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Composting Latrines and Community-Led Sanitation Solutions in Rural Nicaragua

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Abstract

Safe sanitation services are a basic human right, yet almost half the world's population lacks them. The traditional on-site sanitation solutions require proper fecal sludge management to avoid health risks. Composting latrines, on the other hand, are a promising and waterless solution that can also sanitize waste for potential use as fertilizer. However, implementing organizations and agencies have yet to widely adopt these toilets due to high costs, low user adaptability, and acceptance rates. Drawing from the experiences of four community groups in Nicaragua, this article explores the impact of composting latrines for rural and peri-urban families. Following community-led processes, these groups successfully implemented and sustained their composting latrine initiatives since 2010, providing initial evidence of how, where, and why their interventions have been successful.

Keywords: fecal sludge management, composting latrines, community-led development, sanitation sustainability, community-led sanitation

Latrines à compostage et solutions d'assainissement communautaires dans les zones rurales du Nicaragua

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Résumé

Des services d'assainissement sûrs constituent un droit humain fondamental, mais près de la moitié de la population mondiale en est privée. Les solutions traditionnelles d'assainissement sur site nécessitent une bonne gestion des boues fécales pour éviter les risques sanitaires. Les latrines à compostage, en revanche, sont une solution prometteuse et sans eau qui peut également assainir les déchets pour les utiliser potentiellement comme engrais. Cependant, les organisations et agences de mise en œuvre n'ont pas encore largement adopté ces toilettes en raison de leurs coûts élevés, de la faible adaptabilité des utilisateurs et des taux d'acceptation. S'appuyant sur les expériences de quatre groupes communautaires au Nicaragua, cet article explore l'impact des latrines à compostage pour les familles rurales et périurbaines. En suivant des processus menés par la communauté, ces groupes ont mis en œuvre et soutenu avec succès leurs initiatives de latrines à compostage depuis 2010, fournissant ainsi des premières preuves de comment, où et pourquoi leurs interventions ont été couronnées de succès.

Mots clés : gestion des boues fécales, latrines à compostage, développement mené par la communauté, durabilité de l'assainissement, assainissement mené par la communauté

1.0 Introduction

Nearly half of the world's population lacks access to safe sanitation services (WHO, 2023; Muoghalu et al., 2023). The most common on-site sanitation solutions are pit or septic-like systems requiring formal fecal sludge management (FSM) services. However, poor access and affordability of FSM services lead to unsanitary practices such as open defecation, posing immediate threats to human health (Myers, 2016; Mariwah et al., 2022).

Composting latrines hold promise for not only safely managing waste but also effectively sanitizing it for potential use as fertilizer (Manga et al., 2022; Orner & Mihelcic, 2018; Chandana & Rao, 2022). Additionally, composting latrines such as urine divergent and single or double-vault units do not require water, which addresses water scarcity concerns. They are odorless, do not attract flies, or host other health-threatening vectors. Moreover, above-ground design alleviates expense concerns over excavating shallow and rocky surfaces, typically needed for pits and underground septic tanks. Being elevated with a cemented floor also reduces the groundwater contamination risks associated with poorly managed pit latrines (Anand & Apul, 2014; Rieck et al., 2012).

But despite their potential, composting latrine interventions are uncommon. Even within successful global sanitation programs such as Community-led Total Sanitation (CLTS), composting latrines are not a prime technology of choice (Mariwah et al., 2022). Research points to at least three factors inhibiting the solution's adoption and long-term sustainability. First, composting latrines are more expensive, with prices linked to limited supplies of prefabricated components and affordable financing options (Rieck et al., 2012). A second barrier is people's lack of awareness of the technology's benefits and usage (Anand & Apul, 2014). A third barrier involves maintenance. Owners should proactively manage their waste, including turning it, adding bulking agents, emptying chambers, and cleaning the facilities with as little water as possible. These requirements can be off-putting to prospective owners, who are used to "drop-flush-forget" technologies (Drangeart et al., 2002, as cited in Mkize et al., 2017). In combination, cost, low acceptance rates, and maintenance challenges impact composting latrines' uptake within sanitation contexts.

