



Public perceptions of human excretion-based fertiliser in England and Japan

Steven David Pickering^{a,d,*}, Ömer Gökçe^a, Davide Hanna^a, Markus Knell^a, Dayoung Lee^b, Melody Scales^a, Marwan Zeinalabidin^a, Yosuke Sunahara^c, Martin Ejnar Hansen^d

^a University of Amsterdam, the Netherlands

^b Ewha Womans University, South Korea

^c Kobe University, Japan

^d Brunel University London, UK

ARTICLE INFO

Keywords:

Human excretion based fertiliser
Sustainable development
Sewerage
Sewage
Nightsoil

ABSTRACT

This study investigates public attitudes towards the use of human excretion-based fertiliser (HEBF) in agriculture. Focusing on England and Japan, countries with contrasting histories of nightsoil use, we conducted representative surveys to understand public acceptance and sex-based differences in attitudes. Our findings reveal significant cultural and sex-based disparities in the willingness to utilize HEBF. The Japanese are more accepting of using HEBF for food production, with fewer health concerns, compared to the English. However, English respondents are more open to using HEBF in public parks. The study emphasises the need for further research on societal perceptions and highlights the importance of cultural context in adopting sustainable practices like HEBF in agriculture.

Introduction

There is little doubt that the world is facing a climate emergency which presents enormous societal challenges. Increased levels of urbanisation, coupled with a growing demand around the world for consumer goods, presents serious issues for any attempts to address the issue of climate change. Part of the challenge facing the world is how to ensure continuous food production, while at the same time increasing sustainability (Harder et al., 2020).

The production of fertilisers presents significant environmental impacts. Animal-based manures cause nitrate pollution in soil, ground-water and the atmosphere (Nakagawa et al., 2021). On the other hand, the vast majority of synthetic fertilisers are produced using the heavily fossil-fuel-dependent Haber-Bosch process, accounting for up to 2 % of global energy consumption and 1.4 % of global CO₂ emissions (Kyriakou et al., 2020). There is a clear environmental need for alternative fertilisers.

There is a long historical tradition of using human excreta as fertiliser. Referred to in its unprocessed form as nightsoil, societies the world

over have historically depended on human excreta as a vital fertiliser. Yet developed countries today avoid and indeed discourage such practices. But a new form of processed human excreta, known as human excretion based fertiliser (HEBF) offers great potential in dealing with the environmental problems presented by animal and synthetic fertilisers.

Urbanisation makes it easier to collect human excreta and potentially use this for manure in agriculture. Moreover, there have been significant technological advances in collecting and processing human excreta, meaning that historical public health issues with the use of human excreta as fertiliser (Blum & Feachem, 1985) have become manageable, and are no longer regarded as a stumbling block (Gwara et al., 2022).

But one area we do not fully understand is the extent to which the population is willing to consume products grown using human excreta. We want to understand whether there are structural and/or cultural barriers to the use of HEBF. Does acceptance of HEBF vary across cultures? Is there variance by sex? The aim of our study is to answer these questions.

* Corresponding author at: Department of Political Science, Nieuwe Achtergracht 166, 1018 WV Amsterdam, the Netherlands. Brunel Business School, Brunel University London, Uxbridge UB8 3PH, UK.

E-mail addresses: s.d.pickering@uva.nl (S.D. Pickering), omer.gokce@student.uva.nl (Ö. Gökçe), davide.hanna@student.uva.nl (D. Hanna), markus.knell@student.uva.nl (M. Knell), juliejules@ewha.ac.kr (D. Lee), melody.scales@student.uva.nl (M. Scales), marwan.zeinalabidin@student.uva.nl (M. Zeinalabidin), sunahara@people.kobe-u.ac.jp (Y. Sunahara), martin.hansen@brunel.ac.uk (M.E. Hansen).

<https://doi.org/10.1016/j.wmb.2024.08.002>

Available online 13 August 2024

2949-7507/© 2024 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Objectives and scope

HEBF has great potential, both as an agricultural resource and also as a means of dealing with environmental issues. But there are notable barriers to public acceptance of its use. Mary Douglas's seminal work on purity and danger helps us to understand why some materials are considered safe and pure, while others, including human excreta, are seen as impure and associated with danger (Douglas, 1966). Thus, food that is pure is associated with being safe to eat and impure is associated with danger (Ditlevsen & Andersen, 2021). This is interesting, as while the general scientific consensus is that human excreta can be made safe for use (Harder et al., 2020; Sugihara, 2020) the cultural aspects are very different. Thus, alongside the scientific progress in optimising the use of human excreta as fertilisers we need an increased focus on the cultural and societal aspects, especially on public attitudes towards it. But to date, there has been a surprising lack of research in understanding attitudes towards human excreta as fertilisers among the general public. At the same time we have to acknowledge that there are factors influencing how well individuals assess the risk of new technologies and how they adapt to such technological advances in their day-to-day living (Borwein et al., 2024; Li & Li, 2023; Siegrist & Árvai, 2020).

Many countries have abandoned the use of night soil, so to ask people to start using human excretion based fertiliser requires a form of behavioural change. But to achieve successful behavioural change, we need to understand differing perceptions of HEBF, in order to find the appropriate behavioural intervention (Michie et al., 2011). How can we expect people to adopt HEBF when they have been socialised not to? We cannot answer this question without first identifying what those social factors are. Once we have identified this, we can find an appropriate means of achieving behavioural change.

Experiences of using human excreta across the world are not uniform. Indeed, some societies have been much more accepting towards the use of nightsoil in food production, while in others it has become more of a taboo, as the development of sewerage systems was seen as a key means to deal with issues such as cholera (Ferguson, 2014). We expect that these different cultural experiences of nightsoil will have differing effects on the social acceptability of using human manure today.

Cultural differences in perceptions of dirt

Douglas's concept of "dirt as matter out of place" highlights the idea that dirt is a cultural construct, rather than an absolute, universal concept. What one culture considers dirty or impure, another might see as normal or even beneficial, depending on the context and historical background (Douglas, 1966). In Japan, for example, the comparatively recent practice surrounding the use of nightsoil has created a context where human excreta is not necessarily seen as purely waste but rather as a resource. This long-standing practice has shaped a more pragmatic and accepting attitude towards using human excreta as fertiliser (Shirai et al., 2023).

Conversely, in England, the development of modern sewerage systems in the mid-19th century was a pivotal moment in public health and urban sanitation. The "Great Stink" of 1858 and subsequent cholera outbreaks drove home the dangers associated with human waste, reinforcing the perception of excreta as dangerous and something to be kept out of sight (Allen, 2008; Borowy, 2021). This historical experience has ingrained a cultural aversion to using human excreta, contributing to the current scepticism and resistance towards HEBF.

The different historical paths taken by Japan and England in dealing with human waste underscore how cultural contexts shape perceptions. In Japan, nightsoil was seen as a valuable resource and an integral part of agricultural practices well into the 20th century, whereas in England, it became a symbol of public health hazards and was systematically eliminated from sight and daily life (Ferguson, 2014; Watanabe, 2015).

Existing work on the use of wastewater shows a strong sex-

differentiation: females have much lower levels of acceptance on the reuse of wastewater (Chfadi et al., 2021; Fielding et al., 2015; Miller & Buys, 2008; Redman et al., 2019). The literature suggests four reasons for this: i) females may have greater health and safety concerns; ii) females may be more risk averse; iii) males may have greater trust in technological solutions; iv) females may be more likely to have a perception of disgust (the 'Yuck factor' (Beck, 2009; Ricart et al., 2019)).

We might expect the same sex-based differentiation in perceptions of human excretion based fertiliser. But while there is a rich literature testing these notions on the reuse of wastewater, there is very little research looking at perceptions of HEBF. To remedy this, we ran two representative surveys in two countries which have very different histories of nightsoil: England and Japan. We specifically chose two developed countries, as while much existing research has focused on developing countries which are still using human excreta as fertiliser, there is little research on states which have abandoned the use of human excreta. How likely are such states to go back to using human excreta as fertiliser when they have moved on from it?

