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Article

Public Perceptions of Reuse of Faecal Sludge Co-Compost in Bhubaneswar, India

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Abstract: Although faecal sludge (FS) co-compost contains vital nutrients, there are several barriers limiting adoption and reuse of FS co-compost in agriculture. This study in Bhubaneswar found that health risk and bad odour were the two topmost negative perceptions of FS co-compost reuse. The main factors influencing farmers' negative perceptions of FS co-compost were bad odour and fear of infection, whereas socio-cultural/religious beliefs and bad odour were the key factors influencing the negative perceptions of urban households practising kitchen gardening (UHPKG). Fear of infection and bad odour were the key factors influencing fertiliser retailers' negative perceptions, while inadequate information, unavailability, and lack of government policy on FS co-compost reuse were the key factors influencing Farmer Producer Organisations' negative perceptions. The majority of farmers (95%) and UHPKG (72%) were unwilling to consume food crops grown with FS co-compost, mainly because of feelings of disgust, fear of infection, and religious and socio-cultural beliefs.

Keywords: faecal sludge; co-compost; perception



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1. Introduction

Extraction of minerals from human excreta, and their application in agriculture, has become more important today than ever, due to the need to feed the world's growing population. This has contributed to increased demand for soil amendments (e.g., fertilisers) to increase crop yields [1]. This increase in fertiliser demand, coupled with finite mineral reserves, necessitates a need to close nutrient cycles by reintroducing nutrient from wastes into soil [2]. Goals 2, 6 and 12 of the UN Sustainable Development Goals (SDGs)—which underscore promoting sustainable agriculture, ensuring sustainable management of water and sanitation, and sustainable consumption and production—can be supported by linking safely managed sanitation resources with productive agricultural reuse. Safe faecal sludge (FS) treatment, and production of safe nutrient-rich manures, are two effective ways to incentivise support for the SDGs, as nutrients retrieved from FS in agriculture use could help achieve the SDGs and ensure long-term sustainability [3].

FS and its manures contain vital macronutrients (potassium, nitrogen, and phosphorus), micronutrients (copper, iron, zinc, and manganese), and other natural substances, which enhance soil fertility by improving water retention ability, aeration, and infiltration, resulting in a better soil structure that promotes plant development [4]. A study in Sri Lanka revealed that co-compost derived from FS and municipal solid waste could substitute mineral fertilisers [5]. Likewise, a study conducted in Madagascar revealed that fertilisers derived from human excreta, i.e., digestate, co-compost, and vermicompost, resulted in yield comparable with chemical fertiliser [6]. Moreover, FS manures have the added advantage of reducing emissions of greenhouse gas compared to chemical fertilisers [7]. FS is a good source of organic fertiliser but, if used untreated, it can be an easy conduit

for infections like schistosomiasis to spread. According to World Health Organization recommendations, pathogens in fertilisers made from human waste (excreta and urine) can be reduced to safe levels through composting, heating, urea or alkaline add-ons, incineration, or storage [8]. A study conducted in Nigeria showed that co-compost produced from domestic and institutional FS and organic market waste satisfied nutrients and pollutants quality for agricultural reuse [9].

Within a few years of initiation of the Swachh Bharat Mission (Clean India Mission) in India in 2014, there was an upsurge in reliance upon on-site sanitation systems (OSS), and exposure of the shortcomings of off-site sanitation systems. As a result, a national policy on faecal sludge and septage management (FSSM) was introduced in 2017 [10]. In Odisha state in India, OSS were used by 53% of urban households, with just 2% of FS disposed safely after treatment until 2016 [11]. Odisha state was one of the first states to adopt the FSSM policy and commence its implementation. Orissa Water Supply & Sewerage Board (OWSSB), the state's main agency for implementing urban sanitation programs, was given the mandate to lead implementation of the FSSM policy. Under the policy, the state government planned to construct faecal sludge treatment plants (FSTPs) in major cities of the state to ensure all FS collected from OSS was safely treated before disposal or reuse. As of 2019, the state had 11 operational FSTPs [12], serving over 39% of Odisha's urban population, and many FSTPs at different stages of construction. Bhubaneswar, Odisha's state capital, has two FSTPs in operation, each with an installed capacity of 75 m³/day. The biosolids (dried sludge) produced at FSTPs are only used for landscaping [10] because the state government considers it unsafe for reuse in agriculture. Most biosolids produced are left unused at FSTPs, and therefore keep accumulating. Following the introduction of Odisha organic farming policy in 2018, the interest of stakeholders—like farmers, and households practising kitchen gardening, as well as producers—in organic farming is increasing. Some organisations operating in Bhubaneswar, who are aware of the fertiliser value of dry sludge produced at FSTPs, are exploring partnership opportunities with the Odisha state government for its utilization to produce co-compost. Co-composting is regulated aerobic decomposition of organic matter with two or more feedstocks to produce stabilised products. It presents an opportunity that could mark the beginning of a new era for sanitation and waste management in communities, by harnessing the nutrient-rich potential of human waste [13] to meet agricultural, sanitation, and waste-management needs [14]. In Ghana, FS has been co-composted with food waste from markets to produce "Fortifier", which has been approved by the Ministry of Food and Agriculture for agricultural reuse [15]. However, one major concern of organisations interested in its production and marketing is public acceptability of reuse for food crop production using human waste/FS.

Health concerns, especially fear of getting infected with pathogens, are said to be one of the barriers that limit adoption and reuse of FS products in agriculture. A study conducted in Ghana, that sought to investigate perceptions and attitudes of a peri-urban farming community about sterilised human waste and its utilisation, found that most (97%) respondents believed that FS should never be handled because it posed a high health risk [16]. Furthermore, more than half of the respondents were hesitant to use FS product to fertilise their crops, with approximately 40% citing health concerns as the primary reason. The findings are similar to a study carried out in South India, which found that more than 60% of respondents perceived urine reuse as a fertiliser to be harmful to health [17]. However, in Ghana, health risk was not the key driver for the negative perception of FS co-compost, but rather the perception that FS was complete waste that should not be re-used [18]. In Vellore, India, while health risk was acknowledged as a barrier, it was not the primary determinant that discouraged farmers from using FS fertilisers, but rather the fear of being mocked, and doubt about the market behaviour of consumers [19].