These barriers can be overcome if implementers combine the technology with interventions that prioritize local ownership and management. In what follows, we introduce the composting latrine projects of four community groups in Nicaragua, all supported by Alcance Nicaragua (AN), a locally registered nonprofit organization. Using exploratory qualitative data, supported by quantitative data on toilet usage and money saved, we illustrate how composting latrines have positively changed rural families' well-being. Our findings reflect the importance of combining composting technology with community-led practices to overcome barriers of low acceptance rate, maintenance challenges, and high costs.

2.0 Facilitating Sustainable Sanitation Solutions: Alcance Nicaragua

A 2020 World Bank brief reports that only 45% of households globally have access to safely managed sanitation. International and local NGOs and the Nicaraguan government are working towards addressing this challenge (World Bank, 2020). For example, the government has made strides toward water policy reform to ensure equitable and sustainable water while promoting community-based sanitation programs

(LaVanchy et al., 2017). At a local level, nonprofits such as AN are supporting these national efforts by working directly with communities and their households.

AN facilitates community-led development to strengthen the social infrastructure people need to address their shared poverty-related challenges collectively. Throughout a five- to six-year intervention, AN practitioners support people in establishing a self-sufficient, locally registered community-based organization (CBO) with capable leadership, governing systems and diverse projects addressing their most pressing needs.

To develop the groups' organizational infrastructure, AN practitioners follow a community-led development methodology called Participatory Human Development (PHD). This involves AN practitioners engaging community members in ongoing problem-solving processes to solve their most pressing poverty-related challenges. The process includes identifying and prioritizing their challenges, seeking appropriate solutions, planning for and acting toward such solutions, and evaluating and reflecting on their overall progress and successes.

Communities' identified solutions manifest in the form of community-led projects. After deciding on the appropriate solutions, community members list all activities needed to execute their projects, from drafting proposals to submitting them to relevant resource institutions. Members also have to plan and oversee all aspects of project implementation, including training, construction monitoring, and all financial transactions. Since many community members might not have prior management experience, AN practitioners provide on-the-job training and support on project planning, implementation, and financial management.

The scope of projects groups implement is diverse, ranging from food programs to cleaner cookstove initiatives (Cloete et al., 2023). Sanitation projects are often included on such project lists, understandably so, considering the persistent challenge of poor sanitation in rural communities.

2.1 Local Sustainable Solution: Composting Latrines

Between 2010 and 2023, four of AN's community partners implemented sanitation projects featuring urine-divergent double chamber composting latrines. The groups' decision to implement these rather than the typically used pit latrines came after they analyzed their contexts and local needs. The groups live in different geographic locations—mountainous areas further removed from cities and peri-urban regions with flat yet rocky topography. Both areas' topography makes any underground sanitation system costly to build. Like in other Central American locations, pit latrines, the go-to technology for many households, frequently overflow, especially during rainy seasons (Sabogal et al., 2014). In 2009, AN connected with Engineers without Borders (EWB) chapters active within their region, who suggested urine divergent double chamber composting latrines built above ground and with cement floors. EWB's original design was, however, expensive to build. AN and community groups then built prototypes comprising different building materials, eventually reducing the cost by half. After settling on their preferred design, these four communities constructed 107 latrines between 2010 and 2017.

Considering the low implementation rate of composting latrines and barriers to these programs' successes globally, we decided to explore to what extent these Nicaraguan groups' projects have been sustained and how they have impacted participating households' well-being. Three research questions guided our inquiry:

1. How sustainable are these projects with regard to latrine usage?
2. How have these projects impacted the well-being of participating households?
3. What factors contributed to these projects' sustainability?

3.0 Methods

We used an embedded mixed-method design (Creswell & Plano Clark, 2011). To answer the second and third research questions, the research team invited a purposive sample of 35 community members and leaders representing the four AN community partners with the longest-running composting latrine projects (see Table 1) to participate in interviews. These research participants agreed based on availability and interest.

Table 1. *Research Participants - Purposive Sample*

Research participants (Interviews & conversations)	**35**
Identifying as women	24
Identifying as men	11
Group members	22
Group leaders	13
Communities represented	4

Data collection for the qualitative component of the study took place between March and April 2022, informed by Sorcher et al. 's (2023) approach to studying improved sanitation in the Philippines. COVID-19 international travel restrictions necessitated data collection via Zoom. All calls occurred within research participants' communities, ensuring the least disruption to their daily lives.

