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Practical Paper

Lessons learned from a Tiger Worm Toilet implementation project in Sierra Leone

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ABSTRACT

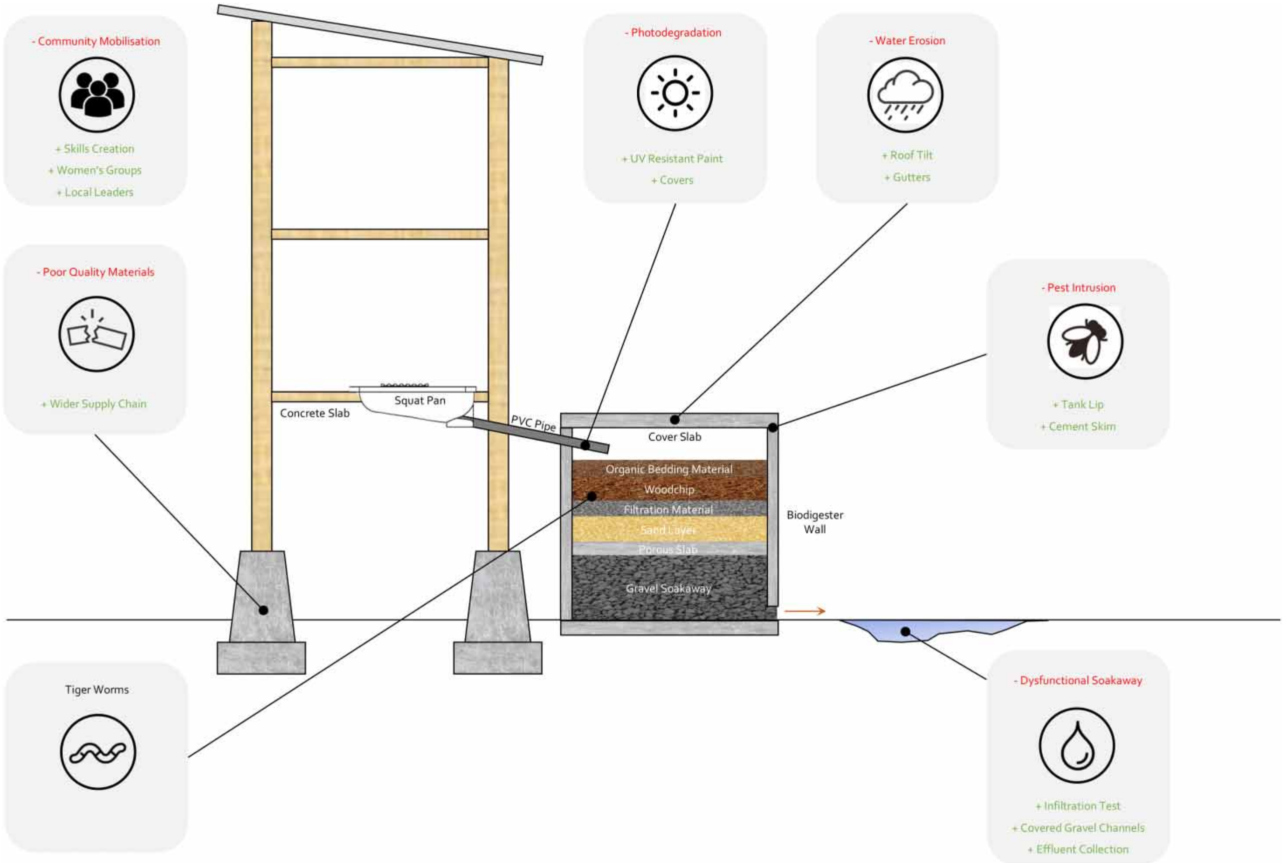
This paper discusses the implementation of Tiger Worm Toilets (TWTs) as a sustainable alternative to pit latrines in areas with challenging environmental conditions. The study was carried out in Koinadugu, Sierra Leone, where TWTs were installed in 200 households, providing safe sanitation for approximately 1,200 individuals within a 17-month period. The study reveals that TWTs offer several benefits over traditional pit latrines, including higher cost efficiency. Despite some setbacks, TWTs have been well-received by the local communities, resulting in a significant reduction in open defaecation in areas where latrines are not viable. The study presents areas of further research and concludes with recommendations for future TWT designs based on the lessons learned.

Key words: pit latrine, sanitation, Tiger Worm Toilet, vermifiltration, worm-based sanitation

HIGHLIGHTS

- Community engagement facilitated the adoption of TWTs and ensured ongoing cooperation and financial viability.
- A sustainable design is presented to prevent fly nuisance and rainwater infiltration in TWT biodigesters.