We find significant variation between England and Japan in how accepting the public are towards the use of human manure for the production of food and for the growing of public plants. We focus not only on the difference between these two countries but also on differences between males and females in the support for use of HEBF. We test these explanations while controlling for education, age, levels of trust and status of the respondent's own health.

Literature review

Night soil

The use of human excreta as fertiliser was the norm for many hundreds of years (Harder et al., 2019). Ferguson reviews the history of nightsoil and argues that it played a significant role in the economic development of Europe and Asia, and that European cities were relatively late in collecting and using human excrement and urine as fertiliser compared to cities in Asia (Ferguson, 2014). Yet while European cities were late adopters of nightsoil, they were also early abandoners, as events such as London's Great Stink of 1858 (Allen, 2008; Dobraszczyk, 2014) and the accompanying cholera epidemic made clear to European cities that water-borne waste removal was the solution to the public health crisis (Borowy, 2021; Kawa et al., 2019).

However, abandoning night soil and adopting sewerage systems was far from a universal norm. Indeed, late into the twentieth century, the World Bank argued that Western societies should learn from the experience of the Asian countries, such as China and Japan, in the use of nightsoil as a fertiliser (Feachem et al., 1985). Following up on this World Bank work, the WHO in 1989 presented an ecological aspect to the use of nightsoil, arguing that past hygiene standards had been unnecessarily strict, and that the reuse of human waste presented many environmental benefits (Borowy, 2021). Clearly, a divide was emerging in the appropriate way to deal with human excreta, and this divide seems to demonstrate a western/ eastern cleavage, or more specifically, a Europe / China and Japan divide (Shirai et al., 2023). Indeed, Watanabe presents the case of a Japanese NGO teaching agriculture in Myanmar, where the use of nightsoil, along with animal waste, was pivotal (Watanabe, 2015).

Wastewater

Studies of public acceptance of the use of HEBF are few and far between. Those that do exist tend to focus specifically on urine (Lamichhane & Babcock, 2013; Martin et al., 2022, 2023; Segre Cohen et al., 2020). But one closely related area that does have a rich literature is the social acceptance of wastewater/ reclaimed water. In that literature, two factors emerge that shape individuals' acceptance of reclaimed water: psychological factors and demographic factors (Fielding et al.,

2015). A common psychological factor identified across multiple studies is disgust towards drinking reclaimed water, which is often referred to as the ‘Yuck Factor’ (Beck, 2009; Ricart et al., 2019). This phenomenon is closely related to the most recurring pattern in research on the acceptance of the use of recycled water: the closer it comes to personal contact with individuals, the lower the acceptance (Chen et al., 2015; Chfadi et al., 2021; Dolnicar & Schäfer, 2009; Gu et al., 2015; Hurlimann & Dolnicar, 2016; Massoud et al., 2018; Ormerod & Scott, 2013; Zhu et al., 2019). The implication of this is that the use of reclaimed water for non-potable purposes such as agriculture is significantly more widely accepted than drinking reclaimed water.

Regarding demographic factors, males were found to be more comfortable with the idea of recycled water than females (Chfadi et al., 2021; Fielding et al., 2015; Miller & Buys, 2008; Redman et al., 2019). Age yields more mixed results with some research finding support for younger people being more open towards recycled water for drinking (Wester et al., 2016; Zhu et al., 2019) while others identified older people as having higher levels of willingness towards reclaimed water for potable use (Chfadi et al., 2021; Fielding et al., 2015).

Religion has also been found to have a relationship with wastewater’s acceptability: in a survey of almost 300 respondents in Beirut, Massoud et al. (2018) found that approximately 20 % of their respondents considered wastewater reuse to be religiously unacceptable (Massoud et al., 2018). Finally, location is also a factor: Redman et al. (2019) find that, at least in the US state of Nevada, that suburban residents are more willing to consume reclaimed water than their urban or rural counterparts (Redman et al., 2019).

Urine

In the few instances that have looked at human excreta more generally, the focus has almost invariably been on developing countries (Harada, 2022; Khalid, 2018; Tran-Thi et al., 2017), and usually looks at urine. For instance, while Mugivhisa and Olowoyo find strong scepticism among African respondents on eating crops fertilised by human urine, Simha et al find broad acceptance of urine as a fertiliser among Indians, but note a clear divide based on age, where younger means less “pro-urine” (Mugivhisa & Olowoyo, 2015; Simha et al., 2018). A more open acceptance to urine as a fertiliser is found by Schreiber et al who report other more societal concerns than direct individual level concerns (Schreiber et al., 2021). Gwara, Wale and Odindo focus on the willingness of farmers in the Vulindlela Traditional Authority of South Africa to engage with the use of human excreta as fertilisers and find that awareness, income, religiosity and view towards the environment were key factors (Gwara et al., 2022).

In one of the few instances of research on human waste in developed states, McConville, Metson and Persson focused on the attitudes of food retailers in Sweden and generally found a scepticism towards the use of urine and concerns about the risks presented by HEBF (McConville et al., 2023). Meanwhile, in the United States, Segrè Cohen et al. find males to be more accepting towards the use of urine as fertiliser as well as people with higher education (Segrè Cohen et al., 2020).

Risk perception and trust

The use of HEBF has become feasible with technological advances, but we still need to consider that some people will see HEBF as a risk. But little research has been carried out linking these two factors. We can, however, draw on the literature looking at risk perception and technological/ social change. In an overview study of risk perception Siegrist and Árvai (2020) reported weak effects of social-demographic variables on risk perception, however this can be mediated by the particular risk, especially when considering technological advances (Li & Li, 2023; Siegrist & Árvai, 2020). It is also well-established that risk perception is culturally dependent, for instance with regards to food (Siegrist et al., 2020), but that equally there are relatively speaking few studies

comparing risk perception across cultures (Siegrist & Árvai, 2020). Attitudes towards new technologies among the public are important for understanding how it is possible to implement technological advances and recent research has shown strong socio-demographic effects, especially between males and females in how technological innovation is perceived (Borwein et al., 2024). Given the evidence that females are generally more in favour of protectionism than males (Betz et al., 2023) it is, as argued by Borwein et al (2024), possible that females could also influence public policy towards technological adaptation. Knowing that risk perception has cultural differences, it makes the present study even more important for understanding how the public perceives technological advances such as HEBF, which historically has been seen as risky.

A crucial element influencing public perception and acceptance of HEBF is trust. Trust in government and trust in other people have been shown to significantly affect public acceptance of new technologies and environmental policies (Citrin & Muste, 1999; Hetherington, 2005; Putnam, 2000; Rothstein & Stolle, 2008; Uslaner, 2002). Trust can mitigate perceived risks and foster a more positive attitude towards innovative practices (Siegrist et al., 2000). For instance, people with higher trust in government and social institutions are more likely to accept government regulations and policies regarding environmental practices (Rothstein & Stolle, 2008). Similarly, interpersonal trust can enhance community acceptance of new technologies by reducing fear and scepticism (Brehm & Rahn, 1997). Therefore, understanding the levels of trust in both government and other people is important for assessing public attitudes towards HEBF in different cultural contexts.

In sum, the literature highlights several key themes regarding public acceptance of HEBF. Historical and cultural contexts significantly influence attitudes towards HEBF, with societies that have a more recent tradition of nightsoil use, such as Japan, being potentially more open to HEBF compared to those which abandoned night soil long ago, such as England. Psychological and demographic factors, especially sex, play an important role, with females generally more risk-averse and skeptical of new technologies. The perception of risk is culturally dependent, and trust in government and other people is a key element that can mitigate perceived risks and improve acceptance. Our study aims to address these gaps by examining public attitudes in England and Japan, focusing on cultural and sex differences, to better understand how to promote sustainable practices like HEBF in diverse cultural settings.