We conducted two sets of interviews. First, we spoke with 13 community leaders involved in their CBOs' sanitation projects using a semi-structured interview protocol. These interviews lasted between 45-60 minutes each. Through these interviews, we wanted to learn more about toilet sustainability, challenges encountered during project implementation, and recommendations leaders might have for future composting latrine initiatives.

The second set of 15-minute-long individual conversations focused on impact. We spoke with 35 individuals, including the same group of 13 leaders interviewed before. All 35 interviewees accessed their latrines through their respective community group's activities. The structure of these latter conversations was inspired by the qualitative methods of *Photovoice* (Wang & Burris, 1997) and *Most Significant Change* (Davis & Dart, 2005). We asked research participants to capture an image in response to the question, "What has been the most significant change your family has experienced as a result of your composting latrine?" We asked all 35 research participants to submit images that best reflect the most significant change they have experienced. Then, during the conversations, they verbally contextualized their submitted images. Some participants chose to submit photos, while others drew pictures. During both interviews and image conversations, a team member took verbatim notes. We recorded the conversations to validate note accuracy.

We conducted inductive qualitative data analyses of the interviews and short conversations (Guest et al., 2013). First, two different coders open coded the interview and conversational data separately, assigning descriptive and structural codes to data segments relevant to the overarching research questions. The coders then deliberated over differently coded segments and, following agreement, collapsed codes into categories or sub-themes and then overarching themes. (Saldaña, 2016). Tables 3 and 4 show themes emerging from the leaders' interviews and most significant change conversations, respectively.

Table 3. *Themes Describing the Sanitation Projects' Impact*

Most Significant Changes		
Themes	**Frequency (%)**	**Subthemes**
The Organization	21	● Unified action brings benefits ● Organisational activities enable results and learning
Better Hygiene, Better Health	14.5	● Changes in hygiene practices ● Perceived health improvement
Privacy, Security, Comfort	13.7	● Greater security, especially for children ● Greater privacy and comfort, especially for women
Cleaner Surroundings	12.9	● Overflowing waste brings insects, animals, and bad smells ● Reducing water source contamination
Fertiliser	12.1	● More, healthier plants
Savings	10.5	● Saving water ● Saving money on pit latrine construction, fertilizer, and cleaning supplies
Stronger Relationships	8.1	● Less conflict between neighbors
Learning New Sanitation Technologies	7.3	● Expanding horizons by adapting to new sanitation practices

Additionally, Table 3 includes the relative frequency of the most significant change themes. Such quantification illustrates the themes' respective weights regarding the number of data segments describing a particular impact (Guest et al., 2012). To consider the trustworthiness of our analyses, we conducted member checks with AN staff and research participants. Both groups agreed with the findings and synthesis. In our synthesis below, we chose pictures and photos, and corresponding quotes that best capture the emerging themes.

Table 4. *Themes Emerging from Leaders' Interviews*

Sustainability Factors	
Themes	**Subthemes/ Recommendations**
The Group Factor	● Being unified in the issue yields greater results
	● Develop community-wide maintenance plans
Involved Group Leaders	● Conduct training
	● Facilitate issue analysis & seek solutions
	● Monitor progress, maintenance & usage
Evidence Speaks for Itself	● Facilitate visits to existing composting latrine owners' units [to hear testimonials]
	● Identify curious & motivated prospective latrine owners
	● Identify, as soon as possible, the latrines' benefits
	● Use evidence to motivate existing & recruit new owners

In addition to the qualitative data collected in 2022, we also administered a survey in 2023. Insights that emerged from the qualitative data, particularly with regard to ongoing toilet usage, prompted us to return to all households one year later with a follow-up survey to capture information that could further bolster our qualitative findings. Most prominent, in addition to ongoing usage, we were also curious about the toilets' positive financial impact—a theme that emerged from the qualitative data. The survey was administered to all 107 toilet recipients in March 2023. The 107 survey participants included 33 community leaders and 74 group members.

