Environmental Science & Technology

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Moving up the Sanitation Ladder while Considering Function: An Assessment of Indigenous Communities, Pit Latrine Users, and Their Perceptions of Resource Recovery Sanitation Technology in Panama

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Cite This: *Environ. Sci. Technol.* 2020, 54, 15405−15413

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ABSTRACT: As households move up the sanitation ladder, health risks presumably decline but the corresponding technologies may require increasing operation and maintenance costs. One critique of the ladder is that it prioritizes technology and could be improved if it included a functional approach to monitoring, such as including aspects of environmental sustainability that consider resource recovery. Using analyses of data obtained from semi-structured interviews, surveys, and field observations, this study examines the functional transition toward improved sanitation technology as a household moves up the sanitation ladder with the added function of resource recovery (from pit latrines to composting latrines). The study took place in six indigenous Ngäbe communities in Panama. The results reveal that of 103 pit latrines studied, 88% were completed and in use, but only 35% were operated appropriately. Approximately 60% of pit latrine owners reported that they would use composting latrines, with compost as the primary perceived benefit. Barriers to adoption include lack of prior experience, user disgust of working with excrement, and the perceived amount of work required for operation. Overall, these findings indicate the importance of establishing demonstration projects and culturally aligned training for more complex sanitation technologies that enable resource recovery. The results have broad implications for understanding sanitation technology transitions in rural and indigenous settlements in other world regions.

1. INTRODUCTION

The construction, adoption, and appropriate use of improved sanitation technologies remain major challenges across the developing world. While 2.1 billion people (26% of the global population) have gained access to basic sanitation services from 2000−2017, just over 2 billion people still do not have access.[1] Among Latin American countries, Panama (the location of this study) has the largest gap between indigenous and nonindigenous populations in sanitation coverage.[2] Gaps between urban and rural coverage are also salient. While 97% of people living in urban regions of the country have access to improved sanitation, only 73% of rural Panamanians do.[1] Moreover, in rural indigenous regions, such as the Comarca Ngäbe-Buglé, Panama's largest and most populous indigenous reservation, only 25% of the population has adequate access to basic sanitation, such as pit latrines.[3] At the same time, it is well documented that in coastal regions, such as the Comarca Ngäbe-Buglé, heavy rainfall and a high-water table make pit latrines unfeasible as the pit can fill with water.[4]

Information concerning sanitation provision and perceptions about sanitation technology are particularly lacking for indigenous communities. The literature about indigenous peoples and water and sanitation provision is also very limited and mostly focused on issues of water resources and conflict.[5] At the same time, research shows that indigenous groups have systematically lower access to basic sanitation services than nonindigenous populations.[6−10] This is often the result of historical, colonial resettlement practices that forced indigenous communities into remote and/or adverse environments and partly because governments have not historically invested in water and sanitation infrastructure development in these areas.[9,10] This is particularly important because there are a reported 250−350 million indigenous peoples in the world that are estimated to make up to 15% of the world's poor and up to 33% of the rural poor.[11] To address these issues, resources are increasingly being invested to provide sanitation coverage in these communities using double vault urine diverting (DVUD) composting latrines, a type of eco-sanitation technology with separate collection of feces and urine without flush water.[12] DVUD composting latrines promote aerobic biological processes within the waste pile that increase temperature, which can inactivate pathogens (Supporting Information, Figure S1). If properly designed and operated, resources, such as P, N, K, and C from the resulting

Received: June 23, 2020
Revised: October 26, 2020
Accepted: November 1, 2020
Published: November 13, 2020

