's aim is to eradicate open defecation, which according to the WHO and UNICEF (2017) was practiced by 40% of the population, as estimated in 2015. Unlike India's past sanitation schemes (*e.g.* Nirmal Bharat Abhiyan), SBM has a strong focus on collective behavioural change. It encourages people to adopt and use, "*cost effective and appropriate technologies for ecologically safe and sustainable sanitation*", and "*develop community managed systems for solid and liquid waste management*" (Ministry of Drinking Water and Sanitation, 2017). However, as Tran (2017) observed in a case study that evaluated the implementation of SBM in India's Punjab region, understanding people's expectations about what constitutes appropriate behaviour (*e.g.* whether or not open defecation carries stigma) and finding ways to change such expectations is key to SBM's success.

The separate collection and recycling of human urine using urine-diverting toilets is one way of promoting ecologically-sound sanitation but, as discussed above, requires significant changes to people's sanitation behaviour. Hence, the objective in this study was to understand whether urine recycling will find support among consumers in India. To survey Indian consumers, this study elected to sample a university community in South India (VIT University), following work done elsewhere (Lamichhane and Babcock, 2013; Ishii and Boyer, 2016). Universities offer an interesting platform to evaluate people's behavioural intentions, since they have been touted as experimental sites for introducing sustainable technologies (Evans and Karvonen, 2010), such as urine recycling. Universities also tend to shape how a country's youth population could behave as local and global citizens (Tuncer, 2008). This aspect is perhaps more significant to India since it is home to the world's largest youth population - according to the latest census, the youth (15–34 years) population of the country stood at 423 million people (Central Statistics Office, 2017).

The motivation to report on consumer behavioural intentions was two-fold: Firstly, to the authors' best knowledge, this is the first study to investigate what Indian consumers think of using human urine as crop fertiliser; Secondly, the results of the present investigation complement those obtained by the authors earlier, where the attitudes of South Indian farmers to new crop fertilisation practices was investigated (Simha et al., 2017). Since this study was performed in a university setting, the results do not represent the urine recycling intentions of all Indian consumers but may be indicative of intentions at other university communities in India. Findings from this study add to the existing literature on socio-cultural aspects of new sanitation systems and also, the socio-technical discourse surrounding environmental technologies in emerging economies.

2. Methodology

2.1. Survey instrument

The survey was conducted at the VIT University campus located in Vellore, South India. All 28,000 people at the university – staff, students, researchers, and faculty were invited to voluntarily respond to an online questionnaire that collected anonymous responses using *Google Forms*. An email with a link to the survey (www.goo.gl/forms/H02ivnYlP5A7XsPn2) was sent using the university's electronic mailing list and made available for a period of four weeks. Reminder emails were sent at the beginning of weeks 2, 3, and 4. The survey instrument and the study methodology were approved by the university's research committee.

The survey requested single responses to closed-ended questions that were either binary (yes/no) or multiple choice type. The questionnaire comprised of three sections (Supplementary Information). After seeking participant consent, demographic information including age, gender, affiliation, religion and caste was requested. The next section sought respondent perceptions of urine (cow/human) as a fertiliser (5 questions), their willingness to consume food grown using urine (4 questions), and whether they perceived any risks associated with the use of urine as fertiliser (4 questions). The revised New Ecological Paradigm (NEP) scale was

used to assess environmental attitudes of the respondents (Dunlap et al., 2000). Participants were asked to indicate their level of agreement with 15 NEP statements on a 5-point Likert-like scale. In the online form, the statements were presented as three matrix-type questions, each comprising of five randomly ordered statements. Following Ogunbode (2013) the wording of the NEP statements was slightly modified.

2.2. Data and statistical analysis

In total, the survey registered 1252 responses giving a response rate of 4.5%. Based on the size of the sample ($n = 1252$) and the population ($N = 28000$), with 99% confidence level, the margin of error is estimated to be <5%. The collected survey data was analysed by assigning all positive responses a numerical value of '2' and negative responses a value of '1', so that the mean ($1 \leq \mu \leq 2$) depicted the probability of the response being positive (Lamichhane and Babcock, 2013). The influence of demographic variables on respondent perceptions to urine recycling was assessed through Chi-squared test (χ^2) and one-way analysis of variance (ANOVA). Differences between categories of variables were considered significant if *P*-value was <0.05.

To analyse consumer environmental attitudes, individual responses to the NEP statements were coded as 1 to 5, where, 1 indicated strong disagreement and 5 indicated strong agreement (Dunlap et al., 2000). The seven even-numbered NEP statements were reverse coded since disagreement with the statements indicated a pro-ecological worldview. The overall NEP rating ($1 \leq \mu_{NEP} \leq 5$) of the dataset was calculated as the average of all responses to the individual scale items (Ogunbode, 2013). An overall NEP rating of 3 was considered the boundary between pro-ecological and anthropocentric worldviews (Van Petegem and Blieck, 2006). Following Dunlap et al. (2000) and Wilhelm-Rechmann et al. (2014), Cronbach's Alpha (α) and McDonald's Omega (ω) tests were performed. Coefficients α and ω, widely used measures of internal consistency reliability, were calculated to see if survey participants were internally consistent in their responses to the statements in the NEP scale. Using hierarchical factor analysis, two forms of the Omega coefficient, Hierarchical Omega (ω_h) and Total Omega (ω_t) were estimated. To analyse the NEP scale and determine its latent structure, exploratory factor analysis was carried out. In addition, principal component analysis with varimax rotation was performed to test the dimensionality of the scale against five hypothesised facets or worldviews: 1) reality of limits to growth, 2) anti-anthropocentrism, 3) fragility of nature's balance, 4) rejection of human exemptionalism (belief that humans are exempt from environmental forces), and 5) the possibility of an ecocrisis (Dunlap et al., 2000; Ogunbode, 2013). To explore whether respondent environmental views affected their attitude to urine recycling, and if these views were influenced by socio-demographical factors, respondents with mean NEP rating of >3 and ≤ 3 were categorised as likely to endorse pro-environmental and anti-environmental worldviews, respectively.

2.3. Theory of planned behaviour

Azjen's (2002) Theory of Planned Behaviour (TPB) was used in this study to investigate consumer behavioural intentions to recycle human urine. The TPB is a well-validated social cognitive model to predict people's intentions and behaviour (Armitage and Conner, 2001). According to the TPB, one's behaviour to act is guided principally by one's intention, which in turn depends on three aspects: attitude towards the behaviour ("the degree of a person's favourable or unfavourable evaluation or appraisal of the behaviour in question") (Fishbein and Ajzen, 1975), the subjective norm ("the perceived social pressure to perform or not to perform the behaviour") (Ajzen, 1991), and perceived behavioural control ("people's perception of ease or difficulty in performing the behaviour of interest") (Ajzen, 2002). If that is the case, in line with the TPB, consumers who have a positive attitude to urine recycling, and believe there is normative support for using it as a crop fertiliser, and feel it is easy for them to engage in urine recycling, should have strong intentions to carry out the behaviour (Fig. 1).