Other barriers, found in studies, to reuse of FS products, included unpleasant odour, and socio-cultural and religious beliefs. A study in South Africa found that farmers considered organic manure from human waste as undesirable due to its unpleasant odour [20]. In

Vellore, India, however, unpleasant odour was not a big worry for farmers, but rather the anxiety of being mocked by others [19]. Studies in Vietnam found that composted FS was odourless and dry, and was assumed to be decomposed and clean for reuse in agriculture, so that people did not see its reuse as dangerous [21]. In Madagascar, the majority of farmers perceived texture and appearance to be important for re-using fertilisers derived from human excreta, and were accepting [6]. Concerning socio-cultural and religious beliefs, a study conducted in Ghana discovered that people's perception of FS as complete waste that should not be re-used was the main motive behind the farmers' negative mindset toward FS co-compost, rather than the health risk [18]. However, this finding contrasts with that of Cofie, who showed that while farmers see FS as an agricultural resource, the perception of health risks associated with its reuse is the most important factor preventing them from using it [22].

Understanding people's perceptions of FS and its products, as well as factors influencing those perceptions, is crucial for its acceptance, adoption, and reuse in agriculture. Against this backdrop, the study sought to ascertain people's perceptions towards FS co-compost, and how that information could be used by interested stakeholders to mitigate negative perceptions of it and promote its use. The specific objectives of the study were to: (1) investigate people's perceptions of FS co-compost; (2) identify factors influencing negative perceptions; and (3) explore people's willingness to consume food crops produced using FS co-compost.

2. Materials and Methods

The study was carried out in three administrative zones of Bhubaneswar: the North; South-West; South-East zones and their surrounding peri-urban areas in Odisha, India (Figure 1). Bhubaneswar has 843,402 inhabitants (197,661 households) in 67 wards and 2386 farmers, comprising 1954 men and 432 women [23]. It has a literacy rate of 82.78%, with 85.42% of males and 79.81% of females.



Figure 1. Map of India with zones of Bhubaneswar Municipal Corporation (Source: <https://office.incometaxindia.gov.in/bhubaneswar/Pages/default.aspx> (accessed on 18 March 2022) and <https://www.bmc.gov.in/bmc/zones-wards> (accessed on 18 March 2022)).

The study used a pragmatic mixed-methods research approach, as an illustrative case study of public perception of FS co-compost reuse in agriculture. The study target population included farmers, UHPKG, fertiliser retailers, farmer producer organisations (FPOs) operating in Bhubaneswar and surrounding peri-urban areas, and the Odisha state

government. The sample sizes of 96 farmers and 104 UHPKG were determined using the Yamane formula [24] with a confidence level of 90% and a 10% margin of error:

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

where, n = the required sample size, N = the population size (farmers and UPHKG), and e = margin of error or allowable sampling error.

The study employed cluster random sampling to select farmers, and UHPKG and purposive sampling to pick 15 fertiliser retailers, two FPOs, and one representative of the Odisha state government. A survey was administered to assess the insights of farmers and UHPKG on the reuse of FS co-compost. Thirty-two farmers were selected at random from each of the three administrative zones, while for UHPKG, 35 were chosen from the South-East and South-West zones and 34 from the North zone. The survey questionnaires were divided into four major sections: socioeconomic characteristics; agricultural practices; use of chemical and organic fertilisers; and awareness and perceptions of farmers and UHPKG on the reuse of FS co-compost. Key Informant Interviews (KII) using semi-structured questionnaires were employed to examine the perceptions of fertiliser retailers towards FS co-compost in relation to chemical fertiliser, FPOs' perception of FS co-compost in relation to compost, and the Odisha state government's insight into FS co-compost reuse in agriculture. Both structured and semi-structured questionnaires were designed and deployed in the field, using KoBo Collect v2021.3.4 (an open-source Android-based application to collect data through KoBo toolbox), and were administered. In addition, focus group discussions (FGDs), one each, were conducted with a selected eight farmers and eight UHPKG that were not included in the survey, to gain in-depth perspective on perceptions of FS co-compost reuse in agriculture, factors influencing perceptions, and measures that could be taken to address them. The findings of the FGDs were triangulated with data collected from the surveys with the farmers and UHPKG, which mutually supported and enhanced the validity and credibility of the findings.

Quantitative data were analysed using Microsoft Excel 2019, while qualitative data were analysed using Quirkos software v2.4. Descriptive statistics such as frequency distribution, percentages, and means were employed. Cross tabulation was also done to examine the effect of gender, education and age on the awareness and perception of farmers and UHPKG.

The limitations of the study were that "public" perception was limited to five stakeholders in Bhubaneswar, and that the study was conducted observing COVID restrictions.

3. Results

Socio-demographic characteristics of farmers and UHPKG are presented in Table 1. 91% of farmers and 62% of UHPKG were male, and the majority (45%) of farmers were aged 41–50, whereas the majority of UPHKG were 31–40 years old (50%). Nearly all farmers and UHPKG followed the Hindu religion, and were literate (95% for farmers and 100% for UHPKG).

Table 1. Farmers and UHPKG demographic characteristics.

Variable	Farmers		UHPKG	
	Respondents (N = 96)	Percentage (%)	Respondents (N = 104)	Percentage (%)
Gender (respondents' sex)				
Male	87	91	64	62
Female	9	9	40	38
Age (years)				
20–30	4	4	32	31
31–40	27	28	52	50
41–50	43	45	12	11
>50	22	23	8	8

Table 1. Cont.