To ensure our research remains ethically sound, we followed a two-step process. First, at the onset of our study and with the facilitation of AN staff, we explained to prospective research participants the study's objectives, described their involvement as voluntary, and shared that if they chose to participate, we might curate their photos, drawings, and sentiments for future research outputs. We also explained that their sentiments will be presented through pseudonyms, as is the case below. Following their interest in participating, we collected signed consent. Each participant also received a copy of their signed form, including a description of the study's rationale, goals, and objectives. The second step involved sharing the final draft with research participants. We also shared our choice in photos and drawings with the respective participants, asking their permission to use these in the final document.

4.0 Findings & Discussion

4.1 Usage

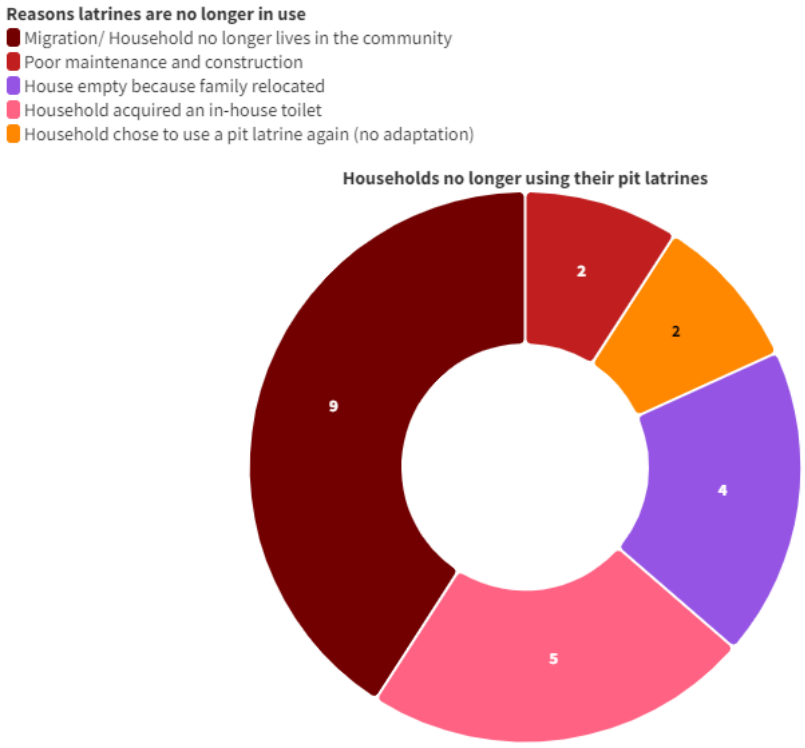
Between 2010 and 2017, four community groups implemented composting latrine projects. With support from AN and financial assistance from international donors, the groups built 107 composting latrines. These were built in different stages, primarily dictated by how much funding groups could access at a time (see Table 2).

Table 2. *Usage Rate of Composting Latrines built between 2010 and 2017*

Community	**Year**	**Latrines built**	**Latrines in use (2023)**	**Sustainability rate**
Community 1	2010/2016	28	20	71%
Community 2	2014/2016	37	34	92%
Community 3	2017	21	15	71%
Community 4	2017	21	16	76%
Total	**N/A**	**107**	**85**	**79.5%**

As of 2023, 85 or 79.5% of the originally built latrines are still fully functional and used by families. Of the 20.5% or 22 initial recipients who no longer use their latrines, only two had difficulty adapting to the technology, while two stopped using their latrines because of poor construction (see Table 2 and Figure 1). The remaining 18 households no longer use their latrines because of migration, relocation, or they have decided to build toilets inside their homes. These results suggest that ongoing usage has been possible among Alcance Nicaragua's community partners six years post-project completion. These rates meet Garn et al.'s (2017) recommendation that an adequate sanitation strategy should secure coverage as well as usage.

Figure1: Reasons families no longer use their composting latrines.



4.2 Impact

If sustained usage is one indicator of success, then the community groups' sanitation projects exemplify a successful solution to local sanitation challenges. But what has been the projects' long-term impact on participating households? Table 3 summarises the most significant changes research participants shared during their conversations. The table also includes the frequency with which these changes appeared across all conversations.