2.4. Attitude towards the behaviour

Consumer attitudes to urine recycling were evaluated according to the following procedure. Three aspects were taken into consideration: (i) perception of human urine as a crop fertiliser; (ii) willingness to consume food grown using human urine; and, (iii) whether respondents felt urine should be disposed and never recycled. The weighted arithmetic mean of participant responses ($r = 1$ or 2) to the three aspects were assumed to represent the individual attitude score (Eq. (1)), whereas overall attitude score of the university community was estimated as the mean of attitude scores of all the respondents.

$$consumer\ \ attitude\ \ score = \frac{1}{n}\sum_{i=1}^{n} w_i \times r_i \tag{1}$$

Initially, all three aspects were considered to be of equal importance ($w = 1$). A mean attitude score of >1.5 was taken to represent a positive attitude while those ≤1.5 represented a negative attitude. On the other hand, 'segregated consumer attitude score' was defined in this study as the mean attitude of respondents belonging to a select category of a demographic variable - *e.g.* the mean attitude of all Christians within the demographic variable, religion; this was calculated using Eq. (2) where, μ is the mean response of all the segregated groups of consumers and n is the number of aspects.

$$segregated\ \ consumer\ \ attitude\ \ score = \frac{1}{n}\sum_{i=1}^{n} w_i \times \mu_i \tag{2}$$

Since an exploratory approach for estimating consumer attitudes was used, the overall attitude and segregated attitudes scores were recalculated by varying the weights used in Eq. (1) and Eq. (2): firstly, more importance was assigned to respondent's willingness to eat urine-fertilised food since this could be a stronger indication of consumer behaviour than whether or not they believed in urine's fertilising potential; secondly, we considered the scenario where more significance is assigned to willingness to consume and respondent beliefs on whether urine should never be recycled. All statistical analyses were performed using R (v 3.3.4).

2.5. Subjective norm

According to Bikhcahndani et al. (1998), people tend to make similar choices when faced with similar action alternatives, payoffs, and information; something that could lead to convergent behaviour according to the authors. Moreover, Frith and Frith (2006) suggest that people tend to predict what others would do in a given situation and that their own behaviour is influenced by observing the actions of others. Hence, in order to capture the subject norm, the respondents were asked to indicate what they believed their friends/colleagues thought about urine recycling in one of the surveys' questions (*que 15*).

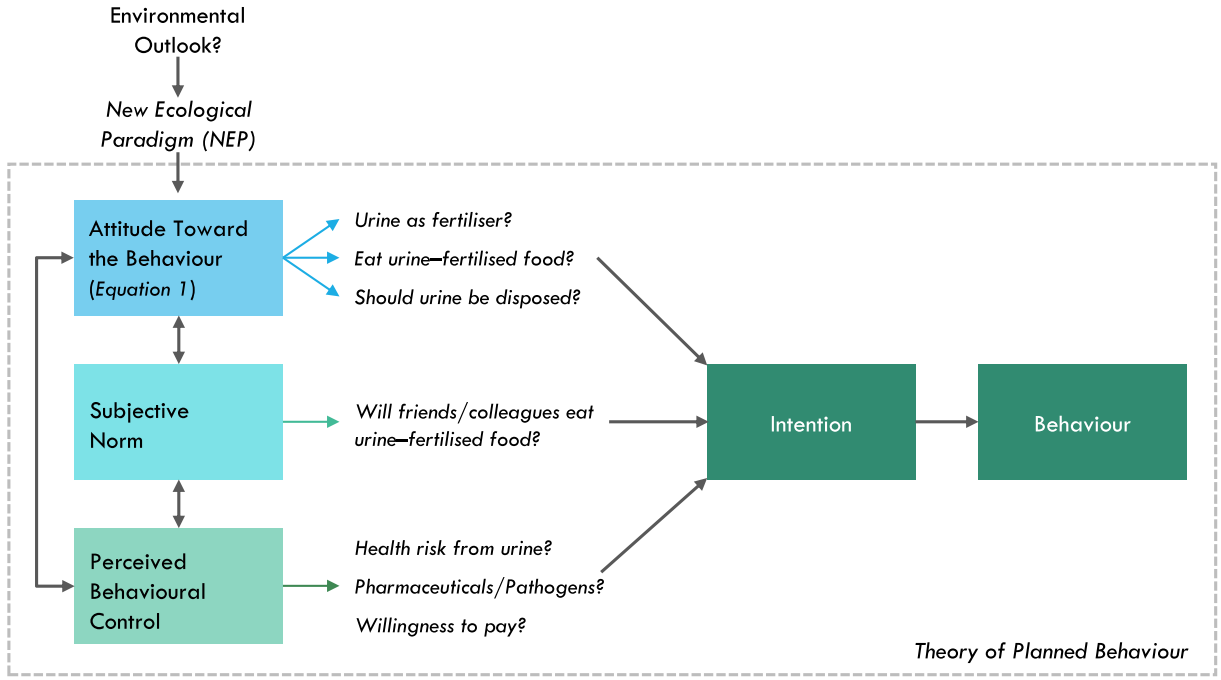

Fig. 1. Illustration shows the framework used in this study. The Theory of Planned Behaviour was used to evaluate consumer behavioural intentions to recycle urine at the university community. The revised New Ecological Paradigm (NEP) scale was used to evaluate consumer environmental attitudes. The theory suggests that consumers who have a positive attitude towards urine recycling behaviour (estimated by Equation (1)), and believe there is normative support for using it as a crop fertiliser, and feel they have high perceived behavioural control to engage in urine recycling, should have strong intentions to carry out the behaviour.

2.6. Perceived behavioural control

Human urine collected in source separating sanitation systems can be cross-contaminated with faeces, which could introduce transmission routes of infectious diseases when urine is used as fertiliser (Schönning et al., 2002). Also, urine and urine-based fertilisers can contain many micropollutants from human metabolism (pharmaceuticals, hormones) (Larsen et al., 2004). Hence, following Mariwah and Drangert (2011), behavioural control was captured by participant responses to questions 17–21 in the survey, where they were asked to indicate perceived health risks (pathogens and pharmaceuticals) against using urine as a crop fertiliser.

In addition, consumer willingness to pay for urine-fertilised food was sought. This was done because, the cost aspect of new systems and practices if often perceived by citizens as a risk (cf. Pahl-Wostl et al., 2003; Ishii and Boyer, 2016), and thus, could point to potential inability to perform urine recycling behaviour.