Table 1. Respondent Demographic Information for Each Community

parameter	Bajo Gavilán	Nance de Risco	Punta Peña de Risco	Bajo Cedro	Nueva Estrella	Hato Nube	total population
HDI[a]	0.668	0.668	0.668	0.668	0.499	0.499	
age							
range	19−74	20−82	17−74	27−69	21−76	20−54	17−82
average	42.0	44.1	40.1	41.7	37.8	35.9	39.9
sex							
% male	71.4	66.7	51.4	70.0	75.0	55.0	61.2
% female	28.6	33.3	48.6	30.0	25.0	45.0	38.8
education							
% none	28.6	16.7	22.9	30.0	33.3	25.0	26.0
% grade 1−6	50.0	50.0	54.3	10.0	41.7	55.0	49.0
% grade 7−12	21.4	25.0	22.9	60.0	25.0	20.0	27.0
% university	0.0	8.3	0.0	0.0	0.0	0.0	1.0
average years of schooling	4.6	6.3	5.1	6.6	4.0	4.6	5.1
household size							
% 1 to 5	35.7	33.3	37.1	55.6	16.7	45.0	36.9
% 6 to 10	35.7	41.7	60.0	33.3	41.7	35.0	45.6
% 11 to 15	21.4	16.7	0.0	11.1	25.0	20.0	12.6
% 16 or more	7.1	8.3	2.9	0.0	16.7	0.0	4.9
average	7.9	8.4	6.3	5.2	11.3	6.9	7.4
primary occupation							
% farmer	42.9	50.0	48.6	40.0	58.3	40.0	46.6
% homemaker	21.4	25.0	48.6	20.0	25.0	35.0	34.0
% store owner	0.0	8.3	0.0	10.0	8.3	5.0	3.9
% unemployed	0.0	8.3	0.0	0.0	8.3	5.0	2.9
% other	35.7	8.3	2.9	30.0	0.0	15.0	12.6
sanitation							
% pit latrine	42.9	83.3	0.0	100	16.7	78.9	42.2
% VIP latrine	21.4	8.3	100	0.0	75.0	21.1	51.0
% open defecation	28.6	0.0	0.0	0.0	8.3	0.0	4.9
% pour-flush toilet	7.1	8.3	0.0	0.0	0.0	0.0	2.0

[a]Human Development Index, from UNDP (2014) for the geographic region of each community.

waste (urine and feces) can then be safely used as a soil amendment.[13]

The "sanitation ladder"[1] is a well-established tool to demonstrate and monitor how households can transition over time from simple to more advanced sanitation technologies, such as the DVUD latrine. As a household moves up the ladder, it is implied that the sanitation technology will reduce health risks.[14] At the same time, advancement requires greater inputs from skilled workers, additional needs for spare parts, and increased knowledge and skill to support operation and maintenance.[15] One critique of the ladder is that it is based solely on technology and could be improved if it included a functional approach to monitoring. In this situation, the lower rungs of the ladder would focus on health improvements and higher rungs could include integration of the technology with environmental functions related to nutrient reuse and integrated resource management.[15] This vision is not much different from the shift in high-income countries to better integrate wastewater management with goals to recover resources to better achieve environmental sustainability[16−18] that has now found its way into discussions on meeting global sanitation provision.[19,20]

When transitioning between various latrine technologies on the sanitation ladder, it is important to identify a technology that is "culturally, economically, and socially suitable to the community as well as environmentally and infrastructurally suitable to the geography in which they are implemented."[21] In addition to determining an appropriately situated technology, it is well documented that user preferences, attitudes, and beliefs are critical to the success of sanitation projects and that perceived public health benefits are not necessarily a strong motivating factor for new adopters.[22,23] Research suggests that comfort, convenience, status, privacy, and dignity can be powerful motivators for individuals and households.[24]

One key to successful sanitation transition projects that utilize culturally appropriate technology is that user buy-in creates broader demand for more sanitation implementation. Jenkins and Curtis[25] found that the prime motivators leading to the desirability of sanitation in indigenous areas of Benin are social prestige, well-being, restrictions on mobility (e.g., illness), and desire to increase rental income. They also identified gender, life stage, education, occupation, experience of travel, wealth, and physical and social geography of the village as motivations underlying decision making. Cost, lack of available credit, design, soil type, and family problems were identified as constraints.[25] The importance of social prestige was also identified in Zambia, where indigenous groups in a latrine survey stated that a household with a latrine had dignity or respect as visitors did not have to open defecate.[26] Here, latrines were also seen by village residents as a form of hospitality toward guests.

In a series of studies in Ghana, researchers found that people's perceptions of fresh human feces were overall negative,[27,28] but their perception of dried and processed composted excrement used as fertilizers were considered acceptable and appropriate.[29,30] These perceptions influenced

https://dx.doi.org/10.1021/acs.est.0c04120
Environ. Sci. Technol. 2020, 54, 15405−15413

household demand for improved sanitation, with the majority of residents preferring ventilated improved pit latrines in domestic settings and double vault composting latrines for public toilets.[31] However, a latrine intervention where the technology is designed and operated to recover resources must not only include understanding of users' values and beliefs to determine if the system is culturally appropriate but also realize that the technology's added complexity may require that users be supported to ensure they understand the system and can operate and clean it, to ensure a safe product and protect the user.[32] To do so will require consideration of stigma surrounding latrine cleaning and maintenance as well as handling composted feces.[33,34] For example, in rural India, researchers found that villagers expressed a preference for toilets connected to septic systems because they believed that pit latrines required "manual scavenging" feces out of the latrine.[35]

