Technical Brief

Sanitation in Challenging Environments: The All Seasons Upgrade (ASU) Product

Pour-flush pit latrines in dense or saturated soil conditions with high groundwater fill up quickly, especially in the rainy season. Latrine owners in these areas often resort to unsafely emptying or discharging their latrine pit contents into the environment. What type of products would allow households in these areas to safely use their toilets year-round?

Context

A "challenging environment" refers to a location where it is either difficult to construct conventional latrines or where the use of conventional latrines is likely to contaminate the surrounding environment, particularly groundwater and surface-water resources.[1] In Cambodia, these challenging environments include areas with low infiltration due to high-clay soils, naturally high groundwater, and/or seasonal flooding. In these environments, liquids seep into the ground at significantly slower rates or cannot be absorbed or infiltrate into the ground. As a result, latrine

[1] National Guiding Principles on Sanitation in Challenging Environments for Rural Households. Ministry of Rural Development in Cambodia, July 2019.

pits fill up at a faster rate. Once full, the toilets are unable to flush resulting in households adopting unsafe mitigation measures. Such measures include releasing fecal sludge into the open environment by opening the pit lid during a flood; putting a hole in the pit wall; or stopping latrine use and reverting to open defecation.[2] The sanitation and health challenges that households in these areas face are expected to be further exacerbated by climate change.

Project Background

iDE partnered with Engineers Without Borders (EWB) Australia to develop and test aspirational, affordable, and market-viable sanitation in challenging environments (SCE) technology.

Between 2017 and 2018, iDE and EWB field tested the 3-Chamber Pit (3C Pit)[3] and Sky Latrine as a combined SCE technology for flood-prone environments in rural Cambodia. The Sky Latrine differs from typical Cambodian latrines as it is constructed inside a stilted house rather than a shelter outside. Based on principles similar to those of a septic tank, the 3C Pit chambers were designed to provide primary settling, followed by primary treatment through gravel filter media, and finally discharge of treated wastewater into the soil. The prototyping and field testing phase showed that the 3C Pit was difficult and costly to construct to appropriate standards of quality, requiring four unique concrete molds and significant training for local masons.

In early 2019, iDE and EWB used the lessons learned from the 3C Pit to design the All Season Upgrade (ASU) product. ASU is meant to provide year-round pit functionality (i.e. flushing) in high groundwater and low infiltration soils. Because the pour-flush latrine pit design has become the standard in Cambodia's rural sanitation market—with roughly 80% of the rural population now owning one[4]—a SCE product upgrade that can connect to an existing pit was considered more marketable than a new alternative design to the standard pit.

Intervention

The ASU is a latrine upgrade product that attaches a gravel filter pit and leach field to an existing latrine pit, providing year-round latrine pit functionality and preliminary treatment of wastewater before discharging into the environment (see figure 1). The filter pit is filled with gravel and offers an additional treatment reactor for reducing biological oxygen demand (BOD), turbidity, and pathogens, and prevents the leach field from clogging. The leach field is designed to increase surface area for infiltration at a depth above the groundwater table, but deep enough to prevent the upward flow of contamination to the surface. The ASU design first diverts the existing pit contents into a filter pit where it undergoes primary treatment. Then it releases the treated content into the soil through a high infiltration leach field. As a result, the ASU minimizes households' exposure to untreated fecal sludge, improving latrine functionality, and reducing environmental pollution.

With the design developed, iDE and EWB engineers conducted small-scale and full-scale prototyping to validate the product's specific design features and functionality. Then, between 2019 and 2020, a one-year field test pilot of the ASU system was performed to: (1) test the

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[2] Context and intentions: practical associations for fecal sludge management in rural low-income Cambodia. Harper, et. al., Journal of Water, Sanitation & Hygiene for Development (2020) 10 (2): 191-201.

[3] Small-Scale Wastewater Treatment Technologies For Challenging Environments. Bukauskas, et. al., 2018

[4] Report of Cambodia Socio-Economic Survey 2019/20. National Institute of Statistics Ministry of Planning, December 2020.