GRAPHICAL ABSTRACT



INTRODUCTION

The disposal of human waste is an important public health and environmental issue that requires effective and sustainable solutions. Pit latrines are a common form of sanitation in many areas of the world, but they have drawbacks that include costly and logistically difficult emptying when full, the potential for exposing sanitation workers to harmful pathogens during emptying, and unpleasant odours. In the past decade, the development and implementation of the Tiger Worm Toilets (TWTs) has been suggested as an innovative approach to address these issues (Furlong *et al.* 2014, 2015). TWTs are similar to pit latrines but use a worm-based ecosystem to break down human waste *in situ*.

TWTs comprise a biodigester tank containing *Eisenia fetida* worms residing in layers of organic bedding material, such as coconut husks or woodchips. Beneath the bedding layers, a sand and gravel drainage system ensures the aerobic conditions necessary for the worms to survive and function optimally (see Graphical Abstract). The worms consume faecal matter that enters the biodigester via a pipe or hole from the toilet, and produces a humus vermicompost and a liquid effluent. The vermicompost is a dry, odourless solid that accumulates within the digester, while the liquid effluent drains into the surrounding soil. Research has shown that TWTs remove over 98% of faecal coliforms over a 24-hour treatment period (Eastman *et al.* 2001), as well as the effective removal of chemical oxygen demand, thermotolerant coliforms, and total solids from the effluent (Furlong *et al.* 2016). Additionally, TWTs are efficient at reducing the solid fraction of the waste, resulting in a lower pit fill rate than traditional pit latrines (Eastman *et al.* 2001; Lalander *et al.* 2015). Hylton *et al.* (2022) estimated the fill rate of Tiger Toilets to be one-half to one-third the rate of a pit latrine of equivalent size and the number of users. The use of TWTs has already been proven to be a cost-effective and accepted technology for on-site sanitation in several countries, making it a promising alternative to traditional pit latrines (Hussaini 2013).

The objective of this paper is to present current information regarding the implementation of TWTs, based on a recent case study in Koinadugu, in the Northern Province of Sierra Leone, to guide professionals in the development of this technology and ensure its success as a viable sanitation solution in new settings.

METHODS

The urban slums in the district of Koinadugu are characterized by their inadequate sanitation facilities, which face challenges posed by the high-water table and rocky terrain. This has resulted in the need for shallow pits that become full within a year, leading to the prohibitive cost of re-digging latrines, and ultimately, an increase in open defaecation. Hence, TWTs were a particularly attractive option here, as the biodigester could be designed to be only partially dug into the ground, while the worm bedding and the toilet pan could be raised over the maximum flooding height.

A total of 86 potential locations for TWTs were identified in areas that either had rocky terrain or a high-water table. The engagement of the local community in these locations was a vital step in sensitizing them to the TWT project components, to gain acceptance and ensure its viability as an intervention. This process, which lasted approximately 3–4 months, helped to address misconceptions and scepticism surrounding the concept of introducing worms in toilets. Moreover, it helped to minimize potential disputes around household selection, siting, and use of the TWTs, helping to successfully identify 200 households through consultative bodies involving 10 community representatives, and ultimately saving time during the implementation phase. The selection of households was based on criteria such as extreme difficulty in digging pit latrines in areas such as hard rock and waterlogged sites and the willingness of all households in the area to receive a TWT and to follow guidelines on how to use this new technology.

The project aimed to mobilize community members in various ways according to their type of involvement with the TWTs. Beneficiaries were urged to take ownership of the project by contributing 60,000 Leones (£6) towards the funding of the TWTs. Women's groups were targeted for training in setting up and managing the wormeries, with the dual aim of supplying worms to the beneficiaries while promoting women's economic empowerment, which has been highlighted as an important factor in previous studies (Maili Saba Research Report 2005). The methods used in this study were reviewed by Oxfam GB in line with their Ethical and Environmental Policy.

RESULTS AND DISCUSSION

Despite best efforts, it was observed that community members were not sufficiently proactive in addressing problems that arose during the project. To address this, it was necessary to enlist local leaders to help encourage communities to exert more effort in bringing the project to completion.

To establish the wormeries, it was crucial to determine the number of users per latrine. Surveys were conducted to determine latrine ownership and usage patterns among households targeted for TWTs. The results showed that 73% of households owned their toilets, while 19% shared them with neighbouring families. Of the shared latrines, 27% had 10–15 users, 22% had 16 or more users, and only 12% had 5 or fewer users. Based on this information, it was determined that two wormeries would be established through the participation of two women's groups. To accomplish this, 40 technicians of mixed genders (16 women and 24 men) were identified and trained.