3. Results

3.1. Consumer attitudes to urine recycling

Individual consumer attitude scores were found to vary considerably. The overall attitude score of the dataset ($n = 1252$) was 1.56 ± 0.37 (Eq. (1)). This suggested that a moderately positive attitude to human urine recycling existed among consumers surveyed at VIT University (Table 1). Segregated attitudes scores of the consumers based on different categories of the demographic variables suggested that: (a) there was a positive correlation between age categories (17–19 to 41–50) and attitude ($R^2 > 0.98$), as acceptance increased with age; (b) female respondents were slightly more negative than their male counterparts (1.53 *vs.* 1.57, $P < 0.01$); (c) religious and caste demographics did not influence consumer attitudes, except among those who identified themselves as Jains ($n = 33$), Buddhists ($n = 7$), and Scheduled Tribes ($n = 8$) (Fig. 2).

When different weights were assigned to the three aspects assumed to determine consumer attitude, the overall attitude score changed albeit not considerably. When more importance was assigned to the willingness of respondents to consume food grown using human urine as fertiliser, the overall score decreased from 1.56 to 1.53. When more importance was given to willingness to consume and whether respondents believed urine should be recycled and not disposed, there was no change in the attitude as against the original attitude of the dataset.

3.1.1. Attitude towards urine recycling behaviour: environmental outlook

The mean NEP rating of the dataset was 3.32, indicating that the respondents were (moderately) environmentally conscious, and in favour of a pro-ecological worldview (Table 2). In particular, the majority endorsed the possibility of an ecocrisis, as well as, anti-anthropocentric views but the acceptance of the view that humankind may be approaching its 'limits to growth' was not high (Table S4).

Cronbach's Alpha ($0 < \alpha < 1$), an indicator of internal consistency in the NEP scale, was calculated as 0.55, which according to Nunnally (1967) is acceptable reliability for preliminary research. McDonald's Omega was estimated as Hierarchical Omega (ω_h) 0.57 and Total Omega 0.79, which also suggested that the NEP scale constituted an internally consistent measure. The principal component analysis revealed that one major factor explained 24.8% of the total variance in the dataset.

The ANOVA revealed that there were no significant difference between the mean NEP ratings of the different categories of demographic variables (Table 3). The only exception to this was the variation displayed by different age categories as it was observed that, the younger the respondent the more pro-ecological the

Table 1
Overall consumer attitude and segregated consumer attitude scores are presented. The scores are estimated as the equally weighted mean of participant responses to que 10, 13 and 23 in the survey; the last two columns show attitude scores when weight change analysis is performed; (+) positive attitude; (−) negative attitude.

Category	*n*	Original attitude score[a]		Modified attitude scores			
				Change I[b]		Change II[c]	
Overall Attitude	1252	1.56	+	1.53	+	1.56	+
Age							
17–19	628	1.51	+	1.48	−	1.51	+
20–22	417	1.57	+	1.54	+	1.56	+
23–30	139	1.66	+	1.65	+	1.67	+
31–40	41	1.69	+	1.69	+	1.70	+
41–50	19	1.75	+	1.75	+	1.74	+
>50	8	1.58	+	1.59	+	1.60	+
Gender							
Male	857	1.57	+	1.54	+	1.57	+
Female	395	1.53	+	1.50	+/−	1.53	+
Religion							
Hinduism	942	1.56	+	1.53	+	1.56	+
Islam	53	1.59	+	1.58	+	1.61	+
Christianism	82	1.51	+	1.48	−	1.51	+
Sikhism	13	1.67	+	1.63	+	1.63	+
Jainism	33	1.49	−	1.47	−	1.51	+
Buddhism	7	1.43	−	1.43	−	1.46	−
I am an Atheist	68	1.56	+	1.54	+	1.56	+
I am Agnostic	40	1.57	+	1.56	+	1.57	+
Other	14	1.62	+	1.55	+	1.64	+
Caste							
Scheduled Caste	32	1.59	+	1.57	+	1.60	+
Scheduled Tribe	8	1.46	−	1.44	−	1.43	−
Other Backward Class	274	1.52	+	1.49	−	1.51	+
Upper Caste	472	1.56	+	1.54	+	1.56	+
Don't know	112	1.58	+	1.54	+	1.58	+
Do not wish to disclose	196	1.56	+	1.53	+	1.57	+
Not Applicable	158	1.58	+	1.55	+	1.59	+
School of Study/Affiliation[d]							
SMEC	197	1.58	+	1.55	+	1.58	+
SCALE	317	1.60	+	1.57	+	1.60	+
SCOPE	178	1.50	+/−	1.46	−	1.50	+/−
SENSE	140	1.52	+	1.48	−	1.52	+
SAS	13	1.59	+	1.56	+	1.58	+
V SPARC	5	1.40	−	1.40	−	1.44	−
SBST	105	1.59	+	1.57	+	1.59	+
SELECT	72	1.54	+	1.52	+	1.54	+
SITE	93	1.46	−	1.42	−	1.45	−
SSL	7	1.33	−	1.25	−	1.31	−
VITBS	26	1.62	+	1.61	+	1.62	+
Other	99	1.61	+	1.59	+	1.62	+
Environmental outlook							
Pro-environmental	899	1.58	+	1.55	+	1.58	+
Anti-environmental	353	1.50	+/−	1.47	−	1.50	+/−

[a] Attitude score calculated as equally weighted mean of participant responses to questions 10, 13 & 23.
[b] Weights of responses to questions 10, 13 & 23 assigned values 0.25, 0.50 & 0.25, respectively.
[c] Weights of responses to questions 10, 13 & 23 assigned values 0.20, 0.40 & 0.40, respectively.
[d] Clarification on abbreviations for schools are found in Table S1.

stated belief ($P < 0.05$). It has been suggested that, environmental concern diffuses through the public over time and thus, younger people who are less attached to traditional outlooks may be more supportive of an ecological worldview (Jones and Dunlap, 1992; Dunlap et al., 2000). Complementary work in support of this hypothesis has however not been carried out.

The environmental outlook of the respondents did not significantly influence their attitude to urine recycling (Fig. 3). The mean NEP rating of the respondents and their urine recycling attitude scores (calculated in Eq. (1)) did not correlate meaningfully, despite indications that respondent groups with a pro-ecological worldview ($3.5 < \mu_{NEP} < 4.5$) displayed more favourable urine recycling orientations than their counterparts. However, for the respondent group with NEP rating between 2.5 and 3.0, an almost equal distribution of respondents with pro-urine ($n = 164$) and anti-urine ($n = 170$) attitudes was seen.

3.1.2. Do consumers perceive cow and human urine differently?

When asked if cow urine could be used as crop fertiliser, the majority (88%) responded positively. However, only little more than half (55%) were of the opinion that human urine could be used as a fertiliser (Fig. 4). The mean NEP rating of the respondents who believed human urine can be used as a fertiliser was 3.35, suggesting that these consumers would most likely be inclined to endorse pro-environmental views. When these consumers were asked to rate the sustainability of urine recycling (*que 11*), 66% believed that using human urine in agriculture was more sustainable than using chemical fertilisers, while 14% thought it was similar to it. However, the NEP rating of those who considered urine recycling to be sustainable and those who did not was very similar. This implied that some respondents ($n = 136$) did not consider urine recycling as being sustainable despite having pro-environmental views.