4.2.1. The Organization. As the most prominent theme, the organization reflects the connection for research participants between their composting latrine and membership in their respective groups. Most impactful for participants was the unity they experienced within their community groups since they started addressing their sanitation challenge. Group membership also means they have organizational spaces in which to strengthen communal relationships while physically working toward improved sanitation. Mercedes, a community member, reflected that,

> The composting latrine project [has had] a great impact. [The analysis of this issue] motivated all the people in this group to work together for the community. To have these benefits, all of us have to work together. We gathered on the day that we purchased the materials, and we all carried our own materials to our own house. We carried it by horse to transport the materials to our house. That was a wonderful experience for us because we started to work together.

In addition to cultivating unity, participants also reflected on how group membership has provided them with learning opportunities. Ramon, a group leader, told us that involvement in the sanitation projects was,

> Like a school…in which I am developing myself, my abilities, and skills to help the work in the community. [Before] we didn't have any experience at all, but now through the years and through the experience, we have gained more…I can say that in the future, someone else can replace me and the work that I'm doing now. We are training, or we are teaching future leaders.

As Ramon's reflection shows, learning about issues like sanitation also implies generational transfer, with leaders like him passing on their knowledge to younger leaders who will sustain the ongoing progress within their group.

4.2.2. Cleaner Surroundings and Better Health, Better Hygiene are discussed together in this analysis due to the overlapping nature of these themes. While not the most significant theme (12.9%), research participants still drew connections between their sanitation projects and cleaner surroundings. Their immediate living areas changed because of the shift from pit to composting latrines. They no longer endure overflowing pit latrines, the accompanying insects, and smell. The description and drawing of group member, Jose (see Figure 2) capture such change:

> …In winter, my latrine overflowed… it had a bad smell, it wasn't hygienic… And [then I was] thinking, "I need to use that latrine…I don't want to go in!" In my experience with the new latrine, the situation is very different…You see in the picture I am sitting on the stairs of the latrine, eating, with no bad smell around the latrine.

Figure 2: Cleaner surroundings, better health & hygiene.

4.2.3. Better Hygiene, Better Health. This represented 14.5% of coded segments, connecting previous dirty surroundings to vector and waterborne diseases. Maria, a group member, shared that because of safer sanitation and cleaner surroundings, "there is no bad odour coming out of the latrine or insects that are carrying different diseases to us; The air does not get contaminated with the bad odour."

Similarly, Felix, a community leader, shared a photo of his daughter drinking water. Before their group's sanitation project, he worried about how households' unlined pit latrines were contaminating groundwater sources, which in turn had severe health consequences. But with his group now using composting latrines, he is no longer worried.

4.2.4. Privacy, Security, Comfort. Like other global contexts, research participants spoke about unimproved sanitation posing safety and security risks (Winter & Barchi, 2016). One such concern relates to the hazardous conditions of unimproved pit latrines. To illustrate such risks, group member Maria drew a picture (see Figure 3), depicting her family's reality before and after their composting latrine. She described her picture as follows:

> …During winter, we were really worried about using the latrine because we felt we could easily have an accident… You can see [in the drawing] a tree and rope outside, in case an accident happens… so that way [the person in the drawing] doesn't fall into the latrine. [On the right side] I'm showing you that we are happy now. I can be using my latrine in safety…there is no rope anymore…I have a garden around my latrine. Even my little dogs go with us as companions to the latrine. Now I can feel the change, I am happy, my family is happy…It is my child playing on the patio…There is no problem, there is no danger, there is no risk.

Figure 3: Increased privacy, security, comfort.

4.2.5. Learning New Technologies & Fertilizer. AN community partners' decision to build composting latrines required them to adjust to FSM processes that are not typical for their region. Such adjustments require both mind and behavioral changes. As Mercedes, a group member, shared, "This new technology of the composting latrine is a whole new experience because the process of building, using it, and maintaining it is different." But similar to other respondents, she recognized that "it's a great experience," which is broadened her and her group members' horizons.

Once people adjust to the technology, one of the selling points of composting latrines is the fertilizer. Many participants referenced this as impactful because they now use it not only in their flower gardens but also in their fruit and coffee trees.