This article addresses these kinds of sociocultural factors (i.e., attitudes and perceptions) that influence the success and sustainability of moving up the sanitation ladder while considering the function of the technology, in this case a resource recovery sanitation technology that supports health and environmental outcomes. These types of latrines meet the definition of improved sanitation, recover and better utilize diminishing resources, and may be appropriate in areas of the world that lack sufficient water,[36] including rural sectors inhabited by indigenous peoples. For the present study, we conducted field observations, interviews, and surveys with 103 pit latrine owners, assessing their perceptions about composting latrine technology (especially handling human excrement), across six communities in the Panamanian indigenous regions of Bocas del Toro and the Comarca Ngäbe-Buglé. The goals of this effort were to assess the correct usage of less complex pit latrines, measure perceived advantages and disadvantages of composting latrines by latrine owners, and document and understand the different cultural perceptions of the handling and use of composted excrement among the Ngäbe. The greater goal of this research is to work toward a better understanding of culturally appropriate sanitation technologies for Ngäbe communities.

Based on comparative research by Naughton et al.,[37] which focused on a population of compost latrine users, two hypotheses guided this study. First, the experiences of indigenous pit latrine owners with their latrines (e.g., use and maintenance) are associated with their attitudes about handling excrement. Second, perceptions about composted excrement (e.g., stigma surrounding its handling and use) are associated with how indigenous latrine owners perceive advantages and disadvantages of composting latrines, which enables or constrains their movement up a sanitation ladder that incorporates a function of resource recovery. By addressing these hypotheses, this study aims to fill a knowledge gap concerning the willingness of users of conventional latrines to adopt resource recovery-oriented sanitation technologies. Moreover, by addressing unmet sanitation needs in rural areas (including those occupied by indigenous populations), our findings hold potential for implementing resource recovery sanitation technologies in other world regions.

2. MATERIALS AND METHODS

Six communities were visited to compile interview and observational data, five in the province of Bocas del Toro and one in the Comarca Ngäbe-Buglé (Table 1). All communities are classified as "indigenous", have populations of less than 1000, and are inhabited mostly by indigenous peoples. However, two communities (Bajo Gavilán and Bajo Cedro) have a small number of respondents (<5) self-identifying as "Latino". As indicated in Table 1, approximately 60% of the respondents were male and 40% female, although the ratio is higher in some communities, such as Nueva Estrella. We believe that this slight bias may have to do with local gender norms in which men felt more comfortable speaking about excrement and latrines with other men (e.g., the lead author) in some cases. Research in nearby rural coastal Ecuador suggests that social norms (including gender) are important predictors of how indigenous peoples interact with excrement and sanitation infrastructure.[38]

The data for this study were obtained using rapid ethnographic assessment procedures, a collection of time-effective appraisal methods for obtaining and assimilating targeted social and behavioral information with limited time and resources.[39,40] For the present study, these procedures included semi-structured interviews using a predetermined interview protocol, a brief oral survey with a freelisting component, and field observation. Details are publically available.[41] Six communities and 103 pit and ventilated improved pit (VIP) latrines were studied in the province of Bocas del Toro and the Comarca Ngäbe-Buglé (Supporting Information, Figure S2 and Table S1). Here, VIP latrines are recognized as a pit latrine with a vent pipe fitted to the pit and a screen attached to the pipe's outlet to reduce insect nuisance and unpleasant odors. The communities were selected for participation in this study because of the high proportion of the population that was indigenous and the presence of pit and VIP latrines as the primary modes of sanitation. Participants in this study were recruited as a convenience sample for expedited data collection, which targeted latrine owners that were available and willing to participate in the study during the period of research. The primary author (referred to below as the researcher) collected data from July to August 2017 while serving two years as an environmental health engineer in Panama as part of his graduate education. All research methods were approved by the Institutional Review Board (IRB) at the University of South Florida, and research was overseen in Panama by a local community leader, as required by the IRB process.