Variable	Farmers		UHPKG	
	Respondents (N = 96)	Percentage (%)	Respondents (N = 104)	Percentage (%)
Religious affiliation				
Hinduism	95	99	94	90
Islam	1	1	10	10
Level of education				
Tertiary	2	2	20	19
Senior High School	20	21	51	49
Junior High School	41	43	25	24
Basic Primary	28	29	5	5
Vocational School	0	0	3	3
No education	5	5	0	0

3.1. People's Perceptions of FS Co-Compost

The study investigated both positive and negative perceptions held by farmers, UHPKG, fertiliser retailers and FPOs, of FS co-compost. The survey found that 'Easy to use' was the dominant positive perception of FS co-compost expressed by more than 70% of farmers, whereas 'Socio-culturally acceptable' was the dominant positive perception that was revealed by UHPKG (Figure 2).

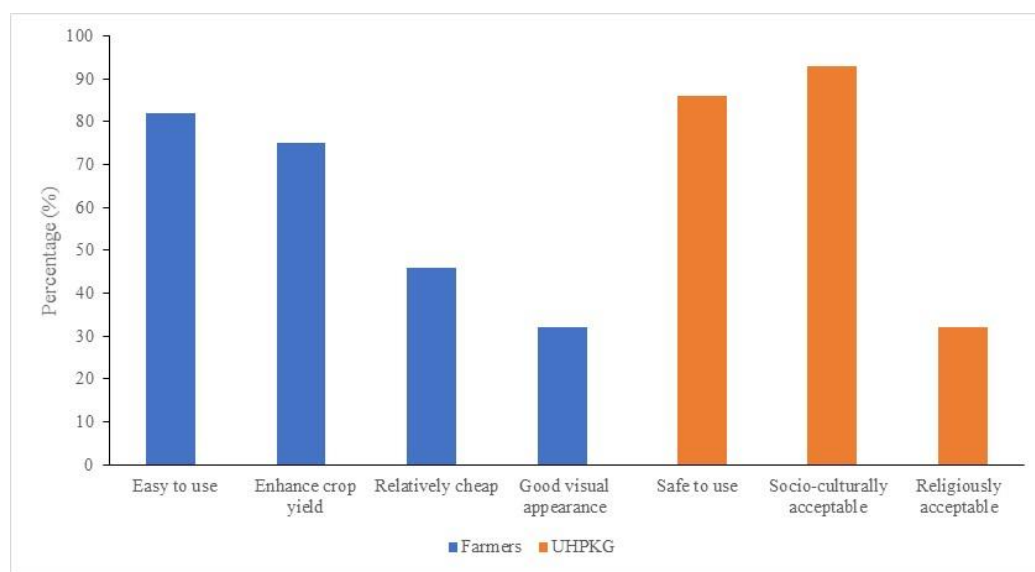


Figure 2. Positive perceptions of FS co-compost by farmers and UHPKG.

The survey also found that bad odour associated with FS co-compost was the dominant negative perception held by 75% of farmers, whereas health risk (risk of infection) was the dominant negative perception by UHPKG (Figure 3).

Fertiliser retailers sell both chemical and organic fertilisers, such as vermicompost; however, the study found that FS co-compost was not available in any retailer's shop: they perceived it to have no market demand, to be less profitable, and to be unreliable. Health risk and unpleasant odour were found to be the dominant perceived negative attributes of FS co-compost; however, nearly 70% of the retailers perceived FS co-compost reuse to be acceptable.

FPOs perceived FS co-compost to be a better option than traditional compost made from either plants or animal waste, but lacked knowledge about its quality, yield potential and safety. They perceived that their members would use FS co-compost when it became available on the market, although they felt that there might be some stigma for early adopters, which would gradually fade away if there was a strong awareness campaign.

They perceived FS co-compost reuse in agriculture to be acceptable, and were willing to use it if it was safe to use, readily available, and accessible, and if it increased crop yield.

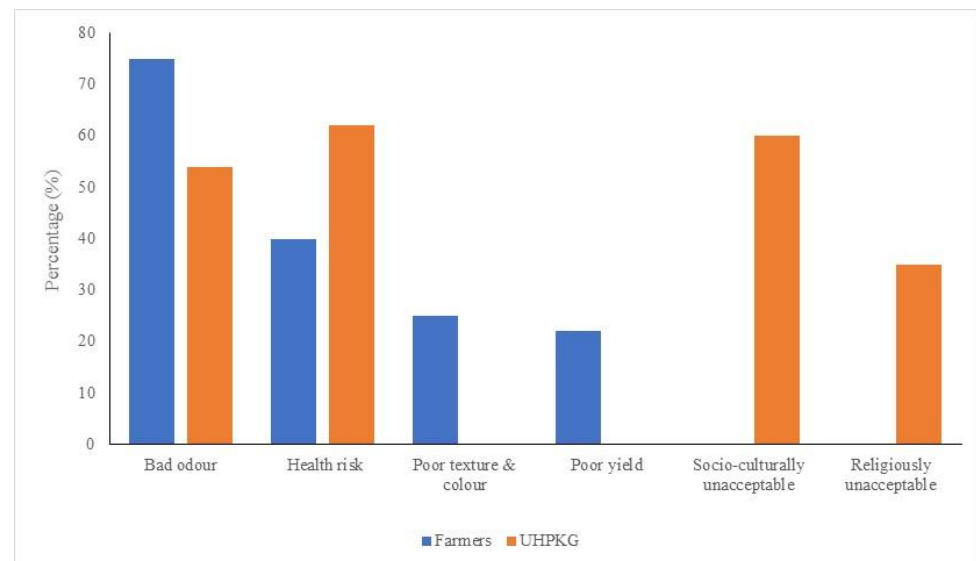


Figure 3. Negative perceptions of FS co-compost held by farmers and UHPKG.