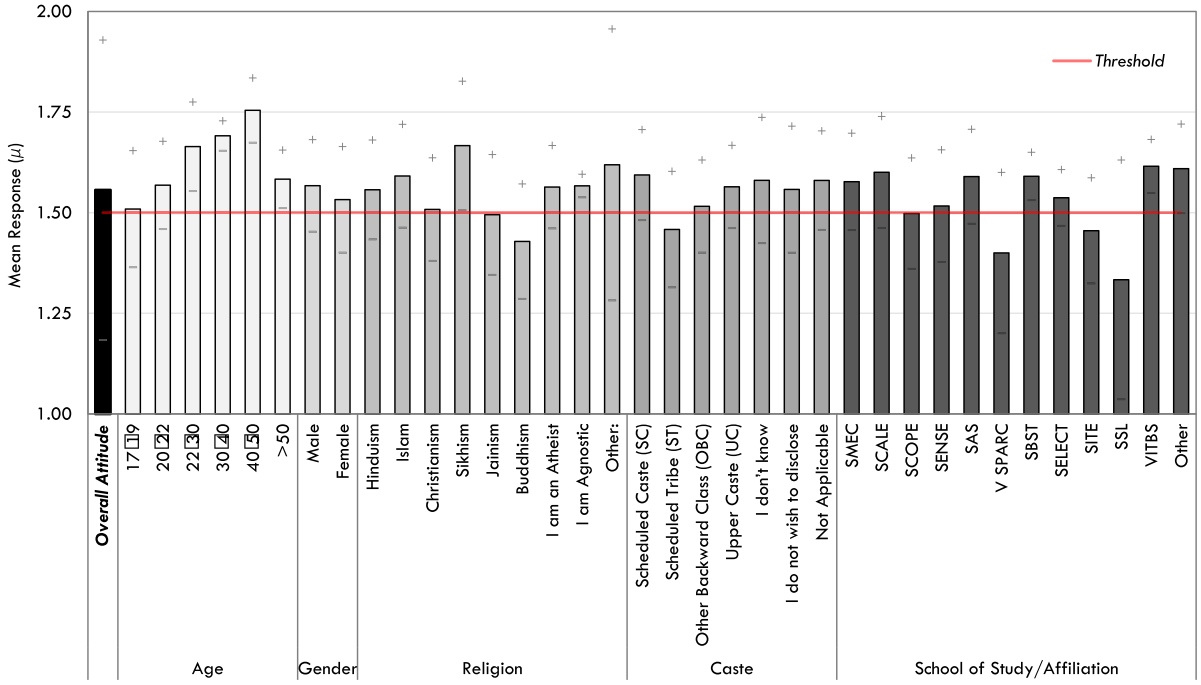

Fig. 2. The figure depicts consumer attitude towards urine recycling behaviour represented in terms of their attitude scores which is also segregated according to various categories of demographic variables; threshold represents a mean score of 1.50; standard deviation of the mean is represented by symbols (+ and −).

Table 2
Responses of 1252 surveyed consumers to the New Ecological Paradigm (NEP) statements coded as 1 = strongly disagree (SD), 2 = disagree (D), 3 = neither agree nor disagree (NA), 4 = agree (A), and 5 = strongly agree (SA); the mean NEP rating for each statement (μ_{NEP}), its standard deviation (σ), and Cronbach's α is presented; the five hypothesised facets viz., reality of limits to growth, anti−anthropocentrism, fragility of nature's balance, rejection of human exemptionalism, and the possibility of an ecocrisis to which each NEP statement belongs to, is also shown.

NEP Statement	Frequency					μ_{NEP}	σ	Cronbach's α if item deleted	Facet
	SA	A	NA	D	SD				
1. We are approaching the limit of the number of people the earth can support	304	453	229	160	106	3.55	1.22	0.51	Limits to growth
2. Humans have a right to modify the natural environment to suit their needs[a]	122	271	281	344	234	3.24	1.25	0.53	Anti-anthropocentrism
3. When humans interfere with nature, it often produces disastrous consequences	320	450	262	135	85	3.63	1.17	0.50	Balance of nature
4. Human intelligence will ensure that we don't make the earth unliveable[a]	153	417	378	212	92	2.74	1.10	0.59	Anti-exemptionalism
5. Humans are severely abusing the environment	370	477	208	92	105	3.73	1.20	0.50	Eco-crisis
6. The earth has plenty of natural resources if we just learn how to develop them[a]	368	502	180	123	79	2.24	1.16	0.61	Limits to growth
7. Plants and animals do not have equal rights as humans to exist	512	393	172	110	65	3.94	1.17	0.51	Anti-anthropocentrism
8. The balance of nature is strong enough to cope with the impacts of modern industrial nations[a]	135	311	291	368	147	3.06	1.20	0.52	Balance of nature
9. Despite our special abilities, humans are still subject to the laws of nature	324	523	201	128	76	3.71	1.14	0.51	Anti-exemptionalism
10. The so-called ecological crisis facing humankind has been greatly exaggerated[a]	134	327	309	313	169	3.04	1.22	0.54	Eco-crisis
11. The earth is like a spaceship with very limited room and resources	207	440	266	225	114	3.32	1.21	0.53	Limits to growth
12. Humans were meant to rule over the rest of the nature[a]	84	218	235	372	343	3.54	1.24	0.50	Anti-anthropocentrism
13. The balance of nature is very delicate and easily upset	189	458	324	198	83	3.38	1.12	0.52	Balance of nature
14. Humans will eventually learn enough about how nature works to be able to control it[a]	102	408	363	270	109	2.90	1.10	0.56	Anti-exemptionalism
15. If things continue on their present course, we will soon experience a major ecological disaster	396	428	223	128	77	3.75	1.18	0.49	Eco-crisis

[a] Indicates reverse coding of the statements.

Participant responses were substantively different when they were asked to state their willingness to consume food that was grown using urine. The majority (71%) stated they would consume food grown using cow urine, while only 44% would eat food that was grown using human urine (Fig. 4). Younger respondents were less positive to the notion of urine as a fertiliser ($P < 0.001$), and less prepared to consume food grown using both cow urine ($P < 0.005$) and human urine ($P < 0.001$) (Table 3). However, responses did not differ significantly with respect to gender, religion or caste demographics of the consumers. Although educational/work affiliation had a strong influence on consumer attitude, inferences could not be drawn as no significant patterns were found. More

Table 3
Results from one-way ANOVA indicate whether or not consumer responses to various questions (Q) varied significantly between different categories of demographic variables; mean consumer responses, segregated according to different variable categories are found as Supplementary Information, Table S5.