4.2.6. Savings. Participants also reflected on the savings associated with composting latrines. It helps "save a lot of money," Denis, a group member, told us, "because once the life of the traditional latrine is over, we have to dig another hole, and we have to pay more money for another traditional latrine…digging a traditional latrine, it's very expensive."

In 2023, the 107 composting latrine users in the study's four focus areas recorded an estimated total of $44,000.00 in savings since the start of their projects. While the most significant savings come from no longer having to build new pit latrines, owners also mentioned how they are spending less on fertilizer, cleaning supplies, and pesticides. Anand and Apul (2014) found similar evidence, confirming that if adequately cared for, a composting latrine represents a one-time investment with many returns.

4.2.7. Stronger Relationships. A final theme pertains to communal relations. Group member Ana shared a photo of her and her neighbor (see Figure 4). Ana described her photo as follows:

> In this photo, I am with my neighbor…[her] patio is above mine. During the winter, when we had traditional latrines, we always had conflicts because her latrine would fill up, and everything that came out of it would flow into my patio. Since we have composting latrines, my neighbor and I live in harmony, and we no longer have conflicts. The composting latrine brought us peace in the neighborhood.

Figure 4: Strong Relationships.

The theme of *Stronger Relationships* represents a smaller number of coded segments yet captures a vital component of community life. It illustrates how access to latrines that are well-maintained, functional, and impactful can significantly improve relationships between community members.

5.0 Factors Contributing to Project Sustainability

From interviews with leaders from the four different communities, three themes emerged as factors contributing to successful project implementation and sustainability (see Table 3).

5.1 The Group Factor

While project participants shared that solving their sanitation problems brought them a sense of unity with their community, leaders spoke about how working together in groups contributed to their projects' successes. For group work to be effective, as Claudia emphasizes, "you need to be organized as a group…because being a group has more strength than being individual…You will achieve more as a group…" When we asked Felix whether he had advice for groups interested in addressing their sanitation challenge, he also spoke about unity. He suggested "they should come together and be united. Work together. Support each other because that's the way they can solve their problems."

Initially, the groups addressed members' limited access to proper and safe sanitation. However, collective action should also extend to developing plans to ensure project sustainability. To this end, leaders shared about their maintenance plans, ensuring that they have the necessary support in place for when members' latrines need repairs. Just like working together to identify the solution, group work is also important to sustain the solution in the long term. Such sustainability implies having a long-term vision and accompanying plans.

The group factor echoes existing scholars' emphasis on the importance of collective action and collaboration between implementing organizations and local communities, but also between community members themselves (Waterkeyn & Cairncross, 2005). When communities are organized and share a collective action agenda, as McGranahan (2015, p. 243) argues, they can "overcome some of the institutional deficiencies of poor sanitation infrastructure." Facilitating the formation of community groups that can facilitate meaningful group activities and community-led projects holds significant potential for successful and sustainable sanitation interventions, composting latrines being no exception.

5.2 Involved Local Leaders

Behind any successful group are individuals with leadership responsibility. Active local leadership is, therefore, an important sustainability factor and a second theme emerging from interview data. Leaders described their responsibilities in raising awareness, training, monitoring, and ongoing support.

Leaders shared how there might often be little awareness among group members of the causes and effects of poor sanitation. During their conversations with group members and also when facilitating meetings, leaders, therefore, focused on deepening people's understanding of sanitation concerns and best practices in addressing such concerns. Then, after groups identified composting latrines as the most suitable solution, leaders were further instrumental in conducting training on

what composting latrines are and how to use them. As Karla explained, "During the time we were analysing the issue, we trained the family who was going to have the latrine how to use it, how to maintain it to guarantee it was going to be a long-term project."

Local leaders also play a pivotal part in follow-up usage and maintenance monitoring. In cases where households neglect their maintenance responsibilities, it is leaders who encourage households to stay the course. When asked how she does this, Claudia shared that she would

> …bring households back to the original issue, reminding them of why the composting latrine is an appropriate solution…we would remind the families what their problem was in the past to keep them aware of the situation in the past to keep them using the latrine.