3.2. Factors Influencing Negative Perceptions of FS Co-Compost

The survey found that bad odour and fear of infection were the major factors influencing negative perceptions held by farmers, whereas socio-cultural and religious beliefs and fear of infection were found to be the dominant factors influencing negative perceptions held by UHPKG (Figure 4). Similar findings were obtained from the FGDs with farmers and UHPKG, and it was revealed that they preferred co-compost made from animal and plant waste over that of FS because of the latter's potential health risk.

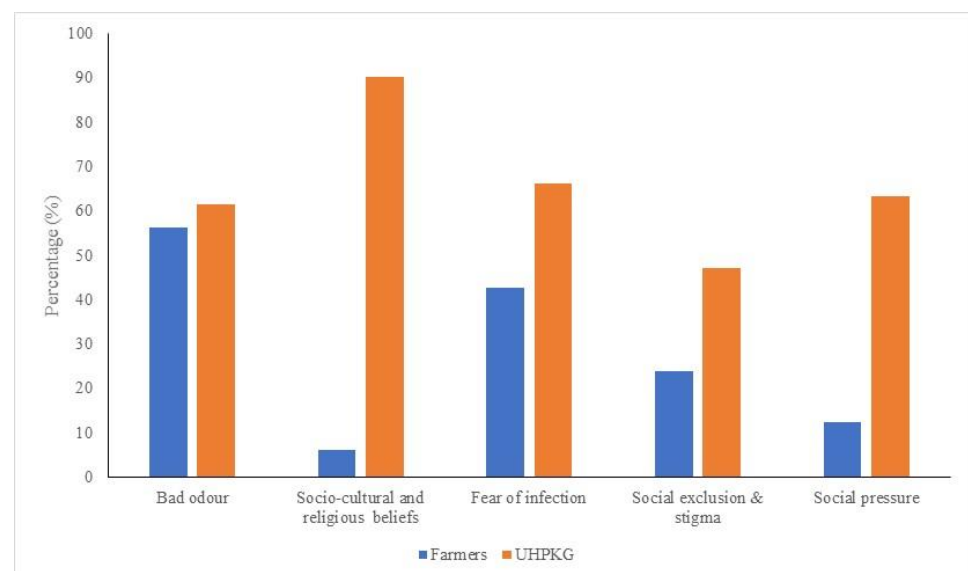


Figure 4. Factors influencing negative perceptions of FS co-compost held by farmers and UHPKG.

Fertiliser retailers perceived fear of infection, bad odour, poor packaging, bulkiness to transport, low demand, and lack of access as factors influencing negative perceptions. FPOs perceived inadequate information, unavailability of FS co-compost, lack of government policy, and lack of a promotion of its reuse in agriculture, as factors influencing negative perceptions of FS co-compost.

3.3. Willingness to Consume, and Perceptions in Regard to Consumption of, Food Crops Produced Using FS Co-Compost

The study found that only 5% of farmers and 28% of UHPKG were willing to eat all food crops produced using FS co-compost. Two major positive perceptions that influenced those farmers' willingness to eat all food crops fertilised with FS co-compost were that it was organic and chemical free. For UHPKG, two dominant positive perceptions were that the food tasted good and was safe to eat (Figure 5).

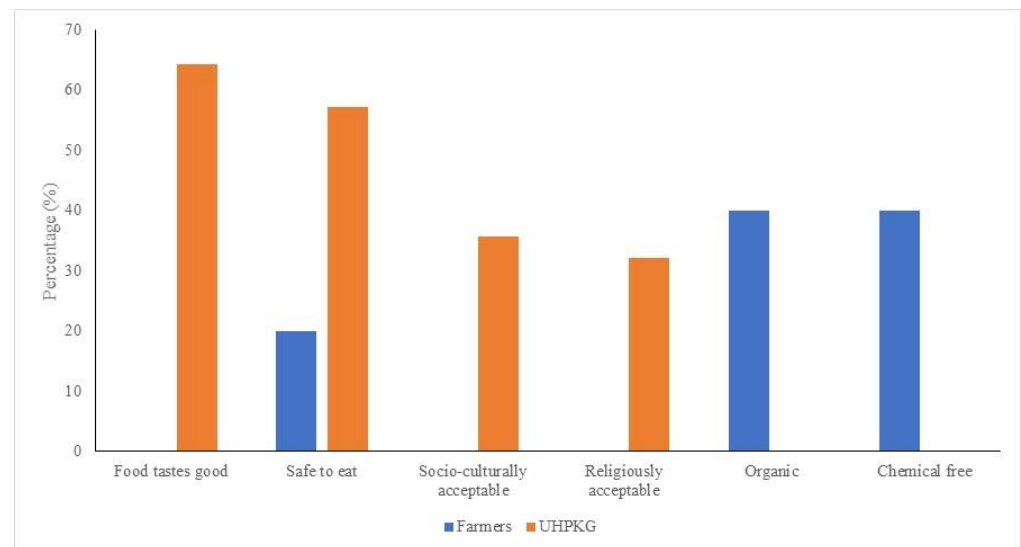


Figure 5. Positive perceptions of FS co-compost that made farmers and UHPKG willing to eat all food crops fertilised with it.

The survey also revealed negative perceptions that influenced the 95% of farmers and the 72% of UHPKG who were not willing to eat any food crops fertilised with FS co-compost. Two dominant negative perceptions for the farmers were (i) a feeling of disgust and (ii) fear of infection; whereas for UHPKG, they were (i) religious beliefs and (ii) a feeling of disgust (Figure 6). All farmers and more than 60% of UHPKG that participated in the FGDs were unwilling to eat any food crops grown with FS co-compost that were not cooked before consumption, due to fear of infection.