Case selection and hypotheses

Since most research on HEBF has been conducted in developing countries, we chose Japan and England as our case studies for two main reasons. First, as developed countries, they provide a contrast to the existing literature predominantly focused on developing nations. Second, their distinct historical and cultural backgrounds regarding the use of nightsoil offer sufficient variation to effectively tease out differences in public attitudes. On the one hand, they are highly comparable cases, in terms of being developed countries with strong socio-economic indicators and well-functioning infrastructure. Moreover, the food consumption in both countries is somewhat comparable, in that the average diet in both countries is heavily reliant on meat products (Ritchie et al., 2023). However, where they differ is that Japan, along with other countries in Asia such as China, has a much more recent tradition for the use of night soil, with it being commonly used in agricultural production until the 1950s. This means that many Japanese people will still have memory of the use of nightsoil, either by themselves or by their parents, and it is culturally not so far removed that we should expect it to have left the collective memory of the Japanese population. This strongly contrasts with England, where the development of functioning sewerage systems took off in the mid-19th Century and soon moved human waste to underground, water-borne sewage systems. As such, there is no living memory of nightsoil usage in England. This leads to our first hypothesis:

H1: Japanese people are more accepting of the usage of HEBF than English people.

However, we also expect there to be differences that are consistent across both cases. One difference established by Segrè Cohen et al was an attitudinal difference between males and females towards urine-based fertilisers. Others have established that females in general are more cautious than males when it comes to health questions (Pinkhasov et al., 2010). Some research finds females to be less accepting of technological advances (Borwein et al., 2024). Thus, if there are differences then we should expect females to be less accepting to the use of HEBF than males. We therefore hypothesise:

H2: Female respondents are less accepting of the usage of HEBF than male respondents.

To address the interaction between sex and country, we also propose a third hypothesis:

H3: Japanese males will be the most accepting of HEBF, while English females will be the least accepting.

Methodology

The majority of existing work looking at public attitudes toward the use of HEBF has depended on small, usually unrepresentative, survey samples. For instance, Lamichhane and Babcock surveyed 132 students and staff at the University of Hawaii, and found that 60 per cent of respondents would be willing to pay a fee to install a urine-diverting toilet. But it is difficult to infer from that survey what the numbers would be on a national level. Similarly, Mugivhisa and Olowoyo surveyed 225 students and staff at the University of Limpopo, South Africa, and found that 80 per cent of male respondents and 85 per cent of female respondents would be unwilling to eat spinach grown with human urine. But again, we cannot make inferences from this to the wider population. These surveys can offer us valuable insights, but cannot claim to be nationally representative or give the option of cross-national comparative analysis. In this article we overcome this by using a representative survey that was run both in England and Japan. To achieve representative samples, we employed the survey companies YouGov and Rakuten Insight. Both survey companies are able to deliver nationally representative samples from their panels. They are widely used in the polling industry and have been shown to deliver consistent results. In total, we had 2014 survey responses (508 from the UK and 1506 from Japan).

Survey

Respondents were asked to what extent they agreed or disagreed with the following statements:

1. I am willing to eat food that was grown with the aid of human excretion-based fertiliser;
2. I have health concerns about eating food that was grown with the aid of human excretion-based fertiliser;
3. I am willing to accept human excretion-based fertiliser for growing plants in public parks.

Responses were recorded on a seven-point scale, where 1 means strongly disagree, and 7 means strongly agree.

Control variables

Existing research suggests that one of the key factors determining public acceptance of social change is trust. If we want to test our hypotheses on country and sex, we need to include trust as a control variable. We measure trust using two discrete but interrelated measures: trust in government (Citrin & Muste, 1999; Hetherington, 2005; Nye & King, 1997) and trust in other people (Putnam, 2000; Rothstein & Stolle, 2008; Uslaner, 2002). While there is overlap between these two measures (Brehm & Rahn, 1997), it is important to look at them separately.

For trust in government, respondents were asked ‘Using a scale of 1 to 7 where 1 means “not at all” and 7 means “completely”, how much do

you trust the government?’ For trust in other people, respondents were asked ‘Generally speaking, would you say that most people can be trusted, or that you can’t be too careful in dealing with people?’ Again, respondents were given a seven point scale, where 1 was ‘You cannot be too careful’ and 7 was ‘Most people can be trusted’. This question and scale have long been used as a measure of interpersonal trust (Almond & Verba, 1963; Luby & Hedegard, 1969; Murphy & Tanenhaus, 1967).

There is a notable difference in levels of trust in government between the two countries: it is quite low in both, but appreciably lower in England. The level of trust in other people between England and Japan is especially pronounced, with 31 % of English respondents willing to trust other people, while only 20 % of Japanese respondents are willing to trust other people. These responses are significantly different to the findings of the Dentsu Foundation which found that 56.7 % of UK respondents believe that people trust each other, compared with 53.8 % of Japanese respondents believing that people trust each other (Dentsu Foundation, 2021). However, as argued by Siegrist, Cvetkovich and Roth (2000) social trust could have an impact on risk perception making it a reasonable variable to include as a control for the present topic (Siegrist et al., 2000).

The health of our respondents may impact their willingness to accept HEBF. There are several reasons for this. Individuals in poorer health or with compromised immune systems often have heightened risk perceptions and increased sensitivity to potential contaminants (Curtis & Biran, 2001; Slovic, 1987). This heightened sensitivity can lead to greater precautionary behaviour (Schaller & Park, 2011), making them less likely to accept HEBF. Furthermore, as societal norms and cultural attitudes moved away from the use of human waste in agriculture, we expect that these norms will be particularly influential among health-conscious individuals (Douglas, 1966). We find that Japanese respondents report on average better health than the English respondents.

Finally, education has the potential to be a key explanatory factor, as education is linked with a willingness to try new things. As such, we employ a simple university degree binary variable (Blundell et al., 2000; Chevalier & Lindley, 2009; Dearden et al., 2002; Kondo, 2007; Machin & McNally, 2008; Ohtake & Tomioka, 2004). We find that a larger proportion in Japan has obtained a university degree than in England.

Descriptive statistics

Table 1 presents basic descriptive statistics of respondents to the surveys in Japan and England. In the Table we show that parity between males and females is achieved in Japan, but in England, there is a slight female bias. However, in terms of age, the distribution across the two countries is highly comparable.

Findings

Converted to percentages, the top level responses between the two countries are presented in Fig. 1. As can be seen, there are some notable differences between the two countries. Approximately 31 per cent of respondents in England are willing to eat food which was grown with HEBF; this rises slightly to 37 per cent in Japan. But a more striking difference is in those who have health concerns with HEBF: almost half of English respondents have health concerns, but this is a full 20 points lower in Japan. One of the more unexpected differences manifests in those who are willing for public plants to be grown with HEBF: compared with those willing to eat food grown with HEBF, this rises by about 13 points for the English, but actually falls for the Japanese. More research is needed on why this might be the case.

Breaking the numbers down by sex reveals more interesting dynamics, as can be seen in Fig. 2. While baseline support across the two countries remains different, a clear trend emerges: males are much more willing than females to use HEBF, and have lower levels of health concerns about its use. The unexpected finding in Fig. 1 regarding levels of support for HEBF being lower for public plants in Japan than for on food

Table 1
Descriptive statistics of respondents in Japan and England.

Number of respondents							
EN				JP			
508				1506			
Sex (%)							
EN				JP			
Female		Male		Female		Male	
56.3		43.7		50.13		49.87	
Age							
Mean	Max	Min	SD EN	Mean	Max	Min	SD JP
EN	EN	EN		JP	JP	JP	
49.15	87	18	17.93	50.04	79	18	16.21
Trust Government (mean, 7 point scale)							
EN				JP			
2.74				3.19			
Trust Other People (mean, 7 point scale)							
EN				JP			
3.56				3.15			
Good health (mean, 7 point scale)							
EN				JP			
3.64				3.44			
University degree (%)							
EN				JP			
31.3				47.08			

would also appear to be explained by sex: Fig. 2 shows no difference at all between HEBF for food or public plants among female respondents, but a 14 per cent drop among male respondents.