Procuring high-quality materials for the construction of the TWTs posed a significant challenge. Several key materials required for the construction of the TWTs were not available locally and had to be obtained from Makeni City, one of the largest cities in Sierra Leone, which was situated over 95 km away from the study site. Among these materials, coconut shells and high-quality materials required to make ceramic toilet bowls were particularly critical to the design and proved difficult to source. This resulted in a delay of approximately 3 months in the implementation of the project.

There were also several design issues encountered during the implementation of the TWTs in Koinadugu. Namely, the soakaways, intended to allow effluent from the toilets to infiltrate into the soil, were found to be ineffective in 90% of cases, leading to contaminated groundwater. While this is not an issue isolated to TWTs, e.g. septic tanks also need functioning soakaways, the infiltration of the liquid fraction of the waste into the surrounding soil is a determinant of the fill rate, and therefore, it is recommended that an infiltration test be conducted prior to construction (Hylton *et al.* 2022). If the test shows poor infiltration, gravel-filled channels or larger pits may be necessary, lined with plastic sheeting to prevent mud from entering.

Another issue was the entry of flies into the biodigester through gaps in the walls and reinforced concrete slabs. A temporary solution involved the installation of mosquito bed nets to cover the biodigester tanks, and while this proved effective in preventing flies from entering, it is not a sustainable solution due to the need for annual replacement. Many groups expressed reluctance to bear the high cost of 45,000 Leones (£4) per net. Therefore, it is recommended that future TWT designs incorporate a lip around the edge of the biodigester tank to ensure that the slabs fit inside it. However, the construction process would require close supervision and skilled labour; therefore, a lower-risk alternative would be to apply a cement skim covering all of the cracks, except for one out of the three slabs, to allow for observation, inspection, and emptying. Rainwater was also found to be eroding the slabs of the biodigester and inundating the wormery, leading to worm death. Simple guttering or repositioning of the roof could alleviate this issue and also provide a means for rainwater harvesting, which can mitigate flushing issues faced by users, particularly during the dry season.

To ensure the long-term sustainability of the TWTs, all households included in the project received 'good practice operation and maintenance training', which involved raising awareness among the households on how to best maintain their TWT, including avoiding using it for disposal of anything other than human waste and not using chemicals to clean it, as this would be toxic to the worm population. A Knowledge, Attitudes and Practices (KAP) survey was conducted to observe to what extent this training was complied with. The survey involved visiting approximately 86 TWTs located in three different environmental contexts, namely rocky areas, areas with high-water tables, and areas where pit latrines could have been used. The visits established that the TWTs were in excellent condition, being regularly used, and cleaned by the beneficiaries. Additionally, regular monthly assessments of the beneficiaries' public health awareness, hygiene practices, environmental cleanliness, and open defaecation showed a significant decrease in open defaecation and an increase in hygiene knowledge.

The viability of selling worms by women's cooperatives after the project was assessed through interviews with two groups consisting of 20 and 25 women, respectively. During the project, these groups collected water, food waste (which they paid for), and cow and goat dung to feed their wormeries. The worms were sold to Oxfam at a rate of 40,000 Leones/kg (£3.6/kg), which barely covered the collection expenses. The sales ceased after the project ended; however, the women continued to collect food waste and dung for the wormeries.

From a technical standpoint, the TWTs should remain operational indefinitely without the need for additional worm supplies as long as they are used and maintained correctly. The number of eggs laid by the worms is dependent on the amount of 'food' present, and the worms will increase or decrease with the supply. According to previous research on TWTs, the bedding material of coconut husks would need to be replaced every 3–4 years, and vermicompost removed every 5 years. Additionally, due to the poorer quality of construction and materials often found in low-income settings, it is expected that the sand cement block biodigester will require repairs every 4–5 years. The PVC pipe from the toilet bowl to the biodigester may become brittle over time when exposed to sunlight but can be painted with UV-resistant paint or covered to minimize damage. If necessary, the pipe may need to be replaced and covered every 4 years.

The two groups of technicians who performed the paid labour on the TWTs were interviewed and asked to provide feedback as part of an investigation into the sustainability of the TWTs post-project completion and their replicability by the local community, private sector, and local authorities. Both groups expressed confidence in their ability to build the TWTs if needed and one group even reported having built a privately funded TWT for a household after the project's completion. There have been many requests for TWTs across Koinadugu District, both from its capital Kabala and from rural areas, indicating high market demand. However, according to a focus group, participants were willing to spend only 12% of the cost on a TWT. Therefore, it is unlikely that local people can finance their own TWTs without external support.