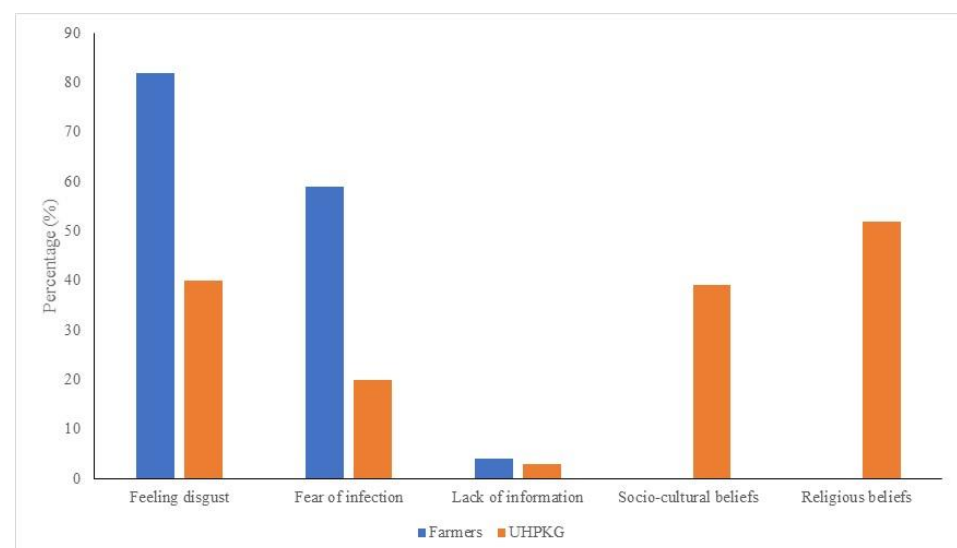


Figure 6. Negative perceptions of FS co-compost that made farmers and UHPKG unwilling to eat any food crops fertilised with it.

The results also showed that more than 70% of farmers were unwilling to disclose to their customers their usage of FS co-compost to fertilise food crops. The main reason was that they felt their customers perceived its usage as bad. However, farmers who were willing to disclose their usage of FS co-compost to their customers, stated that their reasons for so doing were that FS co-compost was an organic manure, and that food crops grown with FS co-compost were chemical-free and were safe (Table 2); similar findings were obtained from the FGD.

Table 2. Farmers' willingness to disclose their usage of FS co-compost to customers, and the reasons.

	Respondents (N = 96)	Respondents (%)
Disclose usage of FS co-compost to customer		
Yes, will disclose	28	29
No, will not disclose	68	71
Reasons for willingness to disclose		
It is chemical free	12	43
It is organic manure	12	43
It is a safe product	4	14
Reasons for unwillingness to disclose		
Perceived as bad practice	28	41
It is associated with health risk	24	35
Rejection of food crop	16	23

4. Discussion

4.1. People's Perceptions of FS Co-Compost

Awareness of FS co-compost was higher (78%) among UHPKG than among farmers (35%). This could be due to access to information, as farmers were sampled from Bhubaneswar's peri-urban areas, while UHPKG were all situated within Bhubaneswar city. Other factors that could have accounted for the difference in awareness are gender and age. In-depth analysis of the socio-demographic data of the two stakeholders showed that female respondents were more aware of FS co-compost than male respondents. This may be due to their greater involvement in social groups and associations compared to males, so that they had more possibilities of getting information than did the males. Participants under the age of 30 were more aware of FS co-compost than those over 30 years of age. This is because people under 30 years of age are more exposed to information technology, and are active on social media, where they can access or receive information on new fertilisers or manures. The low awareness of FS co-compost among farmers corresponded to the findings of three related previous studies, which found that a significant proportion of respondents were not aware of the fertiliser value of FS [18,20,25].

Due to low awareness about FS co-compost, the majority of the farmers (95%) and UHPKG (78%) could not perceive a clear difference between FS manure and FS co-compost. This may have contributed significantly to negative perceptions of FS co-compost, such as bad odour, health risk, and socio-cultural unacceptability, among others. The findings of this study, in regard to bad odour and health risk, are consistent with the findings of a similar study conducted in Ga-Rankuwa, South Africa, which found that bad odour and fear of infection were among the reasons why farmers did not use organic manures [20]. Our findings are also consistent with the results of similar studies conducted in Ghana [16] and in Pakistan [26]. However, our study's finding, that bad odour was the most dominant negative perception held by the majority of farmers about FS co-compost, differs from the findings of a related study conducted in Vellore, India, which found that farmers' most dominant perception was that of a perceived social stigma associated with FS co-compost reuse [19]. This variance in findings could be due to the fact that nearly all the farmers in

Bhubaneswar included in the survey were not using FS or its products as fertiliser in crop production, whereas in Vellore, FS and its products were used by the farmers.

The study revealed that farmers and UHPKG holding positive perceptions of FS co-compost had either used it previously or knew someone who used it. As such, their experience of using it before, or their awareness of others using it without any negative effects or consequences, may have influenced and changed any negative perceptions of FS co-compost which they may have had previously. This suggests that if people become more aware of FS co-compost and try it out, the perception they hold about it will likely turn positive.

The study's findings revealed that there was no market demand for FS co-compost, and that retailers perceiving it as less profitable concurred with the results of a related study by Heinonen-Tanski and van Wijk-Sijbesma, which found that the reuse and market profitability of manures made from FS was still low [27]. Lack of market demand for FS co-compost may have been associated with the fact that FS co-compost was not easily available in Bhubaneswar, and that its production and usage was not promoted by the Odisha state government due to lack of policy to regulate its production and reuse in agriculture. For retailers, making profit was of higher importance than safety, and the study revealed that about 70% of retailers who found FS co-compost reuse acceptable, would sell FS co-compost if there was demand. The perception of FPOs that FS co-compost was better than traditional compost made from either plant or animal waste should be encouraging to stakeholders interested in its production and promotion in Odisha state. This is because both FPOs at the time did not have much knowledge about FS co-compost, nor had they seen or used it.