Demographic variable	Q 9	Q 10	Q 12	Q 13	Q 15	Q 17	Q 20	Q 21	Q 23
	CU as fertiliser?[a]	HU as fertiliser?[b]	Eat CU-fertilised food?	Eat HU-fertilised food?	Friends/Colleagues eat?	Health Risk?	Pharmaceuticals?	Pathogens?	HU Disposed?
Age	0.77	0.0003***	0.005**	5.59e−08***	0.004**	0.005**	0.014*	0.012*	0.07 †
Gender	0.58	0.66	0.28	0.05	0.78	0.27	0.07 †	0.12	0.38
Religion	0.25	0.26	0.95	0.42	0.20	0.32	0.43	0.044*	0.97
Caste	0.47	0.64	0.52	0.66	0.42	0.52	0.02*	0.026*	0.049*
School	0.36	0.22	0.004**	0.0009***	0.63	0.03*	0.24	0.43	0.039*
NEP	0.20	0.003 **	0.68	0.35	0.75	0.11	0.39	0.07 †	0.12

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; †$p < 0.1$.
[a] CU: cow urine.
[b] HU: human urine.

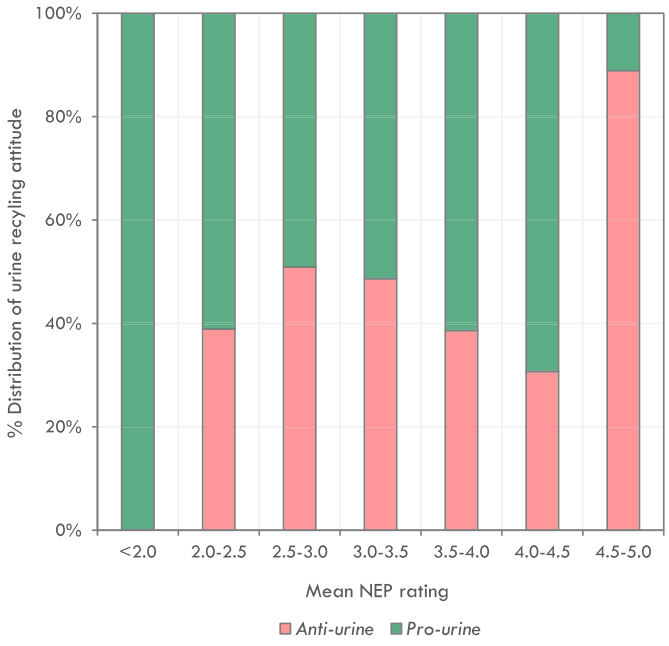

Fig. 3. Consumer urine recycling attitude scores are presented in relation to their environmental attitude. The *x*−axis shows the mean NEP rating, and the *y*−axis depicts the % of consumers who were either for (green) or against (red) urine recycling. An NEP rating of 3 is considered the threshold between pro−ecological and anthropocentric worldviews. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

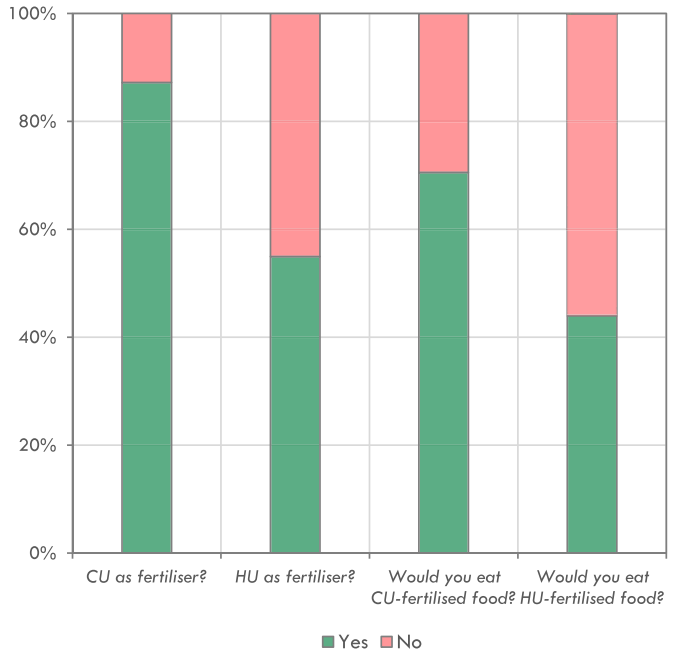

Fig. 4. Respondent views on cow urine (CU) and human urine (CU) as a crop fertiliser and whether they were willing to consume food grown using CU and HU as a fertiliser; the responses are displayed as positive (green) and negative (red). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

respondents from the business (VITBS; $\mu = 1.58$) and bio-sciences (SBST; $\mu = 1.58$) schools were willing to consume human urine-fertilised food. In contrast, majority of the respondents working with, or studying, information technology (SITE; $\mu = 1.31$), computer sciences/engineering (SCOPE; $\mu = 1.37$) and electronics engineering (SENSE; $\mu = 1.38$) were unwilling to do so. No respondents from the language school (SSL; $\mu = 1.00$) were willing to consume human urine-fertilised food.

3.2. Role of subjective norms in forming behavioural intentions

It was our intention to explore whether the urine recycling intentions of others (subjective norm) in the university community had any effect, if at all, on individual consumer attitudes. The respondents were asked to indicate what they believed would be the orientations of most of their friends and colleagues: only 34% of all those who responded to this survey were of the opinion that others in the university community would be willing to eat urine-fertilised food. Around 180 respondents (14% of all respondents) provided comments to the question exploring the subjective norm. Several of these comments expressed their uncertainty in predicting their community's behaviour: “I don't know”, “I am unsure”, “Maybe”, “It depends on whether …”, “Some of them would, not all”, “Can't comment”, etc. An interesting observation was that, 68% of the respondents who did not provide a comment felt their friends or colleagues would be unwilling to eat urine-fertilised food, while only 54% of the respondents who did provide a comment thought so. Some consumers were of the belief that, initially the concept of urine recycling might not be well accepted by others, but “once things set in place”, or if urine fertilised food was “packed attractively”, or others in the university community were not informed how the urine-fertilised food was actually produced, people may accept it. Many respondents indicated that people around them are unaware of how their food is grown today, and that urine use in agriculture may already be happening. To quote respondent # 637, “we are [already] eating crops cultivated on land *polluted* [emphasis added] with human/animal waste”.

Across the socio-demographic variables, consumer age was the only one that significantly influenced this perception ($P < 0.005$). Respondents in the youngest age group (17–19 yrs), which accounts for half of all the survey respondents, were least likely to perceive their friends or colleagues as being willing to consume urine-fertilised food. However, F-test revealed no significant difference in urine recycling attitudes of those who thought their friends/colleagues would eat urine-fertilised food and those who did not.