Interviews were conducted in Spanish and included questions designed to collect basic demographic characteristics of the latrine owner as well as cultural and technical information about latrine use. The inspection process of pit and VIP latrines was adapted from Mehl et al.[4] and Naughton et al.[37] After interviewing the latrine owner, the researcher asked for consent to enter the household latrine and make observations. Once inside the latrine, the researcher noted the presence and type (e.g., water or paper) of anal cleansing materials. The researcher checked if the latrine was covered properly (the hole entering the pit of a pit latrine should be covered between usage, and the hole entering a VIP latrine pit should not). The overall cleanliness of the latrine was observed and recorded on a subjective ordinal scale of 1−5. A value of 1 indicated a well swept floor and a clean seat. A value of 5 indicated that latrine surfaces were fouled by urine and/or excrement. The latrine was then evaluated if it was in working condition, e.g., it was structurally completed, provided privacy to the user, and the pit was not full. A full pit was determined if feces could be seen within one foot of the latrine hole or seat.

https://dx.doi.org/10.1021/acs.est.0c04120
Environ. Sci. Technol. 2020, 54, 15405−15413

Upon completion of the interview and observations with the latrine owner, a brief survey was conducted with the same person. The interviews allowed us to develop rapport with latrine owners so as to reduce "interviewer effects" in the application of our survey instrument, which was standardized for eliciting accurate and comparable responses.[42] Rapport building is important for data quality as it helps survey participants to answer openly and honestly and to understand information being asked.[43] Questions focused on the attitudes of the latrine owner toward the technology and maintenance as well as the perceptions of the latrine owner toward composting latrines, with responses recorded on a three-point Likert-type scale (agree, disagree, and unsure). The survey process also involved the use of freelisting, a cognitive elicitation technique that recorded an inventory of advantages and disadvantages the latrine owner cited with regard to human excrement and compost latrines. Freelists are useful in this context because they can reveal "cultural salience" of particular ideas within groups of latrine owners as well as variation in the owners' topical knowledge across groups.[44] This is because the frequency and consistency of responses help to categorize common answers and recognize culturally specific vernacular language, thereby reducing bias.[45] Freelisting is often used to "find out where to concentrate effort in applied research, and especially in rapid assessment."[46] Questions for the freelists were based on comparative research conducted by others.[37,47]

Finally, we used the IBM SPSS statistical analysis software (v. 24) to conduct Fisher's exact tests for independence to examine associations between survey statement responses and demographic information and to conduct binary logistic regression to understand the relationship between latrine type (basic or VIP) and responses to survey statements (as determined using odds ratios). Both Fisher's exact test and binary logistic regression were selected as optimal for use with smaller sample sizes (e.g., <1000) and discrete/categorical (nominal scale) variables typical of rapid assessments.

3. RESULTS AND DISCUSSION

3.1. Pit and VIP Latrine Use. To understand the current use of pit and VIP latrines in the study area, the latrines were divided into two main categories, "in use" and "not in use" (Supporting Information, Table S1). "In use" refers to completed latrines that were identified by the respondent as being in use, had pits observed to not be full, had a completed privacy structure, and had the presence of feces in the latrine pit. "Not in use" latrines were either identified by the latrine owner as not being in use, had pits that were too full for use, lacked a completed privacy structure, or lacked presence of feces in the latrine pit. Out of 103 total latrines in the study, 93 finished and in-use latrines were identified. A total of 42 latrines were basic pit latrines and 51 were VIP latrines. There were no composting latrines.

The completed and in-use latrines were subdivided into "proper" and "improper" use based on the seat or hole in the latrine floor. Properly used pit latrines have a covered seat or hole to prevent insects from entering and leaving the pit. In contrast, properly used VIP latrines have no such cover, which allows for increased airflow. Just over 35% of latrines were covered properly, with 41% of basic pit latrines properly covered and 29% of VIP latrines properly covered. As the majority of conventional latrines are being used improperly, the adoption of a more complex, resource recovery technology[32] might be initially challenging for the study population without support since users would be required to engage in additional operational practices[48] to ensure the safe use of the recovered resources.

Pit and VIP latrine users participated in semi-structured interviews in which respondents were questioned about their attitudes toward the latrine, its use, and maintenance as well as their initial interest in adopting the latrine. Freelisting questions recorded perceived advantages and disadvantages of owning a basic pit or VIP latrine (Supporting Information, Table S2). Overall, there were more associated advantages of pit latrines than disadvantages, with the majority of advantages relating to comparisons with open defecation. The primary advantage of a pit or VIP latrine according to respondents is the proximity to the home. Respondents also noted the importance of no longer having to practice open defecation in surface waters, and that latrines are both private and safe. These perceptions align with those recorded in other studies, which identify convenience, privacy, and safety as key drivers for adopting pit latrines over open defecation.[25,27]

The primary perceived disadvantages tended to focus on specific characteristics of pit and VIP latrines as well as problems that arise with maintenance. For example, latrine owners noted problems with flies, mosquitoes, and other insects, along with foul odors. Insects are a major problem with the latrines as most respondents use water to clean themselves after using the latrine. The water can also be associated with the foul smell as dry latrines usually have less odor than wet latrines. A total of 70 of the 103 respondents identified water as their anal cleansing material. Of the 54 latrines with anal cleansing materials present, 39 had water available while only 10 had toilet paper available. This suggests that there might be challenges with transitioning to composting latrines and other eco-sanitation technologies (such as dry toilets that utilize heat, time, and low moisture content to dry excreta), since the addition of water for anal cleansing would reduce pathogen inactivation and might create conditions that lead to odors and vector problems. At the same time, composting latrines with a urine diversion system could handle small amounts of water for cleansing, but this would require all users to use the toilet in a seated position.