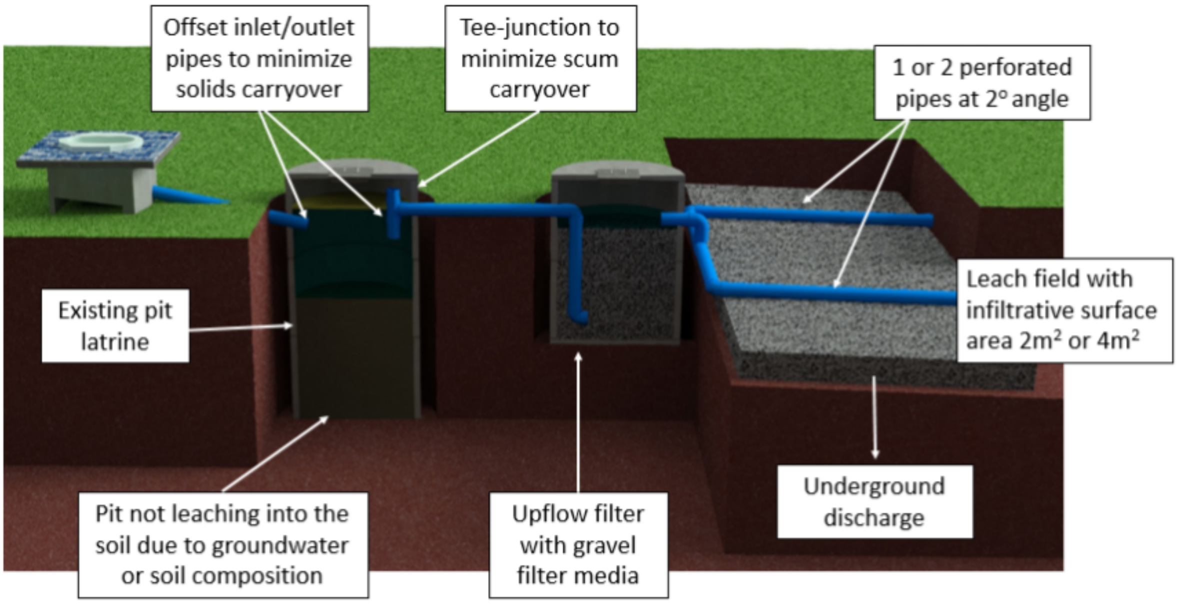

Figure 1: All Seasons Upgrade Product Design Overview

treatment effectiveness of the product to meet standard levels of safe disposal into the environment and (2) understand the functionality and contextual appropriateness of the product.

The product development team selected 14 households in Kandal province for the pilot study. Household selection criteria included living in environments with high groundwater and/or low infiltration, experiencing higher pit filling rates, and practicing unsafe fecal sludge management (FSM) practices. To ensure sufficient infiltration for households with soils primarily composed of clay (low infiltration), a two-pipe system with a $4m^2$ leach field was installed. For households in high groundwater areas with soils primarily composed of sand (high infiltration), a one-pipe system with a $2m^2$ leach field was installed.

To evaluate the effectiveness of the ASU system at improving wastewater quality, wastewater and soil samples were collected from all 14 households every two months during the one-year pilot period. For each of the six rounds, wastewater samples were collected at point A (latrine pit), point B (filter pit), and point C (leach field) then tested in a local laboratory for biochemical oxygen demand, total suspended solids, and E. coli concentrations. Soil samples were collected from point D (soil surrounding latrine pit) and point E (soil surrounding leach field) and tested for fecal coliform concentration.

Additionally, field observations and qualitative user survey questions were used to understand the households' willingness to pay, customer satisfaction, and overall functionality of the ASU system.

Key Findings

ASU improved latrine functionality

Overall, the ASU product met its objective by providing continuous latrine functionality throughout the one-year testing period, despite seasonal changes. The trial demonstrated that by increasing wastewater infiltration, the ASU can increase pit capacity and reduce pit emptying frequency in high groundwater and low infiltration areas.

- The ASU product eliminated bad smell, reduced overflow, and significantly improved ease in flushing (Figure 2).
- All households expressed a level of satisfaction with the ASU and expressed interest in continuing to use it after the one-year pilot study period.
- For an average household size of 4.4 members[5], the ASU can provide a lifetime of roughly four years[6] of use before emptying is needed. This is comparable to a standard pour flush latrine in a non-challenging environment in rural Cambodia.

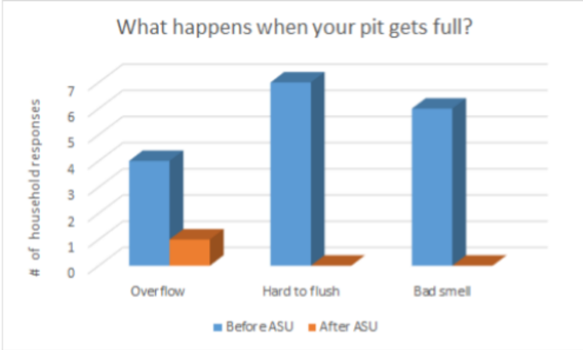

Figure 2: Households' Responses Before and After ASU Installation

ASU provided safer disposal of fecal sludge

Due to field sampling limitations, not enough data was collected to conclusively evaluate the treatment effectiveness of the ASU system. Nonetheless, the data showed that ASU is a significantly safer choice than discharging raw wastewater into the environment, reducing household exposure to wastewater-related pathogens.