3.3. Perceptions of behavioural control: risks against urine recycling

The questionnaire elicited from the respondents whether they felt the use of urine as a fertiliser posed a health risk to them as food consumers. They were also asked if they thought human urine contained pharmaceuticals and pathogens. Out of all the respondents ($n = 1252$), 65% were of the opinion that using human urine as a fertiliser would pose a health risk, 70% thought urine contained pharmaceutical residues, and 73% believed it contained pathogens. Of those who considered urine to pose a health risk, 80% were of the belief that these risks could be mitigated with treatment. The overall attitude to urine recycling was not influenced by consumer health risk perceptions, or their beliefs of the presence of pharmaceuticals or pathogens in urine ($P < 0.05$). On the other hand, consumer willingness to pay for urine-fertilised food factored strongly in shaping their overall attitude: 83% of those that stated they would eat urine fertilised-food ($n = 551$) were willing to do so only if it cost them less than or similar to what they usually paid when buying the same food.

The effects of consumer socio-demography on risk perceptions was also explored. Consumer age significantly affected perceptions (Fig. 5). The perceived health risks seemed more evident among the young respondents (17–19 yrs) than in their older counterparts (41–50 yrs) ($P < 0.005$). Likewise, more of the young consumers stated that they thought human urine contained both pathogens and pharmaceuticals. Caste demographics and to a lesser extent academic/work affiliation and religion, affected consumer risk perceptions. In comparison to the rest, more of the respondents who identified themselves as Scheduled Castes believed that urine did not contain pathogens or pharmaceuticals ($P < 0.05$), and did not pose a health risk (Table S5).

4. Discussion

4.1. Understanding urine recycling intentions in the university community

This study explored urine recycling behavioural intentions of a university community in South India, in the context of Azjen's (2002) TPB. An overall (moderately) positive attitude towards urine recycling behaviour was recorded among the respondents from VIT University's Vellore campus. While the community also displayed a moderately positive environmental outlook, we observed that their environmental outlook did not significantly influence their attitude towards urine recycling. This is interesting as contrasting results have been reported in earlier studies, where it has been observed that one's pro-environmental beliefs of new sanitation systems and one's intention to support/adopt it are related (Lamichhane and Babcock, 2013; Ishii and Boyer, 2016; Poortvliet et al., 2018). However, we did find that the respondents viewed cow urine and human urine very differently, and found this to affect their attitudes. In our survey, 87% of the respondents thought of cow urine as fertiliser, and 70% would eat cow-urine fertilised food but only 55% viewed human urine as fertiliser, with even fewer (44%) willing to consume food grown using it (Fig. 4). In an earlier study, we have reported on perceptions of farmers (also from Vellore District) to urine as crop fertiliser, where we have observed a similar cow urine versus human urine distinction (Simha et al., 2017).

The subjective norm explored in this study did not feature in shaping the community's behavioural intentions. We did not observe any significant difference between the attitude towards urine recycling behaviour of those who thought their friends/colleagues would eat urine-fertilised food and those who did not. If recycling urine and using it as fertiliser is indeed a taboo as noted elsewhere (Black and Fawcett, 2010; Jewitt, 2011a), it could be expected that one's urine recycling behaviour will be influenced by behavioural intentions of others in a community (Arvola et al., 2008). Especially, those that have the opportunity and/or authority to assert such influence. In our case, these would be other students/faculty/staff who as friends, colleagues, or supervisors of the respondents, could influence individual recycling intentions. Since such influence was not explicit in this study, one explanation could be that the respondents perhaps felt that their intention to recycle urine was not contingent on those of others in the community. On the other hand, maybe they did not believe in this social norm, which could be because they ignore or underestimate the extent to which the actions of the community they belong to affect their own actions (*e.g.* Cialdini, 2005). It is also possible that the influence of social norms may be less important than other factors (*e.g.* willingness to pay; cf. Croker et al., 2009) or that there are other normative beliefs that influence consumer intentions to recycle urine, masking the importance of social norm in this study. Future studies will need to explore these aspects.

According to the TPB, a high level of perceived control over performing a behaviour should translate into favourable behavioural intentions. However, consumers may feel they lack volitional control - *e.g.*, consider a hypothetical scenario where a farmer uses untreated human urine to grow vegetables and does not inform consumers about this practice. In an earlier survey in South India, we did find that farmers were unwilling to disclose to their consumers if they used urine as fertiliser (Simha et al., 2017). This was because they were afraid consumers would not buy their produce if they knew how it had been grown. However, consumers surveyed in this study did not raise such concerns.

Health risks, especially from pharmaceutical residues, has been pointed out by consumers elsewhere as one worrying issue with recycling urine (Lienert and Larsen, 2009). However, in our study, we did not find consumer urine recycling intentions to be influenced by their health risk perceptions, or their beliefs that urine contained pharmaceuticals and pathogens. The majority in fact believe that human urine could be treated to not pose health risks to food consumers. We did find respondent willingness to pay for urine-fertilised food to influence their intentions. There is literature that suggests that Indian consumers may be unwilling to pay price premiums towards environment friendly practices (Manaktola and Jauhari, 2007; Dwivedy and Mittal, 2013), because they fear that this would increase their living costs and are of the attitude that such costs must be borne by others (*e.g.* the state). This could be one bottleneck for progress in urine recycling, particularly if consumers with positive attitudes feel they should be paying less for urine-fertilised food, or if consumers think urine-fertilised food costs more than food grown using animal manure or chemical fertilisers.

4.2. Social sustainability of new sanitation systems

Through this survey we identified factors that influence urine recycling intentions of a South Indian university community: respondent age, their willingness to pay for urine-fertilised food, educational/work background, and perceived health risks factored