4.2. Factors Influencing Negative Perceptions of FS Co-Compost

The study's findings on factors influencing negative perception indicated that 'socio-cultural and religious beliefs' was topmost for farmers, whereas 'bad odour' was topmost for UHPKG. The study found that more women had negative perceptions based on socio-cultural and religious beliefs than men, which may be associated with the fact that women are generally more conscious of and obedient to socio-cultural and religious beliefs than men. Farmers and UHPKG respondents under 30 years of age believed more in the existence of socio-cultural and religious beliefs that accounted for their negative perceptions than did those over 30 years of age. One possible explanation is that, about three decades ago, when chemical fertilisers were not readily available, some farmers or producers used human excreta to fertilise their farmlands. Therefore, those over 30 years of age who may have witnessed such practices, socio-cultural and religious beliefs, may not have been negatively influenced in their perception of FS co-compost reuse in agriculture. The study also showed that belief in the existence of, and the negative influence of, socio-cultural and religious beliefs on the perceptions of farmers or UHPKG decreased with an increase in level of education. This is probably because, as level of education increased, farmers or UHPKG had exposure to more information about various manures as well as a better understanding of socio-cultural and religious beliefs. The study found that one socio-cultural and religious belief was that FS carries or invites evil spirits and therefore should not be handled or reused. A similar finding was observed in a study in Uganda, which found that women did not want to use human waste (urine) because it was associated with evil and was also used for witchcraft and magic to bring bad luck to people [28]. Another finding of our study was the belief that FS is complete waste, or dirt, that should not be reused, which was in line with the findings of a related study in Ghana, which found that respondents did not consider FS to be a good source of fertiliser but rather as complete waste that should not be reused [18]. This belief of farmers and UHPKG may be due to lack of awareness of, or limited awareness of, the nutrient value of FS co-compost.

The other main factors influencing negative perceptions, such as bad odour and fear of getting infected with pathogens, correspond with the results of a related study in Uganda that found bad smell, fear of getting infected, social exclusion, and lack of awareness to be

potential barriers to the reuse of fertiliser made from human waste [28]. Other studies in Ghana [16], in South Africa [29], and in India [30] also found health risks, bad smell, and social exclusion to be barriers to the reuse of FS manures. Moreover, belief regarding social exclusion and stigmatisation of users of FS co-compost or products is consistent with the findings of related studies conducted in India [19], which found that some farmers were reluctant to use fertilisers made from human waste for fear of being ridiculed and socially excluded.

Due to the unavailability of, or limited information about, a given product, people created their own positive and negative perceptions about it. In the case of FS co-compost, the existence of alternatives like chemical fertilisers, for which the government had policies in place for their application and promotion, may have created an impression in FPOs minds that FS co-compost was not as good as chemical fertiliser, thus resulting in negative perceptions of FS co-compost.

4.3. Willingness to Consume, and Perceptions in Regard to Consumption of, Food Crops Produced Using FS Co-Compost

Farmers and UHPKG who were prepared to eat all food crops fertilised with FS co-compost, revealed that they had either consumed it before or knew someone who had eaten it without any negative repercussions. Farmers disclosed that food crops fertilised with FS co-compost tasted good and were safe to eat, while UHPKG stated that the main drivers towards consuming food crops fertilised with FS co-compost, were that it was organic and chemical-free. The disparities between farmers' drivers and those of UHPKG might be attributed to differences in their knowledge of and use of FS co-compost as well as geographical settings, i.e., where they lived.

The 95% of farmers and 72% of UHPKG who were unwilling to eat any food crops fertilised with FS co-compost, revealed that they had never seen or used FS co-compost before, and were completely unaware of it. Farmers revealed that they thought it was disgusting, and that they were afraid of becoming infected with pathogens, whereas the major barriers for UHPKG were socio-cultural and religious beliefs, as well as a sense of disgust and health risk. These perceptions (barriers) may have been influenced by low awareness, how they visualised FS co-compost, and the socio-cultural and religious contexts in which they lived. However, it should be noted that even if all the negative perceptions (barriers) of farmers and UHPKG were entirely resolved, some of them might still be hesitant to eat any food crops fertilised with FS co-compost. This is due to the fact that certain people would never eat food crops fertilised with FS, regardless of how they were handled. Some individuals, for example, refused to consume food crops grown on waste grounds because they believed such areas were filthy. Therefore, the unwillingness of some farmers and UHPKG to consume all food crops fertilised with FS co-compost might be linked to their normative ideas as a result of subjective norms or perceived societal pressure, as espoused in the theory of planned behaviour [31]. The findings of this study are comparable with the findings of a case study done in the Philippines [25], in which more than 75% of the participants were hesitant to eat or purchase items grown with FS manure owing to a perceived health risk. The findings are also consistent with similar studies in South Africa, where more than 80% of the participants were unwilling to eat maize and spinach fertilised with human urine due to a perceived health risk [32], and in Ghana, where 28% of respondents were unwilling to eat crops fertilised with FS due to a perceived health risk [16].

The study found that most farmers were unwilling to disclose to their customers their use of FS co-compost. This finding was similar to a study in Madagascar, where the majority of farmers would not disclose to their customers because they had a fear of stigma associated with human faeces [6]. Limited awareness about FS co-compost, unavailability, and certification of FS co-compost that is pathogen free and nutrient-rich, were some of the reasons for farmers' unwillingness to disclose to customers. Farmers were willing to disclose and promote FS co-compost but needed assurance of some improvements, such as

making its texture and colour more similar to cow dung manure, making it odourless, and improving packaging and transportability.

5. Conclusions

The major positive perceptions of FS co-compost held by the majority of the farmers were that it was easy to use, and enhanced crop yield, whereas for the majority of UHPKG, it was safe to use, and socio-culturally acceptable. The majority of fertiliser retailers and FPOs perceived FS co-compost reuse for crop production to be an acceptable practice, with the FPOs willing to use and promote it if it was safe, readily available, accessible, and increased crop yield.