Regression analysis

For formal statistical modelling, we use the same three questions presented above as our dependent variables to ascertain the extent to which there is difference between respondents in Japan and England, and whether there is a difference between males and females in the attitude towards using human excretion-based fertiliser. For each dependent variable we run two models, one without an interaction term between females and Japan, and one with.¹ The first set of models (1 and 2) use the question “I am willing to eat food that was grown with the aid of human excretion-based fertiliser”, models 3 and 4 use the question “I have health concerns about eating food that was grown with the aid of human excretion-based fertiliser” and models 5 and 6 use “I am willing to accept human excretion-based fertiliser for growing plants in public parks”. Each of the variables are measured on a seven-point scale with 1 being “strongly disagree” and 7 “strongly agree”. For models 3 and 4 using the original scale would mean that a positive value would indicate that the respondent has concerns about HEBF, while a positive value for the other models would indicate support. To overcome this issue we have flipped the scale for models 3 and 4 so that all independent variables can be interpreted in the same direction. We use Ordinary Least Squares regression to test our hypotheses and present our models in Table 2 below.

As can be seen, we find support for our first hypothesis. There is a significant difference between respondents from Japan and those from

England. Japanese respondents are significantly more positive towards the use of HEBF than the English for food production and have significantly fewer health concerns, but when it comes to the use in public parks there is either no significant difference and in fact a negative effect when the interaction effect is considered.

Our second hypotheses dealt with sex differences. This hypothesis is confirmed across all models: females are significantly less willing to eat food produced using HEBF, have more health concerns and do not agree it should be used in public parks.

Given that we have variation on both culture and sex we have also included an interaction term between the two variables in models 2, 4 and 6. Interaction terms are best understood when presented graphically, which we do in Fig. 3 below, which presents visualisations of models 2, 4 and 6. Overall, we see that the relationship between sex and willingness to support use of HEBF is moderated by country. Also, we clearly see that for model 2, whether respondents are willing to eat food produced with HEBF, there is a difference both between countries and between sex. For model 4 (no health concerns), we only see a difference between females and country, but no significant difference within the Japan variation. The same is the case for model 6 (the use of HEBF in public parks) There is no difference in Japan based on sex, but there is difference in England. This is potentially further evidence that the cultural dimension needs to be explored more in detail.

Among the control variables we consistently see a positive view towards the use of HEBF among respondents who have a university qualification. We also see a positive relationship between levels of trust in other people and whether there is support for the use of HEBF. There is additionally a positive effect of age for the health question and the use in public parks question, but not for food production. While there is only a significant negative effect for trust in government for the question on health. Interestingly, the status of the respondents' own health has no significant influence on their attitudes towards HEBF.

Discussion

The results are interesting on several dimensions. The finding on public parks might be a particular cultural difference when it comes to the concept of public parks; Cassegård and Sakai both report that the public space has a different connotation in Japanese society, which could be a potential explanation for this difference (Cassegård, 2011; Sakai, 2011). Another possibility would be that the issue is of less concern to respondents, i.e. it is much less clear cut than is the case for impact on the food that one eats or one's own health.

The finding based on sex is similar to that of Segrè Cohen whose study of urine-based fertiliser found that males were more accepting of its use than females (Segrè Cohen et al., 2020). This finding is also interesting, as the effect sizes are large and highly significant. This is different to findings reported in the literature on risk perception (Siegrist & Árvai, 2020), but it does agree with recent studies on the public acceptance of new technology (Borwein et al., 2024). Specifically, our results show that the gender differences in attitudes towards HEBF are not only statistically significant but also substantively large, which contrasts with other studies where gender differences typically yield very small effect sizes.

One possible explanation for the larger effect sizes in our study could be the cultural context and the specific nature of HEBF as a novel technology. The cultural familiarity and historical context of nightsoil in Japan might amplify the gender differences observed. In England, where there is a greater historical and cultural distancing from nightsoil use, the gender differences might be more pronounced due to heightened risk aversion and perceived disgust among females.

Another perspective to help understand this difference would be to draw on Mary Douglas' engagement with dirt as a matter 'out of place' (Douglas, 1966). This explains why human excrement is seen by some as one of the last taboos (Black & Fawcett, 2008). In other words, the cultural aspects of understanding the role of HEBF should be taken into

¹ It should also be noted that due to the slight female bias reported in Table 1, separate regression models, not reported here, were run on the English data, both with and without weighting. This weighting made no substantive difference to the significance of any of the results.

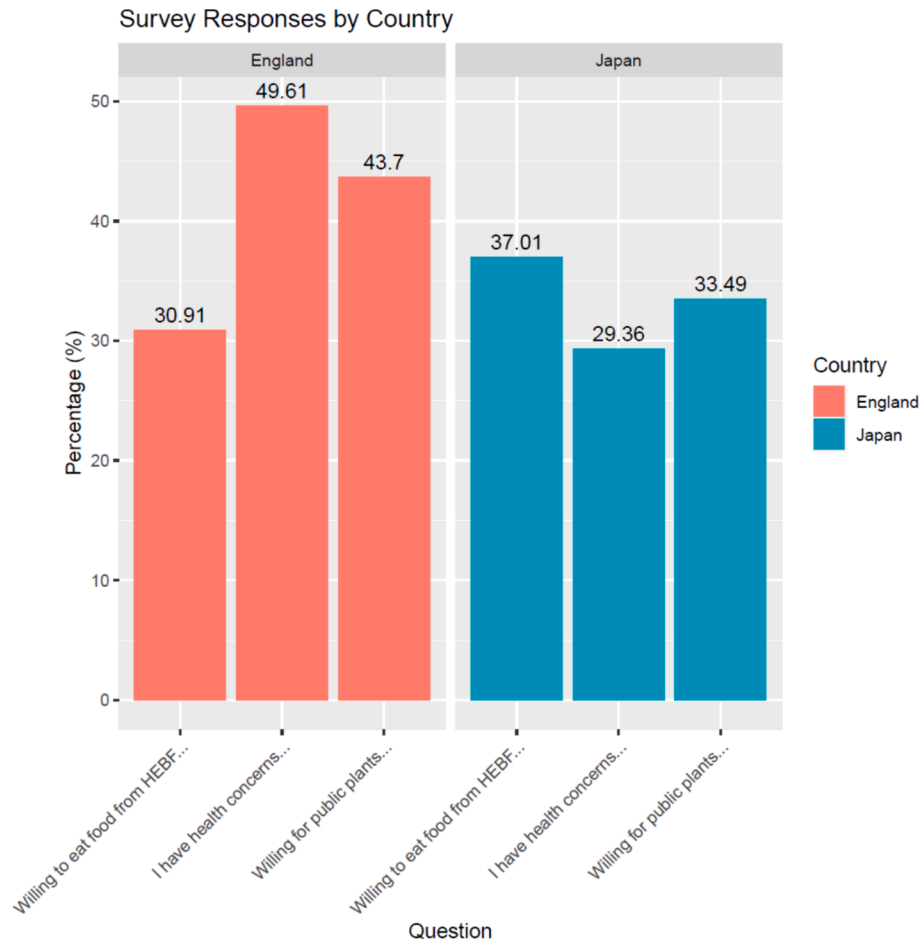


Fig. 1. Percentage of respondents agreeing with the three key statements across England and Japan.