A comparative cost analysis was conducted to determine if TWTs were an economically feasible option in this region of Sierra Leone. The cost of owning a toilet was assessed based on several factors, including construction costs, lifetime of the toilet, number of users, installation costs, and emptying costs. The cost of owning a TWT was compared to the cost of a pit latrine and other locally available toilet options (Table 1).

The capital cost of a TWT was found to be slightly lower than that of a mud brick toilet with an unlined pit. The material costs far outweigh the labour costs of constructing a TWT, with the pre-fabrication of cover slabs, porous slabs, and block moulding costing £43, the purchase of materials for the construction and installation of the biodigester amounting to £122, and materials for the construction and installation of the superstructure amounting to £154. While some capital cost-saving techniques are available – such as using cheaper materials to build the biodigester and superstructure – altering the design is not recommended as this can lead to higher repair costs in the long run. For instance, a cheaper model of TWT was previously tested by Oxfam in Ethiopia, which excluded the porous slab, resulting in the washing out of worm eggs into

Table 1 | Cost[a] comparison of toilet options in Koinadugu, Sierra Leone

Type of toilet	Installation cost (£) Material cost (£)	Installation cost (£) Labour cost (£)	Lifetime of toilet (years)	Number of users	Cumulative cost (£) After 5 years (£)	Cumulative cost (£) After 10 years (£)
Mud brick toilets with unlined pits	323	111	1	16	2,170	4,340
Unlined pits with makeshift super structure	92	92	1	10	920	1,840
Lined septic tank with water closet	692	231	5–10-year desludging	12	923	1,015
TWT	319	100	5–10	1–10	419	419

[a]Unless otherwise stated, the costs provided in this paper were obtained through Oxfam International's operations and observations in the field.

the soakaway and incurring a new cost of replacing the wormery. Furthermore, the improvements discussed above would not add to the cost, as they represent only a slight difference in the way the TWT is constructed. A covering material is not budgeted for as it is assumed that people would use their own firepit ash or free sawdust; however, none of the families in this project were buying covering material.

TWTs present a clear financial advantage over time, as the fill rate of Tiger Toilets is estimated to be only one-half to one-third the rate of an equivalent pit latrine, and therefore, the life of a TWT is expected to be at least 10 years (McBride *et al.* 2017; Hylton *et al.* 2022). Hence, there are no emptying costs associated with a TWT for the first 10 years of its life, which explains why its cost remains identical for 5 and 10 years after installation (Table 1). In contrast, in the context of Koinadugu, which presents a combination of rocky terrain and risks of flooding, the unlined pits evaluated for this study were typically very shallow as there was only 1 m of soil before hitting the rock. This, combined with the absence of a pit lining to reinforce the structural stability of the pit, meant that attempts to empty the pit would cause it to collapse, and so the pits required complete rebuilding every year. This is a particularly onerous process in areas with high-water tables or rocky ground. However, even lined pit latrines would need emptying every 5 years (Brouckaert *et al.* 2013). Moreover, in the absence of desludging facilities in Kabala, households would need to hire a company based in Freetown for any desludging service, which would cost between £46 and £184 for pits and roughly £92 for emptying a septic tank – an amount that would be prohibitively expensive for most households (Bennett *et al.* 2011).

CONCLUSIONS

The project successfully delivered 200 TWTs to households in the targeted area, providing safe sanitation for approximately 1,200 individuals within a 17-month period, despite some setbacks. The post-implementation viability study conducted in Koinadugu demonstrated the effectiveness of TWTs in providing multiple benefits to the local communities, resulting in high demand for the TWT technology. TWTs have proved to be a cost-efficient alternative to pit latrines and have been well-received by the local communities, resulting in a significant reduction in open defaecation in areas where latrines are not viable. Monitoring surveys have shown that the programme has been successful from the beneficiaries' perspectives, with high satisfaction levels at living in a defaecation-free environment and requests for more TWTs in the surrounding area. TWTs have also offered additional opportunities for improved livelihoods and skills training for both the women's cooperatives and local technicians. The success of this project has encouraged the Sierra Leone government to implement this technology in the capital, Freetown, where the effect of reduced open defaecation and pit fill rates would be felt even more sharply due to the densely populated urban environment.

This investigation has yielded important insights into the design of future TWTs and has identified areas for further research, including the prevention of effluent seepage into the surrounding soil and the protection of the biodigester from flies and water erosion to ensure the well-being of the worms.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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