3.2. Perceptions of Human Feces and Its Use as a Soil Amendment. We were also interested in how pit latrine users' experiences might influence their perceptions about human feces and its use as a soil amendment. Table 2 shows the relative proportions of responses ("agree", "disagree", and "unsure") for 16 statements about human feces and their reuse as compost. Statements 1−6 concern perceptions about human excrement, statements 7−14 concern perceptions about the use of excrement as a soil amendment, and statements 15 and 16 concern perceptions about animal manure. Items 1−6 have a Cronbach's α = .57, indicating a low level of reliability regarding consensus among latrine owners (although the lower α could be due to the smaller set of statements), and items 7−14 have a Cronbach's α = .74, indicating a higher level of reliability (we did not compute α for items 15 and 16 due to the small number of items). These findings suggest that, while there is some disagreement concerning perceptions about the safety of handling human excrement in general, there is relatively strong agreement regarding its use as a soil amendment.

The most significant perceived advantage of a composting latrine to these populations was the value of the compost. The most cited barriers to adopting composting latrines was the

https://dx.doi.org/10.1021/acs.est.0c04120
Environ. Sci. Technol. 2020, 54, 15405−15413

Table 2. Responses to Statements Regarding Perceptions of Excreta and Its Use as Fertilizer

survey statements	agree (%)	disagree (%)	unsure (%)
1) Human excreta are a waste and should only be for disposal.	38.8	56.3	4.9
2) Handling excreta is a great health risk.	68.9	28.2	2.9
3) Human excrement should not be handled in any way.	42.7	52.4	4.9
4) Human excrement has no benefit to humans.	29.1	67.0	3.9
5) It is OK to touch excrement with your hands.	2.9	97.1	0.0
6) It is OK to touch composted excrement.	25.2	70.9	3.9
7) Human excrement is a resource for the soil.	89.3	7.8	2.9
8) Human excrement from a composting latrine can be used as fertilizer.	87.4	9.7	2.9
9) I would use composted human excrement on my crops.	82.5	16.5	1.0
10) Taste of vegetables will change when composted human excrement is used.	51.5	37.9	10.7
11) Smell of vegetables will change when composted human feces is used.	40.8	48.5	10.7
12) Crops can be killed when fertilized with composted human excrement.	20.4	72.8	6.8
13) Crops fertilized with human excrement are good for consumption.	72.8	24.3	2.9
14) I will never consume crops that used composted human excrement.	19.4	80.6	0.0
15) Animal manure can be used as fertilizer.	83.5	14.6	1.0
16) I have used animal manure as fertilizer.	71.8	28.2	0.0

lack of previous experience, followed by culturally situated notions of disgust with working with human feces and the amount of labor it takes to operate a composting latrine. Defining a high level of consensus as ≥75%,[39] the participants showed a high level of consensus in statements 5, 7, 8, 9, 14, and 15. Respondents agreed (97%) that it is not acceptable to touch fresh excrement with the hand. Many respondents also agreed that composted human excrement is a resource for the soil (89%), composted excrement can be used as a fertilizer (87%), and that they would use composted human excrement as a soil amendment (83%). Additionally, respondents generally agreed that they would be open to the idea of eating crops fertilized with human excrement (81%) and that animal manure can also be used as a fertilizer (84%).

Responses with percentages ranging from 60−74% reflect moderately high levels of consensus (see ref 39). Statements 2, 4, 6, 12, 13, and 16 showed moderate agreement in responses. Respondents were in moderate agreement that handling fresh excrement is a health risk (69%) and that human excrement has a benefit to humans (67%). Respondents also reported that it is not acceptable to touch composted excrement (71%), crops will not be killed when fertilized with composted human excrement (73%), and that they had used animal manure as fertilizer in the past (72%).