The study concluded that fear of pathogen infection (health risk) and bad odour were the two topmost negative perceptions of FS co-compost reuse in agriculture. The main factors influencing farmers' negative perceptions of FS co-compost were bad odour and fear of infection, whereas socio-cultural/religious beliefs and bad odour were the key factors influencing the negative perceptions of UHPKG. Inadequate information, unavailability, and lack of government policy on FS co-compost reuse were the factors influencing FPOs' negative perceptions, while fear of infection and unpleasant odour were the factors influencing retailers' negative perceptions. The majority of farmers and UHPKG were unwilling to consume any food crops grown with FS co-compost, mainly because of feelings of disgust, fear of infection, and religious and socio-cultural beliefs. Likewise, more than 70% of farmers and UHPKG were hesitant to disclose their use of FS co-compost to customers if asked, because they thought that customers perceived its use as bad practice, associating it with health risk, and they feared that customers would reject food crops fertilised with it.

It was encouraging that people had positive perceptions of FS co-compost because they were aware of it and had used it previously or knew someone who had used it without any negative consequences; this could change the negative perceptions of the majority of people. It has been reported that providing training, conducting behaviour-change campaigns/communication, participatory demonstration trials, and promotion could support the enhancement of knowledge, awareness, and social acceptance of FS co-compost, and contribute to mitigating negative perceptions of it [3,33]. In a study conducted in Malawi, it was found that seeing a sample and hearing about FS co-compost had a strong association with the perception and acceptance of it, with 96% willing to buy maize grown with FS co-compost compared to 30% who hadn't seen or heard of FS co-compost [34]. Our study recommends designing and carrying out a comprehensive and intensive public education campaign (drama, radio, community sensitisation, and field demonstrations) on FS co-compost reuse in agriculture, focusing on its safety for both users and consumers, its odourlessness, and its yield potential, amongst other factors, as well as developing a policy.

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References

- Harder, R.; Wielemaker, R.; Larsen, T.A.; Zeeman, G.; Öberg, G. Recycling nutrients contained in human excreta to agriculture: Pathways, processes, and products. *Crit. Rev. Environ. Sci. Technol.* **2019**, *49*, 695–743. [CrossRef]
- Cordell, D.; Drangert, J.-O.; White, S. The story of phosphorus: Global food security and food for thought. *Glob. Environ. Change* **2009**, *19*, 292–305. [CrossRef]
- Gwara, S.; Wale, E.; Odindo, A.; Buckley, C. Attitudes and Perceptions on the Agricultural Use of Human Excreta and Human Excreta Derived Materials: A Scoping Review. *Agriculture* **2021**, *11*, 153. [CrossRef]
- Guzha, E.; Nhapi, I.; Rockström, J. An assessment of the effect of human faeces and urine on maize production and water productivity. *Phys. Chem. Earth* **2005**, *30*, 840–845. [CrossRef]
- Grau, F.; Drechsel, N.; Haering, V.; Trautz, D.; Weerakkody, W.J.S.K.; Drechsel, P.; Marschner, B.; Dissanayake, D.M.P.S.; Sinnathamby, V. Impact of Fecal Sludge and Municipal Solid Waste Co-Compost on Crop Growth of *Raphanus Sativus* L. and *Capsicum Anuum* L. under Stress Conditions. *Resources* **2017**, *6*, 26. [CrossRef]
- Moya, B.; Parker, A.; Sakrabani, R.; Mesa, B. Evaluating the Efficacy of Fertilisers Derived from Human Excreta in Agriculture and Their Perception in Antananarivo, Madagascar. *Waste Biomass Valorization* **2019**, *10*, 941–952. [CrossRef]
- Rahman, N.; Bruun, T.B.; Giller, K.E.; Magid, J.; Van De Ven, G.; De Neergaard, A. Soil greenhouse gas emissions from inorganic fertilizers and recycled oil palm waste products from Indonesian oil palm plantations. *GCB Bioenergy* **2019**, *11*, 1056–1074. [CrossRef]
- World Health Organization. *WHO Guidelines for the Safe Use of Wastewater Excreta and Greywater*; World Health Organization: Geneva, Switzerland, 2006; Volume 1.
- Aluko, O.O.; Oloruntoba, E.O.; Ana, G.R.E.E.; Hammed, T.B.; Afolabi, O.T. Characteristics of co-composts produced from raw faecal sludge and organic market waste in Osun state, southwest Nigeria. *Int. J. Recycl. Org. Waste Agric.* **2000**, *9*, 333–347. [CrossRef]
- Rao, K.C.; Velidandla, S.; Scott, C.L.; Drechsel, P. *Business Models for Fecal Sludge Management in India*; CGIAR Research Program on Water, Land and Ecosystems (WLE), Resource Recovery and Reuse Series 18: Special Issue; International Water Management Institute (IWMI): Colombo, Sri Lanka, 2020.
- Nayak, P.P. Fecal Sludge Management Scenario in Odisha [PowerPoint Slides]. 2016. Available online: <https://www.pas.org.in/Portal/document/UrbanSanitation/uploads/Faecal%20Sludge%20Management%20Scenario%20in%20Odisha%20-%20Pragyan%20Nayak.pdf> (accessed on 7 July 2021).
- Bhullar, L.; Koonan, S.; Cullet, P. *Faecal Sludge and Septage Management in Odisha: A Review of the Law and Policy Framework*; Centre for Policy Research: New Delhi, India, 2019. Available online: <https://cprindia.org/research/reports/faecal-sludge-and-septage-management-odisha-review-law-and-policy-framework> (accessed on 24 June 2021).
- Roefs, I.; Meulman, B.; Vreeburg, J.H.; Spiller, M. Centralised, decentralised or hybrid sanitation systems? Economic evaluation under urban development uncertainty and phased expansion. *Water Res.* **2017**, *109*, 274–286. [CrossRef]
- Cofie, O.O.; Nikiema, J.; Impraim, R.; Adamtey, N.; Paul, J.; Kone, D. *Co-Composting of Solid Waste and Fecal Sludge for Nutrient and Organic Matter Recovery*; CGIAR Research Program on Water, Land and Ecosystems (WLE), Resource Recovery and Reuse Series 3; International Water Management Institute (IWMI): Colombo, Sri Lanka, 2016. [CrossRef]
- Nikiema, J.; Impraim, R.; Cofie, O.; Nartey, E.; Jayathilake, N.; Thiel, F.; Drechsel, P. *Training Manual for Fecal Sludge Based Compost Production and Application*; CGIAR Research Program on Water, Land and Ecosystems (WLE), Resource Recovery and Reuse Series 15; International Water Management Institute (IWMI): Colombo, Sri Lanka, 2020; 63p. [CrossRef]
- Mariwah, S.; Drangert, J.-O. Community perceptions of human excreta as fertilizer in peri-urban agriculture in Ghana. *Waste Manag. Res. J. Sustain. Circ. Econ.* **2011**, *29*, 815–822. [CrossRef]
- Simha, P.; Lalander, C.; Ramanathan, A.; Vijayalakshmi, C.; McConville, J.R.; Vinnerås, B.; Ganesapillai, M. What do consumers think about recycling human urine as fertiliser? Perceptions and attitudes of a university community in South India. *Water Res.* **2018**, *143*, 527–538. [CrossRef] [PubMed]
- Appiah-Effah, E.; Nyarko, K.B.; Adum, L.; Antwi, E.O.; Awuah, E. Perception of Peri-Urban Farmers on Fecal Sludge Compost and Its Utilization: A Case Study of Three Peri-Urban Communities in Ashanti Region of Ghana. *Compos. Sci. Util.* **2015**, *23*, 267–275. [CrossRef]
- Simha, P.; Lalander, C.; Vinneras, B.; Ganesapillai, M. Farmer attitudes and perceptions to the re-use of fertiliser products from resource-oriented sanitation systems—The case of Vellore, South India. *Sci. Total Environ.* **2017**, *581*, 885–896. [CrossRef]
- Mugivhisa, L.L.; Olowoyo, J. 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.* **2015**, *15*, 999–1010. [CrossRef]
- Knudsen, L.G.; Phuc, P.D.; Hiep, N.T.; Samuelsen, H.; Jensen, P.K.; Dalsgaard, A.; Raschid-Sally, L.; Konradsen, F. The fear of awful smell: Risk perceptions among farmers in Vietnam using wastewater and human excreta in agriculture. *Southeast Asian J. Trop. Med. Public Health* **2008**, *39*, 341.
- Cofie, O.; Adeoti, A.; Nkansah-Boadu, F.; Awuah, E. Farmers perception and economic benefits of excreta use in southern Ghana. *Resour. Conserv. Recycl.* **2010**, *55*, 161–166. [CrossRef]
- Census India. Bhubaneswar City Population—Khordha, Odisha. 2011. Available online: <https://www.censusindia2011.com/odisha/khordha/bhubaneswar-mcorp-population.html> (accessed on 5 June 2021).
- Yamane, T. *Statistics: An introductory Analysis*, 2nd ed.; Harper & Row: New York, NY, USA, 1967.