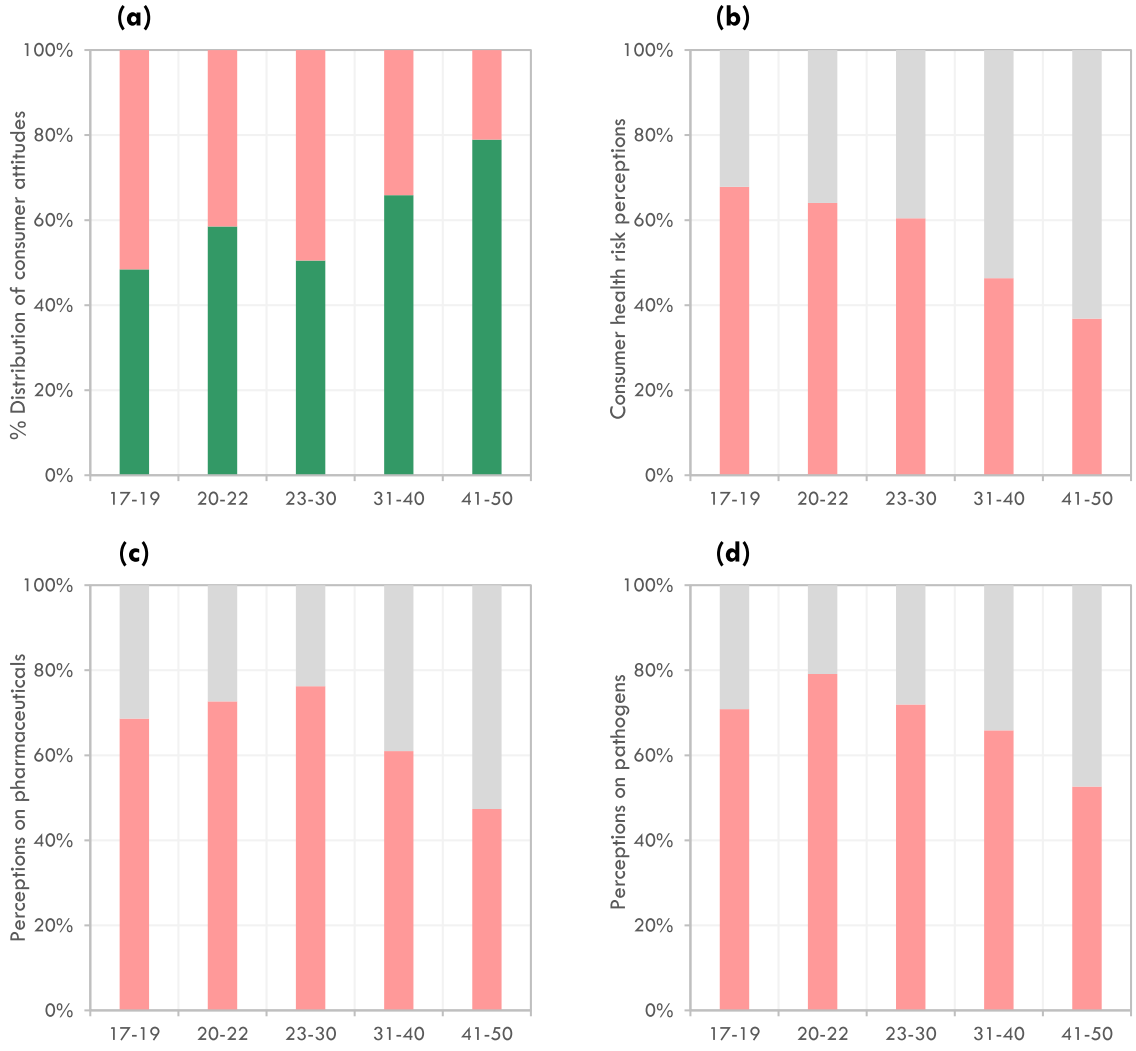

Fig. 5. Bar charts illustrates the effect of consumer age groups (yrs) on (a) consumer attitude to urine recycling (b) perceived health risk against urine use as fertiliser, consumer beliefs surrounding the presence of (c) pharmaceutical residues, and (d) pathogens in human urine. In the first bar chart (a), consumer attitude to urine recycling is shown as being positive (green) or negative (red), while the rest three charts depict the extent of risk perception (red) consumers hold against the respective aspects. The age category '> 50' was not depicted due to low sample size ($n = 8$). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

significantly in explaining their behavioural intentions. Religion and caste demographics, environmental attitude or the explored social norm did not have as large of an impact. While we find similarities between our findings and those reported earlier in literature, we also find some differences. Very few of our respondents were willing to eat urine-fertilised food. Similarly, Mariwah and Drangert (2011) observed that peri-urban residents in Ghana would accept the use of human excreta in agriculture, but were less inclined to do it themselves or consume crops grown using it. Farmers in South India pointed to cultural norms and religious objections as factors constraining them from using human urine (Simha et al., 2017), as did farmers in Nigeria and Ghana (Cofie et al., 2010). In contrast, surveys in Europe and in other western countries have indicated a rather high level of acceptance of human urine as a fertiliser, as well as, consumer willingness (and preference, in some cases) to buy/eat food grown using urine or urine-based fertilisers (Pahl-Wostl et al., 2003; Lienert and Larsen, 2009; Lamichhane and Babcock, 2013). In contrast to what we found, respondents in these surveys raised concerns about micro-pollutants, pharmaceuticals, health risks and governmental regulations surrounding urine recycling. Lamichhane and Babcock (2013) even found that, more than 60% of their respondents at a university community in Hawaii were willing to pay a price premium for diverting toilets to be installed on campus. According to the results of our survey, the majority of our respondents were willing to eat urine-fertilised food only if cost them similar to or less than what they usually paid, and were unwilling to pay a price premium for urine-fertilised food.

While we recognise that our results and those reported by others do not necessarily qualify for direct comparison, we believe that qualitative indications of differences between these studies are sufficient grounds to re-examine the notion of social sustainability of new sanitation systems. The above discussion certainly underpins the need for identifying place-based definitions of sustainable sanitation, as suggested by Guest et al. (2009). Jewitt (2011a,b) too noted that social conceptualisations of human excreta vary enormously in both space and time and that, there is a need for spatially-specific understanding of sanitation-related issues. Further sociological research may help unlock various internalised aspects that shape human behaviour and attitudes to new sanitation systems in different regions of the world.

4.3. Implications of this study

4.3.1. Should we appeal to people's environmental sensitivities?

Some studies performed in high-income countries (EU, USA) have indicated that there is a positive correlation between pro-environmental attitudes and support/acceptance of new sanitation systems. The thinking is that, environmental arguments in favour of such systems should be communicated to people to improve its adoption (Lienert and Larsen, 2009; Lamichhane and Babcock, 2013; Ishii and Boyer, 2016; Poortvliet et al., 2018). In the present study, while the majority of our respondents also endorsed a pro-ecological worldview (Table 3), we did not find their environmental attitudes to factor significantly in shaping their attitudes to urine recycling behaviour (Fig. 3). We also observed that a considerable number of respondents (136 out of 1252) did not think of urine recycling as being sustainable despite having pro-environmental views. As no pre-survey information package was provided to the participants and their level of awareness on various sanitation issues was not evaluated, it is difficult to conclusively state that their environmental sensitivities will not determine their urine recycling behaviour. Then again, if such environmental sensitivities do exist, the question remains, should they be appealed to or not? A pro-environmental outlook does not necessarily translate directly into pro-environmental behaviour. In the context of an emerging economy like India, environmental commitments often tend to be given lower priority than say, economic growth or poverty alleviation (Atteridge et al., 2012). If that is the case, there is an urgent need to understand how new environmental technologies should be introduced to the public. Since urine diversion and recycling can promote to an extent, both socio-economic wellbeing and environmental protection (Etter et al., 2011; Dickin et al., 2018), the relative importance that people assign to these aspects must be understood. This could possibly help guide sanitation planning and implementation.