Finally, below 60% represents low levels of consensus (see ref 39). The low-level consensus statements include 1, 3, and 10. Only small majorities of respondents agreed that human excreta (from a pit latrine) is only fit for disposal (39%), that human excrement should not be handled (43%), and that the taste of vegetables will change with the addition of composted human excrement as a fertilizer (52%). No consensus was reached for question 11, that the smell of vegetables will change with the addition of composted human excrement as a fertilizer. Questions 10 and 11 included the highest number of respondents who answered that they were unsure (11%).

Overall, respondents had a higher level of consensus on more statements of reusing human excrement as compost than in the Naughton et al. study,[37] which found high levels of consensus in statements 5, 6, 7, 8, 12, 13, 14, and 15, moderate consensus in 3 and 9, and low levels of consensus in 1, 2, 4, 10, 11, and 16. However, the population in the Naughton et al.[37] study was composed of those who owned a composting latrine and there was a low level of consensus that human excrement has a benefit to humans (54%). In the current study, 67% of respondents agreed that excrement had a benefit. More respondents also agreed in the current study that handling human excrement is a health risk (69%) than in the Naughton et al.[37] study (57%). This result likely has to do with the fact that composting latrine owners must work with the compost and have a better understanding of the technology's greater

Table 3. Significance Results from Fisher's Exact Tests for Independence between Survey Statement Responses in Table 2 and Selected Demographic Characteristics from the Participants in Table 1[a]

survey statement	community	san. type	gender	occupation	age	education	HH size
1	0.15	0.41	0.10	0.27	0.62	0.32	0.49
2	0.60	0.66	0.82	0.82	0.36	0.38	0.71
3	0.10	0.55	0.84	0.84	0.39	0.34	0.37
4	0.85	0.19	0.18	0.33	0.33	0.71	0.47
5	0.52	0.59	0.28	0.13	>.99	>.99	0.77
6	**0.03**	0.36	0.82	0.22	0.56	0.28	0.27
7	0.30	0.29	0.71	0.14	>.99	0.44	0.51
8	**0.04**	**0.02**	**0.01**	0.07	>.99	>.99	0.87
9	0.10	0.11	**0.03**	0.14	0.15	0.33	0.54
10	0.74	0.29	0.20	0.19	>.99	0.54	0.08
11	0.79	0.29	0.20	**0.02**	0.91	0.48	0.20
12	**0.01**	0.80	**0.02**	**0.03**	0.81	0.89	0.47
13	0.30	>.99	0.24	0.30	0.32	0.64	0.65
14	0.74	>.99	0.13	0.33	0.51	0.64	0.15
15	0.70	>.99	0.09	0.09	0.59	0.68	0.55
16	0.21	0.83	0.26	0.20	0.25	>.99	0.80

[a]Note that numbers in bold font indicate $p \leq 0.05$.

https://dx.doi.org/10.1021/acs.est.0c04120
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complexity, while most pit latrine users are only trained about the public health dangers of open defecation.[48]

3.3. Potential for Adopting Resource Recovery Technologies. In addition to understanding latrine owners' perceptions of using human feces for compost, we were also interested to learn how these perceptions might articulate with the potential for adopting resource recovery technologies such as composting latrines. Table 3 presents significance (p) values for Fisher's exact tests for independence evaluating associations between demographic characteristics of the population from Table 1 and the statements about excrement from Table 2. Knowing which demographics respond favorably to resource recovery can aid in future interventions by identifying which groups are more likely to adopt the technologies.[49] They could also help evaluate success, training, and future use of ecological sanitation (EcoSan) technologies.[37]

The community in which the respondent lived was found to be statistically associated with three statements: statement 6 ("It is ok to touch treated excrement"), statement 8 ("Human excrement from a composting latrine can be used as fertilizer"), and statement 12 ("Crops can be killed when fertilized with composted human excrement"). Residents from the community of Nueva Estrella were the only ones to respond positively to statement 6, perhaps because of the proximity to Silico Creek, a community documented in Naughton et al.[37] to have had success with composting latrine projects (residents of Nueva Estrella must wait for public transportation in the community of Silico Creek). Bajo Gavilán was the only community that responded 100% positively toward the reuse of composted excrement (statement 8), which may be influenced by the fact that the lead author of this study lived in Bajo Gavilán. Bajo Cedro and Nueva Estrella were the only communities to respond 100% negatively to statement 12. Sanitation classification was found to be associated with statement 8. People who own a basic pit latrine were mostly found in Hato Nube and Nance de Risco. Gender was associated with statements 8, 9, and 12, where men were more likely to respond that human excrement can be used as a fertilizer and that they would use composted excrement on their crops (men were also more likely to state that crops cannot be killed with composted human excrement). Primary occupation was associated with statements 11 and 12.