25. Ignacio, J.J.; Malenab, R.A.; Pausta, C.M.; Beltran, A.; Belo, L.; Tanhueco, R.M.; Era, M.; Eusebio, R.C.; Promentilla, M.A.; Orbecido, A. Perceptions and Attitudes Toward Eco-Toilet Systems in Rural Areas: A Case Study in the Philippines. *Sustainability* **2018**, *10*, 521. [[CrossRef](#)]
26. Nawab, B.; Nyborg, I.L.; Esser, K.B.; Jenssen, P.D. Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan. *J. Environ. Psychol.* **2006**, *26*, 236–246. [[CrossRef](#)]
27. Heinonen-Tanski, H.; van Wijk-Sijbesma, C. Human excreta for plant production. *Bioresour. Technol.* **2005**, *96*, 403–411. [[CrossRef](#)]
28. Andersson, E. Turning waste into value: Using human urine to enrich soils for sustainable food production in Uganda. *J. Clean. Prod.* **2015**, *96*, 290–298. [[CrossRef](#)]
29. Okem, A.E.; Xulu, S.; Tilley, E.; Buckley, C.; Roma, E. Assessing perceptions and willingness to use urine in agriculture: A case study from rural areas of eThekweni municipality, South Africa. *J. Water Sanit. Hyg. Dev.* **2013**, *3*, 582–591. [[CrossRef](#)]
30. Burt, Z.; Prasad, C.S.S.; Drechsel, P.; Ray, I. The cultural economy of human waste reuse: Perspectives from peri-urban Karnataka, India. *J. Water Sanit. Hyg. Dev.* **2021**, *11*, 386–397. [[CrossRef](#)]
31. Ajzen, I. Perceived Behavioral Control, Self-Efficacy, Locus of Control, and the Theory of Planned Behavior. *J. Appl. Soc. Psychol.* **2002**, *32*, 665–683. [[CrossRef](#)]
32. Mugivhisa, L.L.; Olowoyo, J.O.; Mzimba, D. Perceptions on organic farming and selected organic fertilizers by subsistence farmers in Ga-Rankuwa, Pretoria, South Africa. *Afr. J. Sci. Technol. Innov. Dev.* **2017**, *9*, 85–91. [[CrossRef](#)]
33. Brinkman, A. *Marketing of Compost in Emerging Markets: A Guidance Document for Compost Producers*; Netherlands Enterprise Agency: The Hague, The Netherlands, 2019. Available online: <https://english.rvo.nl/sites/default/files/2019/07/FDW-Compost.pdf> (accessed on 18 March 2022).
34. Roxburgh, H.; Hampshire, K.; Tilley, E.; Oliver, D.M.; Quilliam, R.S. Being shown samples of composted, granulated faecal sludge strongly influences acceptability of its use in peri-urban subsistence agriculture. *Resour. Conserv. Recycl. X* **2020**, *7*, 100041. [[CrossRef](#)]