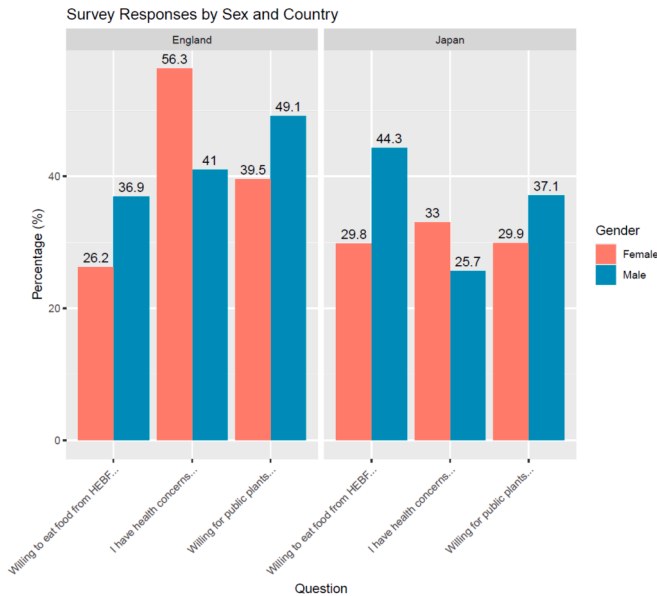


Fig. 2. Percentage of respondents agreeing with the three key statements across England and Japan, broken down by sex.

account; this may explain the difference we see between England and Japan. Furthermore, there may be differences between males and females in how HEBF can be used. This is a serious challenge that has to be

overcome, and while we here show a clear, significant relationship, we also acknowledge that we can only get so far with quantitative evidence on this aspect. To fully understand whether there is a taboo in place, or whether there is a different explanation, we would have to rely on an in-depth qualitative analysis which lies outside of the aims of this article. We also acknowledge that while we are looking directly at sex, i.e. male and female, in this contribution, there might be sex-based impacts which are more likely to be recoverable through a qualitative framework.

Our interaction terms between sex and country (Fig. 3) revealed how the relationship between sex and willingness to support HEBF is moderated by cultural context. Specifically, the moderation effect means that the impact of being male or female on HEBF acceptance is different in England compared to Japan. This difference was anticipated based on cultural and historical contexts. In England, the significant gender gap in willingness to use HEBF can be attributed to higher levels of perceived risk and disgust among females, a finding consistent with existing literature on waste reuse and risk perception (Chfadi et al., 2021; Miller & Buys, 2008). In contrast, Japan's more recent historical use of nightsoil may contribute to a cultural context where both males and females have relatively higher acceptance of HEBF, though males still show greater acceptance than females. These findings support our third hypothesis (H3), which anticipated that Japanese males would be the most accepting of HEBF, while English females would be the least accepting. This is most likely due to the cultural familiarity and more recent historical use of nightsoil in Japan, reducing the perceived risks and disgust. Conversely, English females exhibit the lowest acceptance levels, which can be attributed to the cultural and historical distancing from nightsoil use and higher risk aversion.

The differences between two developed countries, England and

Table 2
Support for HEBF across three different scenarios.

	Dependent variable:					
	Eat food		No health concerns		Use in public parks	
	(1)	(2)	(3)	(4)	(5)	(6)
Female	−0.448*** (0.075)	−0.637*** (0.147)	−0.426*** (0.071)	−0.848*** (0.139)	−0.239*** (0.077)	−0.486*** (0.150)
Japan	0.624*** (0.088)	0.480*** (0.130)	0.535*** (0.083)	0.214* (0.123)	−0.075 (0.089)	−0.263** (0.133)
Age	0.002 (0.002)	0.002 (0.002)	0.006*** (0.002)	0.006*** (0.002)	0.005** (0.002)	0.005** (0.002)
Trust government	0.007 (0.026)	0.009 (0.026)	−0.070*** (0.025)	−0.066*** (0.025)	0.021 (0.027)	0.023 (0.027)
Trust others	0.145*** (0.025)	0.143*** (0.025)	0.105*** (0.023)	0.101*** (0.023)	0.119*** (0.025)	0.117*** (0.025)
Own health	0.001 (0.038)	0.001 (0.038)	0.031 (0.036)	0.031 (0.036)	0.002 (0.039)	0.002 (0.039)
University	0.268*** (0.078)	0.283*** (0.078)	0.173** (0.074)	0.207*** (0.074)	0.252*** (0.079)	0.272*** (0.080)
Female:Japan		0.257 (0.172)		0.572*** (0.162)		0.335* (0.175)
Constant	2.999*** (0.211)	3.104*** (0.223)	3.138*** (0.200)	3.371*** (0.210)	3.390*** (0.216)	3.526*** (0.227)
Observations	1,998	1,998	1,995	1,995	1,989	1,989
R ²	0.074	0.075	0.059	0.065	0.030	0.032
Adjusted R ²	0.071	0.071	0.055	0.061	0.027	0.028

Note: *p < 0.1; ** p < 0.05; *** p < 0.01.

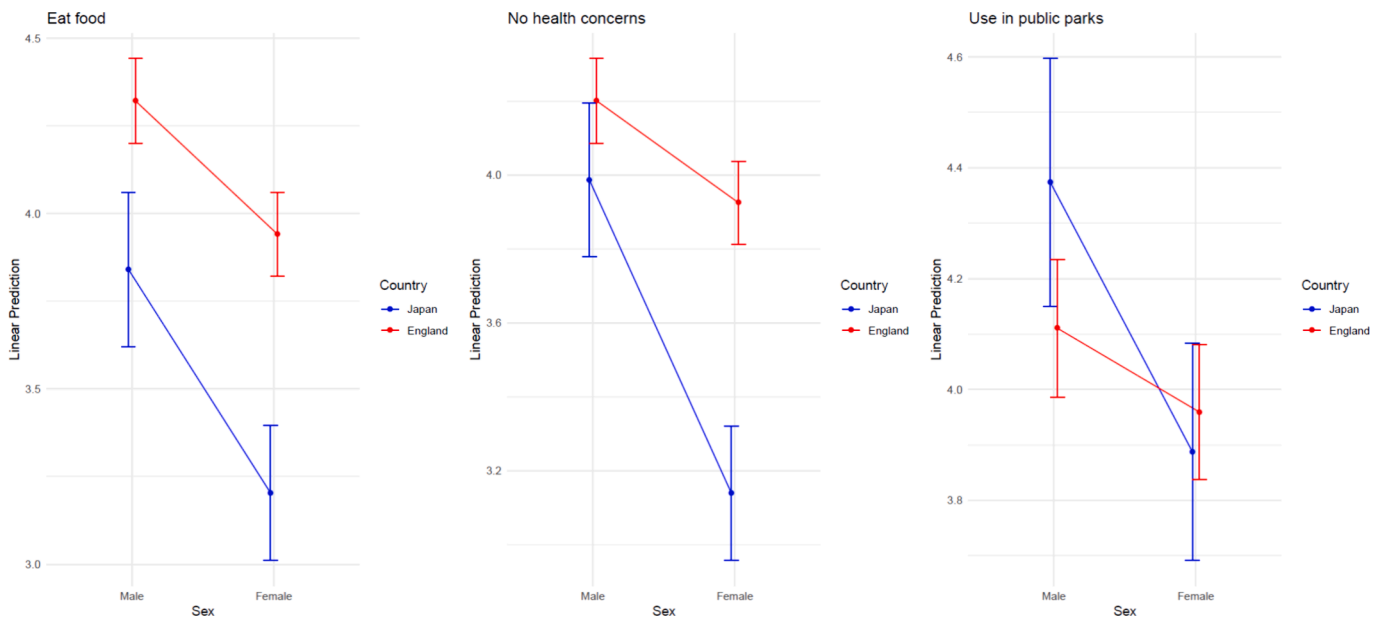


Fig. 3. Interaction plots.