- Within two months of ASU installation, BOD concentrations were low enough to meet safe effluent BOD standards[7]. The decreasing trend over time hints that the ASU system could reach even lower concentrations (Figure 3).
- Over the six rounds of sampling, the average latrine pit E. coli concentration was reduced by 69% as it traveled through the system and reached the leach field. However, the average E. coli concentration at the leach field does not reach the effluent standard[8] (Figure 4).
- Outside sources of surface contamination due to feedstock and animals were thought to have impacted soil sample testing around the latrine pit and leach field. Nevertheless, data showed the ASU to have some effect in reducing the fecal coliform concentration content in the soil. These safer levels of fecal coliform in the soil are assumed to be due to eliminating surface-level, direct raw wastewater discharge from the latrine pit.

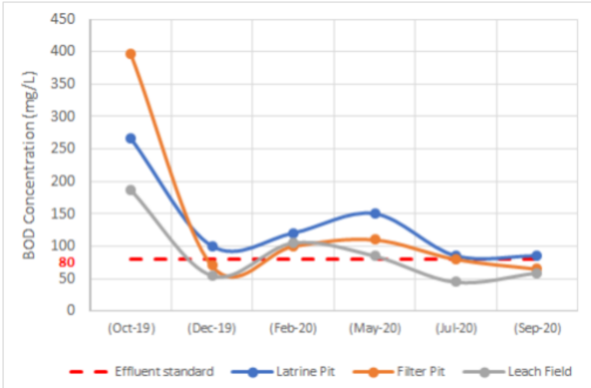

Figure 3: Change in BOD Concentrations Over Time

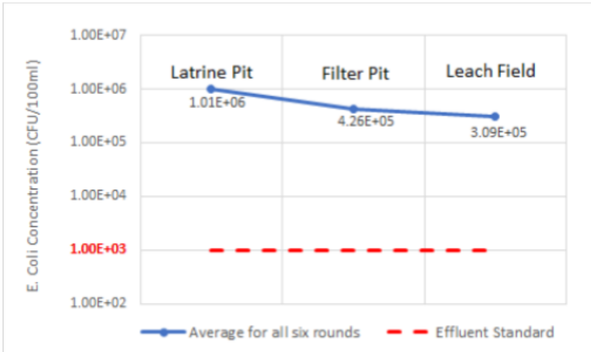

Figure 4: Change in Average E. Coli Concentrations

[5] Household size for Kandal Province. Table 2.2 in General Population Census of the Kingdom of Cambodia 2019. National Institute of Statistics Ministry of Planning, June 2019.
[6] Calculated using a density of 1.06 g/ml and a median fecal wet mass production of 128 g/cap/day based on The Characterization of Feces and Urine: A Review of the Literature to Inform Advanced Treatment Technology. Rose, C. et. al. (2015). Critical Reviews in Environmental Science and Technology.
[7] BOD_5 (5 days at 200 C) < 80 mg/L. Sub Decree On Water Pollution Control. Ministry of Environment, The Royal Government of Cambodia, 1999.
[8] Concentration of E.Coli upon disposal to any land < 1000 CFU/100ml. WHO Guidelines For The Safe Use Of Wastewater, Excreta And Greywater, Volume 1. WHO, 2006.

Lessons Learned and Recommendations

The inherently more complex and expensive nature of sanitation technology in challenging environments requires further planning, design simplification, and appropriate financial considerations.

- The ASU design and construction process can be simplified further (e.g. reduce large space required for leach field) to reduce overall retail cost. The material and installation cost for ASU was on average: $80-90 for a single pipe or $115-130 for two-pipe system. Clay soils particularly have higher construction connected costs as they prevent a latrine pit from being excavated manually.
- Consider financial tools (e.g. payment installment plans, targeted subsidies,[9] etc.) for SCE technology that are more affordable for rural households and lower income populations.
- The ASU is recommended to be installed during the dry season to prevent surface or groundwater from impacting the construction process, particularly water entering the system while digging.
- Since all households surveyed had claimed a lack of familiarity with the ASU, further marketing and educational efforts are likely needed to increase demand for the product.
- Further safe FSM considerations are needed for the ASU, as it does not prevent the need for eventual emptying.

There is a need for improved methods to identify where SCE technology is appropriate.

- For the ASU pilot project, it was a significant challenge to identify households living in challenging environments where a standard latrine would fail and the ASU would be appropriate. There is a clear need for practical tools and validation criteria to map, identify, prioritize, and target challenging environments at the household level.

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[9] Tactic Report - Reaching the poorest with sanitation through targeted subsidies. iDE Cambodia, 2020.