Research has shown that involving local actors, including natural leaders, teachers, and health workers in CLTS, can increase interventions' sustainability (Harter et al., 2019; Crocker et al., 2017). When introducing new technology, in this case, dry composting systems, programs are therefore more likely to see success if implemented by local groups and their leaders.

5.3 Let the Evidence Speak for Itself

A third theme emerging from leaders' interviews captures strategies of introducing community members to the new technology, recruiting prospective composting latrine users, and keeping new users motivated to use and maintain their composting latrines appropriately.

For AN's community partners, the first set of latrines, built in 2010, served an essential purpose. These latrines became the learning venue for other community groups interested in adopting the technology. Karla shared how the cross-learning experience was pivotal in getting her group interested in using composting latrines:

> My group of composting latrines was the second group in the community. So already in our community was a group with composting latrines. When I saw the families using composting latrines, we started to investigate…how they are built, how we can get one. Our group also did a mobilization to different families in the community [who] already had composting latrines, how they are functioning. We fell in love with that type of design. We organized in the community, and we started to mobilize for resources.

Limited funding, especially during the first phase of groups' composting latrine projects, meant that not all group members could access a latrine. Group leaders, therefore, had to develop selection criteria. Karla added that who they chose as first owners then ended up influencing their project's overall success:

> I think one important factor [for sustainability] is when we are selecting the family that would get the toilet. [They were] families showing interest in solving their problem and also having the issue that was impacting the family.

By starting with those households, local leaders established a strong track record. Initial households reaping the benefit of their newly acquired latrines began discussing these benefits with their neighbors. Such initial benefits also become crucial data points for new owners to stay the course. Claudia explained how being reminded of the benefits at the beginning of the project was necessary. She shared that "when we were visiting these families, they were giving testimonies and sharing with us the benefits…how they use it. So we start[ed] to be aware of the technology of the composting latrine to solve our problem."

6.0 Conclusion and Recommendations

Research considering the role composting latrines can play in addressing challenges in global sanitation shows that the technology has not been as popular because of higher implementation costs, low adoption and usage rates, and maintenance challenges (Mkhize et al., 2017). These challenges, our findings illustrate, were not strong enough to prevent the successful implementation and ongoing usage of composting latrines for four community groups in Nicaragua. On the contrary, users reported continued usage of their systems as long as 13 years after implementation. While some latrines are no longer in use, this is because of outmigration or households relocating, leaving their homes vacant.

Context-specific solutions will yield context-specific benefits. Research participants reported such benefits, including access to fertilizer and savings from no longer replacing their pit latrines. Plus, the themes emerging from participants' most significant change stories provide the basis for future research exploring the non-physical impact of improved sanitation. As Sorcher et al. (2023) hold, expanding on a non-physical list of outcomes related to improved sanitation can strengthen organizations, local communities, and practitioners' case for increased funding and ongoing investment in sanitation. Our findings on ongoing usage rates and meaningful benefits provide a strong foundation for follow-up research exploring further how composting latrine interventions can be sustainable and impactful long past project implementation.

A recent systematic review focused on gaps within Water Sanitation and Hygiene (WASH) in the humanitarian sector includes mention of the "how," i.e. better mechanisms to provide services (Yates et al., 2023). Our findings can act as a potential recommendation list to strengthen sanitation interventions. While these recommendations emerged from the context of Nicaragua and composting latrine projects, we believe they can also be applied to other sanitation contexts.

The recommendations are, however, directly linked to community-led processes that facilitate meaningful participation and local ownership. As demonstrated by Alcance Nicaragua and its community partners, local ownership starts when those most affected by sanitation challenges identify and analyse them themselves, then seek solutions most appropriate for their contexts. After identifying solutions, in this case, composting latrines, it is the community groups themselves who manage and monitor these projects. Post-implementation monitoring, as Sabogal et al. (2014) have seen, contributes to overall project sustainability.

Alcance Nicaragua and its community partners' sanitation projects illustrate that composting latrines can be a safe and effective alternative to other sanitation systems, especially considering current challenges around fecal sludge management. As in the case of the Nicaraguan households featured in this study, people can adjust to alternative approaches to sanitation. Such an adjustment is even more possible when interventions prioritize community-led approaches to development.

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