Japan, that we have established to be present is further evidence that Campkin and Cox were right in pointing out the need for further research in this area as a geographical variation is clearly manifested

(Campkin & Cox, 2007). What Jewitt describes as the threat of human waste (the discharge of untreated sewage into water bodies), and also the opportunities presented by human waste (using it as manure) have

not diminished since that work was published (Jewitt, 2011); far from it. Given the climate emergency facing the planet it is important to consider all possible solutions to mitigate these issues and to increase sustainability. Part of this work is to ensure that there is support among the public for any interventions and policies suggested. Thus, our research has shown that there is work to do to convince the public that the use of HEBF in agriculture for food production or for use in the public space is safe and worthwhile.

While educating the public about the benefits and safety of using HEBF is important, it is essential to recognise that education alone may not be sufficient to overcome public resistance. The knowledge deficit model, which assumes that providing more information will lead to acceptance, has been critiqued for its oversimplification of how people perceive risks (Sturgis & Allum, 2004). Effective risk communication requires a more nuanced approach that includes not only disseminating information but also addressing underlying concerns, emotions, and cultural factors that influence risk perception (Kasperson et al., 1988).

Based on our study of England and Japan, we find that the use of HEBF will likely have an easier path to acceptance in some countries compared to others, supported by cultural differences in risk perception (Siegrist & Árvai, 2020). In regions where there is a relatively recent history of nightsoil use, there may be inherent cultural acceptance or less skepticism towards HEBF. But existing studies have predominantly focused on urine-based fertilizers and often use non-representative samples, such as convenience samples (Simha et al., 2018). Our study contributes to broader knowledge on public attitudes towards HEBF in a comparative framework. It also highlights the need for further comparative work to fully understand these attitudes across a more diverse global cross-section.

Therefore, beyond education, strategies such as engaging with communities, understanding local cultural contexts, and involving stakeholders in dialogue are important for fostering the acceptance of HEBF. This multi-faceted approach should be able to help address the complex nature of risk perception and improve public acceptance of innovative agricultural practices.

Another issue that needs to be acknowledged is that in this study we have not made a distinction based on the type of HEBF, instead simply using “human excreta based fertiliser”. It cannot be ruled out that our findings would be different if we had used a more direct question separating out urine-based and faeces-based, although whether there is a conceptually different understanding of these terms is beyond the aim of this article. We also do not directly consider questions such as pharmaceutical residues, which was also found by Lienert and Larsen to speak to the broader issue of risk and risk acceptance among the public (Lienert & Larsen, 2010).

Future research

Our study raises a number of important questions regarding the design of research on this topic and general acceptance towards HEBF. Going forward, more qualitative and quantitative research is required, potentially providing respondents with more details about the type of HEBF, how it is to be collected, and how it will be introduced into the food production process or used in public spaces. However, there is also a balance to strike between overloading the public with too detailed technical information about fertilisation processes and providing enough information to make a considered judgement. This could for instance take the point of departure in qualitative focus groups to get a deeper understanding of why the public is sceptical towards HEBF and to get a stronger understanding of the benefits and risks. Further research could also examine how the industry communicates regarding the use of HEBF. New surveys could test what type of information is most effective in alleviating the concerns of the public.

We also need to consider which other potential variables could be influential for how public attitudes towards this topic are created. A further examination of other individual level factors might influence

opinion are required, and tested on a broader geographical sample.

Conclusion

There are clear differences between respondents in England and Japan towards the use of HEBF. In general, Japanese respondents are significantly more positive than English respondents in terms of willingness to eat food produced using HEBF and Japanese respondents have fewer health concerns, although are less willing than the English to see HEBF used in public parks. We also confirm the differences between males and females found by previous research and report that females are significantly less supportive towards the use of HEBF than males and this is also the case when considering the interaction between geographical location and sex.

Our study is important for understanding the challenges ahead should HEBF be used for food production processes, or used in fertilising public spaces such as parks. The climate challenges facing the earth are significant and require intervention, and if HEBF is among these interventions there is work ahead about educating the public about the safety of HEBF for food production, and in doing so acknowledging the cultural differences and historical experiences with HEBF processes. It is unlikely that HEBF can be successfully introduced unless education and information are provided to the public. We therefore suggest that further research is carried out to fully understand the differences both between countries and cultures and at the individual level.

Funding

This research was funded by the UKRI/ ESRC (grant number ES/W011913/1) and the JSPS (grant number JPJSJRP 20211704).

Ethics

The Ethical Review Committee of Brunel University London approved this research, reference number 35290-LR-Jan/2022-37313-1.

Data availability

Survey data and replication code are available on the Harvard Dataverse, at <https://doi.org/10.7910/DVN/0VNQPP>.

CRediT authorship contribution statement

Steve Pickering: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization, Funding acquisition, Project administration, Data curation, Visualization, Supervision. **Ömer Gökçe:** Writing – original draft, Investigation, Conceptualization. **Davide Hanna:** Writing – original draft, Investigation, Conceptualization. **Markus Knell:** Writing – original draft, Investigation, Conceptualization. **Dayoung Lee:** Writing – original draft, Investigation, Conceptualization. **Melody Scales:** Writing – original draft, Investigation, Conceptualization. **Marwan Zeinalabidin:** Writing – original draft, Investigation, Conceptualization. **Yosuke Sunahara:** Funding acquisition, Conceptualization. **Martin Ejnar Hansen:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Roos van Maanen and the Amsterdam Green Campus for their inspiration behind this research. We would also like to thank Dorothy Yen, Naoko Matsumura, Thomas Scotto, Atsushi Tago, Jason Reifler, Naofumi Fujimura, Han Dorussen, Masahiro Zenkyo and Shun Ikeda for their work on grant capture and survey design. This project is sponsored by the Japan Society for the Promotion of Science (JSPS, grant reference JPJSJRP 20211704) and the UK Research and Innovation's Economic and Social Research Council (UKRI-ESRC, grant reference ES/W011913/1).