Table 4 presents the results of a binary logistic regression of latrine type (basic = 1, VIP = 0) on the survey statements from Table 2. The odds ratios ($\exp(\beta)$) suggest that someone who responded positively to statements 4 ("Human excrement has no benefit to humans") and 5 ("It is OK to touch human excrement with your hands") are 2.4× and 4.5×, respectively, more likely to own a basic pit latrine. Someone who responded positively to statements 15 ("Animal manure can be used as a fertilizer") and 16 ("I have used animal manure as a fertilizer") are 1.9× and 3.0×, respectively, more likely to own a basic pit latrine. These findings suggest that basic pit latrine users' experiences with human and animal feces may, in some way, be associated with their perceptions of the potential for reuse of composted excrement as fertilizer. While this regression describes the dataset presented (Nagelkerke R^2 = 0.35 with 90.2% correct classification of pit latrines), the overall lack of statistical significance for the Wald statistic indicates that these results should not be generalized beyond this specific study.

Given that many latrine owners in Nueva Estrella and Bajo Gavilán responded positively toward reusing composted excrement, residents in these communities might be more interested in learning about these technologies. We speculate that if successful pilot projects are demonstrated to the community, along with education and training that address local understandings of human waste and potential stigma of handling composted excrement, these groups might be more receptive to adopting composting latrine sanitation infrastructure (e.g., ref 50). Training follow-ups need to be part of the pilot project to ensure that composting latrines are being operated properly and to familiarize the rest of the community with the added function and complexities of composting latrines. Thus, pilot projects and culturally sensitive trainings can assist development workers and government agencies in better gauging local interest in particular sanitation technologies.

Table 4. Binary Logistic Regression of Latrine Type on Survey Statements in Table 2

survey statement	β	S.E.	Wald	significance	$\exp(\beta)^a$
1	0.22	0.72	0.10	0.76	1.25
2	0.07	0.74	0.01	0.32	1.07
3	−0.76	0.75	1.03	0.31	0.47
4	0.87	0.74	1.18	0.28	**2.38**
5	1.50	1.61	0.09	0.35	**4.50**
6	0.10	0.69	0.02	0.88	1.11
7	−0.39	1.56	0.06	0.80	0.68
8	−3.13	1.73	3.26	0.07	0.04
9	0.39	1.53	0.06	0.80	1.47
10	−0.36	0.72	0.25	0.62	0.70
11	−1.51	0.78	3.70	0.06	0.22
12	−1.50	1.00	2.23	0.14	0.22
13	−0.50	1.16	0.19	0.66	0.60
14	−1.01	1.19	0.72	0.40	0.36
15	0.65	1.58	0.17	0.68	**1.92**
16	1.08	1.20	0.81	0.37	**2.96**

[a]$\exp(\beta)$ represents the odds ratio; bold values are discussed in the text.

3.4. Perceptions of Composting Latrines. When asked about preferred sanitation technologies overall, most respondents (75%) stated that they would prefer pour-flush toilets or septic systems. A small number of respondents (15%) stated that they would prefer composting latrines. Sixty percent of those respondents cited the compost as the main motivation for preferring a composting latrine over all other sanitation technologies. After asking about preferred sanitation technology, respondents were described a composting latrine and asked if they would be interested in adopting this form of technology. Of 103 respondents, 61% responded that they have interest, while 36% responded that they do not. Table 5 presents freelists that record perceived advantages and disadvantages associated with the use of composting latrines. A total of 47 respondents indicated that they would be interested in a composting latrine for the use of the fertilizer, with an additional three respondents expressing a desire for better harvests. The main reason for not being interested in a composting latrine was the lack of prior experience (35%). Other reasons include disgust (24%) and the amount of work required to maintain the latrine (22%).

Previous research was conducted on composting latrine use and perceptions in indigenous and Latino communities in Panama.[37] In that study, the perceptions were only of owners of existing composting latrines. The primary associated advantage of composting latrines in that study, in addition to

https://dx.doi.org/10.1021/acs.est.0c04120
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Table 5. Freelist of Perceived Advantages and Disadvantages of Composting Latrines Identified by Respondents

advantages	frequency
compost	47
better harvests	3
less smell	3
to gain experience	3
prior experience	2
better than a pit latrine	2
no insects	1
more comfortable	1
easier than digging a new hole	1
convenient	1
always dry	1
two rooms in compost latrine	1
disadvantages	**frequency**
no prior experience	13
disgust	9
too much work	8
malodorous	2
several have failed in nearby community	2
not interested	1
goats already eat all my crops	1
prefer pour flush	1
they can make compost out of other things	1
family could get sick	1
too old	1