There is a wealth of studies supporting the view that new sanitation technologies based on urine diversion and recycling have excellent environmental benefits to offer (*e.g.* Tidåker et al., 2007; Lam et al., 2015; Ishii and Boyer, 2015). However, if people do not value these benefits, value it less in comparison to other benefits, or do not agree with the results of these studies, efforts to convince them to adopt the technologies might not succeed. For instance, while communicating the water saving benefits of urine diversion is certainly an appropriate measure for targeting a community that greatly values water conservation (Lamichhane and Babcock, 2013; Ishii and Boyer, 2016), in others it might not be. As experiences from the Erdos project in China suggest, the drivers for improving sanitation tend to be quite temporal: here, rapid changes in the local economy and opening of a new water pipeline resulted in residents not perceiving water shortage to be a significant problem, and thus, not a driver for acceptance of dry toilets (Rosemarin et al., 2012). This again ties back to the discussion in the earlier section where we talk about the need for identifying place-based definitions of sustainable sanitation.

4.3.2. Theoretical and managerial implications

Based on this study, it is arguable that consumer attitude is not the limiting factor for the spread of urine recycling in the surveyed community. According to diffusion of innovations theory (Rogers, 2003), uptake of innovations within a population follows an s-curve; innovators and early adopters first use the technology, followed by exponential adoption once the use of the technology reaches 16–25% of the population. As the market share of a technology increases, knowledge, attitudes and norms also change, making it easier for others to adopt the innovation. According to the results of this study, over 40% of the respondents would eat food fertilised by human urine. This is well beyond the acceptance rate needed to start an exponential spread of urine recycling.

However, as discussed above, a positive attitude does not necessarily lead to behaviour change. According to the TPB, our actions arise first from an intention to act, which in turn is influenced by norms, attitudes and knowledge (Ajzen, 2002). This study highlights a range of attitudes, knowledge regarding risks, and an intention for urine recycling on behalf of the respondents. This should not be surprising considering that the use of urine is a rather innovative concept and there are few established norms regarding the practice. It is also likely that people do not fully understand the risks or potential benefits with urine recycling. Instead, individuals come from different backgrounds and have access to different levels of knowledge that influence their normative perspectives and attitudes. Given that consumer attitude in the studied case is not strictly negative, the question becomes what information or agency do consumers need to move from a positive attitude to intention and action? Here there is room for further research.

The results of this study may help guide two possible research strategies: First, what messaging is needed to form a positive attitude in the most conservative consumers? In this study, this group is the youngest respondents who are at the beginning of their university education. While further research is needed to understand why this group has a lower acceptance level, they are also a group that is relatively easy to target with educational material at the university. In fact, Rothman et al. (2015) suggest that, major shifts in people's environment (*e.g.* moving to the university's residence) could temporarily leave their habits vulnerable to change and act as entry points for initiating support for a new behaviour. Second, research could focus on what policy or communication instruments are needed to enable the 40% of consumers who are positive to consuming food fertilised with human urine to actually do so. Here, it is likely that communication messages will need to be matched with economic and technological steering mechanisms that cover the entire chain of urine management, from toilet to field. New behaviour such as using a urine diverting toilet or buying urine fertilised food is easy to neglect or forget, but this can be mitigated by creating support for people to repeat the behaviour and develop a stable behavioural pattern (Neal et al., 2016). In this regard, universities are likely to be ideal settings for initiating and sustaining positive sanitation behaviour, especially among young students that move into campus residence (context shift), where they could be encouraged (and also rewarded, at least initially) to repeat a desired habit in the same setting for extended time periods.

This study has also shown that consumers are unlikely to pay a price premium for urine fertilised food, meaning that urine fertilisers will need to be economically competitive with other fertilisers. The challenge of urine recycling is more likely to lie in creating the infrastructure and logistic systems to enable recycling, rather than in creating a market for end-products. Many actors in the food industry refer to low consumer acceptance when they reject urine fertilisers; utilities with mandates for management of human waste also refer to a lack of a market for urine fertilisers (McConville et al., 2015; McConville et al., 2017). The main barriers to urine recycling may well be the attitudes of other stakeholders within the service chain, than with consumers or farmers. This study concludes that there is enough consumer acceptance to support the spread of urine recycling systems in the surveyed community. At the same time, it is clear that consumer demand is not a driving force for a shift to increased urine recycling. Further research is needed to understand where the largest resistance is within the urine management service chain and what policy measures and information campaigns would be needed to change attitudes at that blockage point.

4.4. Study limitations

There were some limitations to this study. Urine recycling attitudes of the respondents were quantified using an aggregated metric through an exploratory approach. Although this facilitated an understanding of pro- and anti-urine attitudes, it would need to be refined in future studies. When statistically treating the dataset, mean consumer attitude score (calculated in Eq. (1)) of 1.5 and mean NEP rating of 3 were considered to represent negative attitudes to urine recycling and anti-environmental outlooks, respectively, although they merely indicated consumer indifference to the two aspects. Since consumers who displayed neither positive nor negative attitude may change their stance over time, the overall positive attitude may have been underestimated.

When presented with the question, 'do you think your friends/colleagues would consume urine-fertilised food?' more than 180 respondents provided comments in addition to the response (yes/no). Many of the comments expressed their uncertainty or inability to predict the behavioural intentions of others in the university community. We recognise that this is a very difficult question to answer. However, people around us do affect our own cognition of things and thus, asking respondents to take a stance may provide indirect indications of what they themselves think about urine recycling.

Another limitation to this study was that, some demographic variable categories were not adequately represented in the sampled population. ANOVA revealed that respondents associated with demographic variables that had low sample sizes responded significantly different to certain questions (Table 3). For instance, the segregated attitudes of Jains ($n = 33$), Buddhists ($n = 7$) and people belonging to Scheduled Tribes ($n = 8$) was not positive toward urine recycling. However, these results may not be representative of all consumers on the university campus who identify themselves as belonging to these religions or caste and therefore must be taken with caution.

5. Conclusion

This study presented the urine recycling perceptions and behavioural intentions of 1252 consumers from a South Indian university community. The majority of the consumers believed urine should be recycled, were moderately positive to the idea of urine as fertiliser, but less than half of them were willing to eat urine-fertilised food. The results of this study, and those available in literature seem to suggest that there is sufficient support among farmers, consumers, and toilet users for recycling human urine collected in new sanitation systems. If that is the case, future studies should evaluate where the resistance to recycle urine lies in the urine management chain and how existing behaviour (*e.g.* open defecation among toilet users) of various stakeholders could be disrupted. Also of research interest will be case studies that help identify regional drivers and barriers to the adoption of urine recycling. Such studies should attempt to understand not only what aspects of sustainable sanitation technologies people think are important, but also the relative importance they assign to each aspect. This could help bridge the knowledge gaps that remain with respect to the social aspects surrounding source separating sanitation systems and will be vital to inform policymaking.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.watres.2018.07.006.

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