References

- Allen, M.E., 2008. *Cleansing the City: Sanitary Geographies in Victorian London*. Ohio University Press.
- Almond, G.A., Verba, S., 1963. *The Civic Culture: Political Attitudes and Democracy in Five Nations*. Sage.
- Beck, S., 2009. Between disgust and trust: State of social science research on the implementation and acceptance of water and wastewater reclamation and re-use (WWT&R). https://www.ufz.de/export/data/2/80139_Beck_State_of_Social_Science_Research_on_WWT_R.pdf.
- Betz, T., Fortunato, D., O'Brien, D.Z., 2023. Do women make more protectionist trade policy? *Am. Polit. Sci. Rev.* 117 (4), 1522–1530. <https://doi.org/10.1017/S0003055422001307>.
- Black, M., Fawcett, B., 2008. *The Last Taboo: Opening the Door on the Global Sanitation Crisis*. Earthscan.
- Blum, D., Feachem, R.G., 1985. Health aspects of nightsoil and sludge use in agriculture and aquaculture: part III - An epidemiological perspective.
- Blundell, R., Dearden, L., Goodman, A., Reed, H., 2000. The returns to higher education in Britain: evidence from a British Cohort. *Econ. J.* 110 (461), F82–F99. <https://doi.org/10.1111/1468-0297.00508>.
- Borowy, I., 2021. Human excreta: hazardous waste or valuable resource? Shifting views of modernity. *J. World Hist.* 32 (3), 517–545. <https://doi.org/10.1353/jwh.2021.0035>.
- Borwein, S., Magistro, B., Loewen, P., Bonikowski, B., Lee-Whiting, B., 2024. The gender gap in attitudes toward workplace technological change. *Soc. Econ. Rev.* <https://doi.org/10.1093/ser/mwae004>.
- Brehm, J., Rahn, W., 1997. Individual-level evidence for the causes and consequences of social capital. *Am. J. Polit. Sci.* 41 (3), 999. <https://doi.org/10.2307/2111684>.
- Campkin, B., Cox, R., 2007. *Dirt: New Geographies of Cleanliness and Contamination* (B. Campkin & R. Cox, Eds.). I. B. Tauris.
- Casagård, C., 2011. Public space in recent Japanese political thought and activism: from the rivers and lakes to Miyashita Park. *Jpn. Stud.* 31 (3), 405–422. <https://doi.org/10.1080/10371397.2011.619172>.
- Chen, W., Bai, Y., Zhang, W., Lyu, S., Jiao, W., 2015. Perceptions of different stakeholders on reclaimed water reuse: the case of Beijing, China. *Sustainability* 7 (7), 9696–9710. <https://doi.org/10.3390/su7079696>.
- Chevalier, A., Lindley, J., 2009. Overeducation and the skills of UK graduates. *J. R. Stat. Soc. Ser. A Stat. Soc.* 172 (2), 307–337. <https://doi.org/10.1111/j.1467-985X.2008.00578.x>.
- Chfadi, T., Gheblawi, M., Thaha, R., 2021. Public acceptance of wastewater reuse: new evidence from factor and regression analyses. *Water* 13 (10), 1391. <https://doi.org/10.3390/w13101391>.
- Citrin, J., Muste, C., 1999. Trust in government. In: Robinson, J.P., Shaver, P.R., Wrightman, L.S. (Eds.), *Measures of Political Attitudes*. Academic Press.
- Curtis, V., Biran, A., 2001. Dirt, disgust, and disease: is hygiene in our genes? *Perspect. Biol. Med.* 44 (1), 17–31.
- Dearden, L., Ferri, J., Meghir, C., 2002. The effect of school quality on educational attainment and wages. *Rev. Econ. Stat.* 84 (1), 1–20. <https://doi.org/10.1162/003465302317331883>.
- Dentsu Foundation, 2021. Quality of Society Index: Attitudes to Society in the UK and Comparison with Japan. <https://qosen.dentsusoken.com/articles/232/>.
- Ditlevsen, K., Andersen, S.S., 2021. The purity of dirt: revisiting Mary Douglas in the light of contemporary consumer interpretations of naturalness, purity and dirt. *Sociology* 55 (1), 179–196. <https://doi.org/10.1177/0038038520934980>.
- Dobraszczyk, P., 2014. *London's Sewers*. Bloomsbury Publishing.
- Dolnicar, S., Schäfer, A.I., 2009. Desalinated versus recycled water: public perceptions and profiles of the accepters. *J. Environ. Manage.* 90 (2), 888–900. <https://doi.org/10.1016/j.jenvman.2008.02.003>.
- Douglas, M., 1966. *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*. Routledge.
- Feachem, R., Bradley, D., Garelick, H., Mara, D., 1985. Sanitation and disease (Health aspects of excreta and wastewater management) World Bank Studies in Water Supply and Sanitation 3. *Water Res.* 19 (1), 131. [https://doi.org/10.1016/0043-1354\(85\)90337-9](https://doi.org/10.1016/0043-1354(85)90337-9).
- Ferguson, D.T., 2014. Nightsoil and the 'Great Divergence': human waste, the urban economy, and economic productivity, 1500–1900. *J. Glob. Hist.* 9 (3), 379–402. <https://doi.org/10.1017/S1740022814000175>.
- Fielding, K.S., Gardner, J., Leviston, Z., Price, J., 2015. Comparing public perceptions of alternative water sources for potable use: the case of rainwater, stormwater, desalinated water, and recycled water. *Water Resour. Manag.* 29 (12), 4501–4518. <https://doi.org/10.1007/s11269-015-1072-1>.
- Gu, Q., Chen, Y., Pody, R., Cheng, R., Zheng, X., Zhang, Z., 2015. Public perception and acceptability toward reclaimed water in Tianjin. *Resour. Conserv. Recycl.* 104, 291–299. <https://doi.org/10.1016/j.resconrec.2015.07.013>.
- Gwara, S., Wale, E., Odindo, A., 2022. Behavioral intentions of rural farmers to recycle human excreta in agriculture. *Sci. Rep.* 12 (1), 5890. <https://doi.org/10.1038/s41598-022-09917-z>.
- Harada, H., 2022. Acceptability of Urine-Diversion Dry Toilets and Resource Values of Excreta in Rural Societies, pp. 209–226. doi: 10.1007/978-981-16-7711-3_12.
- Harder, R., Wielemaker, R., Larsen, T.A., Zeeman, G., Öberg, G., 2019. Recycling nutrients contained in human excreta to agriculture: pathways, processes, and products. *Crit. Rev. Environ. Sci. Technol.* 49 (8), 695–743. <https://doi.org/10.1080/10643389.2018.1558889>.
- Harder, R., Wielemaker, R., Molander, S., Öberg, G., 2020. Reframing human excreta management as part of food and farming systems. *Water Res.* 175, 115601. <https://doi.org/10.1016/j.watres.2020.115601>.
- Hetherington, M.J., 2005. *Why Trust Matters: Declining Political Trust and the Demise of American Liberalism*. Princeton University Press.
- Hurlimann, A., Dolnicar, S., 2016. Public acceptance and perceptions of alternative water sources: a comparative study in nine locations. *Int. J. Water Resour. Dev.* 32 (4), 650–673. <https://doi.org/10.1080/07900627.2016.1143350>.
- Jewitt, S., 2011. Poo guru? Researching the threats and opportunities presented by human waste. *Appl. Geogr.* 31 (2), 761–769. <https://doi.org/10.1016/j.apgeog.2010.08.003>.
- Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X., Ratick, S., 1988. The social amplification of risk: a conceptual framework. *Risk Anal.* 8 (2), 177–187.
- Kawa, N.C., Ding, Y., Kingsbury, J., Goldberg, K., Lipschitz, F., Scherer, M., Bonkiye, F., 2019. Night soil: origins, discontinuities and opportunities for bridging the metabolic rift. *Ethnobiol. Lett.* 10 (1), 40–49. <https://doi.org/10.14237/eb1.01.2019.1351>.
- Khalid, A., 2018. Human excreta: a resource or a taboo? Assessing the socio-cultural barriers, acceptability, and reuse of human excreta as a resource in Kakul Village District Abbottabad, Northwestern Pakistan. *J. water sanit. hyg. dev.* 8 (1), 71–80. <https://doi.org/10.2166/washdev.2017.019>.
- Kondo, A., 2007. Does the first job really matter? State dependency in employment status in Japan. *J. Jpn. Int. Econ.* 21 (3), 379–402. <https://doi.org/10.1016/j.jjie.2006.04.002>.
- Kyriakou, V., Garagounis, I., Vourros, A., Vasileiou, E., Stoukides, M., 2020. An electrochemical Haber-Bosch process. *Joule* 4 (1), 142–158. <https://doi.org/10.1016/j.joule.2019.10.006>.
- Lamichhane, K.M., Babcock, R.W., 2013. Survey of attitudes and perceptions of urine-diverting toilets and human waste recycling in Hawaii. *Sci. Total Environ.* 443, 749–756. <https://doi.org/10.1016/j.scitotenv.2012.11.039>.
- Li, C., Li, Y., 2023. Factors influencing public risk perception of emerging technologies: a meta-analysis. *Sustainability* 15 (5), 3939. <https://doi.org/10.3390/su15053939>.
- Lienert, J., Larsen, T.A., 2010. High acceptance of urine source separation in seven European countries: a review. *Environ. Sci. Tech.* 44 (2), 556–566. <https://doi.org/10.1021/es9028765>.
- Luby, E.D., Hedegard, J., 1969. *A study of civil disorder in Detroit*. William Mary Law Rev. 10 (3), 586–630.
- Machin, S., McNally, S., 2008. The literacy hour. *J. Public Econ.* 92 (5–6), 1441–1462. <https://doi.org/10.1016/j.jpubeco.2007.11.008>.
- Martin, T.M.P., Esculier, F., Levassasseur, F., Houot, S., 2022. Human urine-based fertilizers: a review. *Crit. Rev. Environ. Sci. Technol.* 52 (6), 890–936. <https://doi.org/10.1080/10643389.2020.1838214>.
- Martin, T.M.P., Aubin, J., Gilles, E., Auberger, J., Esculier, F., Levassasseur, F., McConville, J., Houot, S., 2023. Comparative study of environmental impacts related to waste production with human-urine based fertilizers versus mineral fertilizers. *J. Clean. Prod.* 382, 135123. <https://doi.org/10.1016/j.jclepro.2022.135123>.
- Massoud, M.A., Kazarian, A., Alameddine, I., Al-Hindi, M., 2018. Factors influencing the reuse of reclaimed water as a management option to augment water supplies. *Environ. Monit. Assess.* 190 (9), 531. <https://doi.org/10.1007/s10661-018-6905-y>.
- McConville, J.R., Metson, G.S., Persson, H., 2023. Acceptance of human excreta derived fertilizers in Swedish grocery stores. *City Environ. Interact.* 17, 100096. <https://doi.org/10.1016/j.cacint.2022.100096>.
- Michie, S., van Stralen, M.M., West, R., 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement. Sci.* 6 (1), 42. <https://doi.org/10.1186/1748-5908-6-42>.
- Miller, E., Buys, L., 2008. Water-recycling In South-East Queensland, Australia: what do men and women think? *Rural. Soc.* 18 (3), 220–229. <https://doi.org/10.5172/rsj.351.18.3.220>.
- Mugivhisa, L., Olowoyo, J., 2015. An assessment of university students and staff perceptions regarding the use of human urine as a valuable soil nutrient in South Africa. *Afr. Health Sci.* 15 (3), 999. <https://doi.org/10.4314/ahs.v15i3.39>.
- Murphy, W.F., Tanenhaus, J., 1967. Public opinion and the United States Supreme court-mapping of some prerequisites for court legitimization of regime changes. *Law Soc. Rev.* 2 (3), 357–384.
- Nakagawa, K., Amano, H., Persson, M., Berndtsson, R., 2021. Spatiotemporal variation of nitrate concentrations in soil and groundwater of an intensely polluted agricultural area. *Sci. Rep.* 11 (1), 2598. <https://doi.org/10.1038/s41598-021-82188-2>.
- Nye, J.S., King, D.C., 1997. *Why People Don't Trust Government*. Harvard University Press.
- Ohtake, F., Tomioka, J., 2004. Who Supports Redistribution? *Jpn. Econ. Rev.* 55 (4), 333–354.