the production of compost, is the lack of insects and foul odors. These identified advantages are because the latrine remains dry (due to urine diversion and addition of a desiccant after each use), and water washing is not possible as it is in pit latrines (except in the case where the user sits and wash water enters the urine diversion tubing). Other advantages align with those associated with pit and VIP latrines, including privacy, proximity, and lack of contamination of the environment. Naughton et al.[37] found that the primary disadvantage associated with composting latrines was the lack of provision within the latrine for water-based anal cleansing. This is because the composting latrine (and dry desiccation latrine) needs to maintain appropriate moisture content[4,51] to promote biological activity (or pathogen desiccation) within the latrine. As noted previously, the current study found that most respondents use water for anal washing after latrine use, but respondents cite odor and insects as the main disadvantage of composting latrines. These problems are more prevalent because of the use of water for anal cleansing. Water is the preferred method to clean oneself in these communities, and selection of appropriate technologies and the success of sanitation projects will ultimately rely on a culturally appropriate solution that allows the user to wash in this way.

In addition to the freelisting, our survey asked what the participant would think of their neighbor if they built a composting latrine, and then what they would think if that neighbor began using composted excrement on their crops. In a follow-up question, we also asked what the respondent's neighbor might think of the respondent should they build a composting latrine, and what the neighbor would think should they begin using composted human excrement on their crops. These questions were developed from research by Simha et al.[47] in south India and were asked to gain a clearer perspective on what residents' perceptions are of composting latrines and using composted excrement. In the present study, the majority of pit latrine owners responded favorably to the first question (64%), with much smaller numbers responding neutral (27%) and negative (9%). In the follow-up question, the highest percentage of respondents had a neutral response (50%), with equal numbers responding positive and negative (25%). This suggests that while respondents may feel positively about the concept of reusing human excrement as compost, the greatest barriers for adoption of composting technology may be perceptions of working with human excrement by people living near them. In his study of composting latrines in the rural highlands of Mexico, for example, Bates[48] found that the greatest barriers to adoption included fear and disgust of handling human waste, especially leveling of waste and maintaining the urine diversion tubes. Ngäbes live in close-knit communities, often physically close to their immediate family.[52,53] The perceived alienation from family and friends could prevent first adopters from adopting a composting latrine. These findings suggest the importance of culturally aligned education for composting latrine programs.

4. SUMMARY

In sum, we found associations between the experiences of indigenous pit latrine owners and their views on handling composted excrement. Their attitudes about human excrement appear to be associated with their perceptions about the advantages and disadvantages of composting latrines as well as their willingness to learn more about, and potentially adopt, these types of resource recovery sanitation technologies that would be found on higher rungs of a functional sanitation ladder. This research also demonstrates the potential for rapid ethnographic assessment involving field observations and interviews to address these kinds of questions and suggests that scaling up the research design with a larger sample size and more rigorous quantitative assessment (including the use of control groups, for example) can provide additional insights with greater explanatory capacity. Such research could inform behavioral change interventions aimed at improving access to improved sanitation technologies and services as well as more nuanced understandings of local perceptions of sanitation and hygiene that could lead to more culturally sensitive approaches to sanitation improvements. Ngäbe preferences for water as a medium for anal cleansing suggests that future research should consider sanitation technologies that align with local preferences, for instance, consideration of the ways in which bidets or washlets (combined toilet and bidet) might be incorporated into composting latrines.

As countries advance progress on the Sustainable Development Goals for sanitation and hygiene, composting latrines (and other eco-sanitation technologies) are a promising technology for addressing multiple goals while recovering and reusing limited resources. At the same time, for these types of technologies to be implemented sustainably and equitably, our research demonstrates that it is important to understand the complex ways in which social and cultural characteristics and local perceptions of resource recovery intersect. This is especially the case for indigenous communities, where residents may hold values and beliefs about sanitation technologies and practices that are different from those involved in infrastructure development projects.

https://dx.doi.org/10.1021/acs.est.0c04120
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■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.est.0c04120.

DVUD latrine; VIP latrine and a basic pit latrine; latrines and their use status in each community; freelist of perceived advantages and disadvantages of pit/VIP latrines identified by respondents; and statement regarding collaborations and interactions with local partners (PDF)

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under grant no. DUE-0965743. The work was performed with the permission of the Institutional Review Board of the University of South Florida, IRB Study No. Pro00031389.

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https://dx.doi.org/10.1021/acs.est.0c04120
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