- Ormerod, K.J., Scott, C.A., 2013. Drinking Wastewater. *Sci. Technol. Hum. Values* 38 (3), 351–373. <https://doi.org/10.1177/0162243912444736>.
- Pinkhasov, R.M., Wong, J., Kashanian, J., Lee, M., Samadi, D.B., Pinkhasov, M.M., Shabsigh, R., 2010. Are men shortchanged on health? Perspective on health care utilization and health risk behavior in men and women in the United States. *Int. J. Clin. Pract.* 64 (4), 475–487. <https://doi.org/10.1111/j.1742-1241.2009.02290.x>.
- Putnam, R.D., 2000. *Bowling Alone: The Collapse and Revival of American Community*. Simon and Schuster.
- Redman, S., Ormerod, K.J., Kelley, S., 2019. Reclaiming Suburbia: differences in local identity and public perceptions of potable water reuse. *Sustainability* 11 (3), 564. <https://doi.org/10.3390/su11030564>.
- Ricart, S., Rico, A., Ribas, A., 2019. Risk-yuck factor nexus in reclaimed wastewater for irrigation: comparing farmers' attitudes and public perception. *Water* 11 (2), 187. <https://doi.org/10.3390/w11020187>.
- Ritchie, H., Rosado, P., Roser, M., 2023. *Diet Composition*. Our World in Data.
- Rothstein, B., Stolle, D., 2008. The state and social capital: an institutional theory of generalized trust. *Comp. Polit.* 40 (4), 441–459. <https://doi.org/10.5129/001041508X12911362383354>.
- Sakai, A., 2011. The hybridization of ideas on public parks: introduction of Western thought and practice into nineteenth-century Japan. *Plan. Perspect.* 26 (3), 347–371. <https://doi.org/10.1080/02665433.2011.575555>.
- Schaller, M., Park, J.H., 2011. The behavioral immune system (and why it matters). *Curr. Dir. Psychol. Sci.* 20 (2), 99–103.
- Schreiber, T., Opperman, S., Hardin, R., Cavicchi, J., Pallmeyer, A., Nace, K., Love, N., 2021. Nested risks and responsibilities: perspectives on fertilizer from human urine in two U.S. regions. *J. Agric. Food Sys. Community Dev.* 1–22. <https://doi.org/10.5304/jafscd.2021.103.016>.
- Segrè Cohen, A., Love, N.G., Árvai, J., 2020. Communicating the risks and benefits of human urine-derived fertilizer. *Sustainability* 12 (23), 9973. <https://doi.org/10.3390/su12239973>.
- Shirai, Y., Leisz, S.J., Kyuma, K., 2023. A short history of the utilization of nightsoil in agriculture. *Sanitation* 7 (2).
- Siegrist, M., Árvai, J., 2020. Risk perception: reflections on 40 years of research. *Risk Anal.* 40 (S1), 2191–2206. <https://doi.org/10.1111/risa.13599>.
- Siegrist, M., Cvetkovich, G., Roth, C., 2000. Salient value similarity, social trust, and risk/benefit perception. *Risk Anal.* 20 (3), 353–362. <https://doi.org/10.1111/0272-4332.203034>.
- Siegrist, M., Bearth, A., Hartmann, C., 2020. Food disgust sensitivity influences the perception of food hazards: results from longitudinal and cross-cultural studies. *Appetite* 153, 104742. <https://doi.org/10.1016/j.appet.2020.104742>.
- Simha, P., Lalander, C., Ramanathan, A., Vijayalakshmi, C., McConville, J.R., Vinnerås, B., Ganesapillai, M., 2018. What do consumers think about recycling human urine as fertiliser? Perceptions and attitudes of a university community in South India. *Water Res.* 143, 527–538. <https://doi.org/10.1016/j.watres.2018.07.006>.
- Slovic, P., 1987. Perception of risk. *Science* 236 (4799), 280–285.
- Sturgis, P., Allum, N., 2004. Science in society: re-evaluating the deficit model of public attitudes. *Public Underst. Sci.* 13 (1), 55–74.
- Sugihara, R., 2020. Reuse of human excreta in developing countries: agricultural fertilization optimization. *Consilience* 22, 58–64.
- Tran-Thi, N., Lowe, R.J., Schurer, J.M., Vu-Van, T., MacDonald, L.E., Pham-Duc, P., 2017. Turning poop into profit: cost-effectiveness and soil transmitted helminth infection risk associated with human excreta reuse in Vietnam. *PLoS Negl. Trop. Dis.* 11 (11), e0006088.
- Uslaner, E.M., 2002. *The Moral Foundations of Trust*. Cambridge University Press.
- Watanabe, C., 2015. Waste, incorporated. *Gastronomica* 15 (4), 6–13. <https://doi.org/10.1525/gfc.2015.15.4.6>.
- Wester, J., Timpano, K.R., Çek, D., Broad, K., 2016. The psychology of recycled water: factors predicting disgust and willingness to use. *Water Resour. Res.* 52 (4), 3212–3226. <https://doi.org/10.1002/2015WR018340>.
- Zhu, Z., Wang, H., Li, A., 2019. On the factors influencing public knowledge and acceptance of reclaimed water from a survey of three cities in northern China. *J. Water Reuse Desalin.* 9 (2), 193–202. <https://doi.org/10.2166/wrd.2018.049>.