Designing a Low-Cost **Urine-Diverting Toilet Seat**

Challenge:

To design an inexpensive urine-separating toilet seat that can be integrated into a composting toilet system appropriate for households.

Access to adequate sanitation systems is a huge issue in the developing world.

Pit latrines are currently the most prominent option, but are expensive and often unavailable, as well as smelly and unhygienic. Once full, there is rarely an infrastructure in place to handle the waste safely. Often, then, pit latrines must be replaced entirely.

The urine-separating composting toilet.

A urine-separating composting toilet has several key advantages over pit latrines:

- Smell is significantly reduced when urine and feces are separated before coming into contact with one another.
- Adding soil/ash dries the feces and largely eliminates both smell and flies.
- Urine is available almost immediately for use as fertilizer.
- When feces are left to compost for 12 months, they can be safely removed and used as fertilizer.
- The system requires no water.

However, composting toilets are often expensive alternate options to the pit latrine, and have not been considered seriously for use as household toilets.

Our product.

This paper presents a lightweight concrete urine-separating toilet seat that can be integrated into a reduced-cost composting toilet system. It is made using latex, which adds to the concrete a flexibility that reduces both its vulnerability and reduces the amount of cement needed. It is designed to be lightweight such that the bench on which it sits requires less structural rigidity, and thus is less costly.

Photo credit: Jonathan Lau. Location: Tamale, Ghana

Key components:

1. *The seat:* this is the user interface and separates out the urine from feces.
2. *Collection:* collects the feces after separation.
3. *Composting:* stores the feces as composting happens over the course of approx. 12 months.

The cost of a composting toilet can be reduced when its key functional components are isolated and dealt with separately.

The composting toilet system consists of two separate units: the toilet itself and the composting pit. This differs from more classical designs in that the toilet is not situated directly on top of the composting site so as to avoid contact with feces before it has been fully composted.

Our motivation for having the composting separate from the toilet itself was to minimize costs:

- The structural requirements when the toilet is located directly on top make the superstructure expensive.
- A composting site can be shared among several families, while private ownership of the toilet is still retained. This will decrease the cost of the site.
- The composting site does not have particular specifications: depending on the capacity needed, it can be anything from an above- or below-ground pit to garbage containers.

The urine-separating toilet seat.

There are currently no commercially available separators that fit into this design and that are low-cost. A plastic model can be purchased from Ecovita at $115.

How it works.

A bucket is placed underneath a toilet bench. Urine are feces are separated into separate containers via the urine-separating toilet seat, which sits in the bench. Urine goes through a tube to a jerrycan outside the back of the toilet. Feces drop into the bucket and are covered with a ash/soil mix after each toilet use. More is added if the smell is bad: the drier, the less smell. Every week or so the bucket is taken out through a small door at the back of the toilet structure and dumped into the composting pit. It is then put back for continued use. The composting pit has two separate compartments, one of which is used at a time. Before use of a compartment, the bottom of it should be covered with leaves and some soil. Once the compartment is full (or at desired capacity), it is left for 6-12 months during which time the other compartment is used. After 12 months it should have become a soil/humus and can be emptied out and used as fertilizer. The urine can be used for watering fairly immediately since urine is mostly sterile. WHO advises that one waits a month before use.

Functional Requirements:

- ***Design captures 90% of urine:*** our seat aims to reduce smell and flies by separating the urine from the feces.
- ***Costs less than $30 and made from locally available materials:*** the goal of the project is to make urine-separating seats affordable.
- ***Weighs less than 5 kg:*** our seat will be resting on a larger structure built by its users. We want to minimize the structural requirements of this structure to keep cost low.
- ***Robust, with a life-span of approx. 2 years. This means:***
    - *Tubing can be attached and removed 50 times.*
    - *A point force of 400N will not crack the rim.*
    - *The separator can be dropped from human height 5 times.*
    - *The rim can withstand 130 kg of straight pressure without cracking.*
- ***No sharp corners or small crevasses:*** for cleanability, we wish to keep the surface smooth and free of germs.
- ***No splashback on seat rim.***

Our community partner lives in a village in the Brong-Ahafo region, Ghana.

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Mr. Manu is a respected elder of New Longoro, located in the Brong-Ahafo region of Ghana, approximately a three-hour drive from Kumasi. He has previously worked with IDDS on the composting toilet team, and has taken ownership of the project in New Longoro.

A composting toilet system (toilet stall and composting pit) are in the process of being built next to the SDA church in New Longoro and will act as a prototype for user testing. Mr. Manu is a member of the SDA church and chose the site.

The toilet has two stalls: one will be fitted with the commercial Ecovita seat, while the other is to be fitted with our lower-cost urine-separating seat. The installation will happen in July during this year's IDDS.

The bin-bin composting toilet.

The pictures above show the composting toilet system as they currently stand at the site. The composting pit has been named "the bin-bin" because it has two separate compartments and "bin" is Mo (the local language) for "poop".

Conversations with our community partner identified the need for household toilets.

Cost breakdown: based on material use of bin-bin composting toilet in New Longoro.

4 bags of cement	=	56 cedis
300 soil blocks	=	30 cedis
4 roofing sheets	=	40 cedis
Nails	=	5 cedis
Innertube	=	4 cedis
Bench	=	10 cedis
Frames	=	20 cedis
TOTAL	=	165 cedis (~$100)

not including labor costs

The toilet situation in New Longoro.

New Longoro currently has a number of public pit latrines. *Very few* families own a toilet in their home.

The public latrines are plagued by intense smell and a vast numbers of flies. There are about four locations throughout New Longoro. The upkeep is poor, and one latrine location has recently reached capacity and so use has been discontinued. It has been left untouched and flies fly freely in and out of the pits. Typically paper is used for wiping, and then burned.

There are new toilets at the new rest stop. These operate via a mechanized pump and so are flush with a basket on the side for used toilet paper. These toilets are cleaned regularly and have very little smell and few flies. Outside is a urinal, which is also fairly smell- and fly- free. The toilets, however, are not intended for use by the general community. Furthermore, the mechanized pump at the rest stop is the only one in New Longoro and probably will be for a while still. The other pumps are all hand pumps and flush toilets are not generally an option as the water would have to be carried to the toilet.

Mr. Manu is particularly interested in household toilets, because this would eliminate the problem of no one taking proper care of cleanliness and general hygiene.

Costs.

Mr. Manu estimated the cost of building a household pit latrine (he is currently installing one for his mother at her home) to be approx. 250 cedis. Of this, digging the hole costs 100 cedis.

He further estimates that an average family would be able to pay

no more than 150 cedis for a household toilet.

If we budget $30 for the urine-separating seat, this leaves approximately $70 for the toilet and composting pit structures.

The cost of a structure based on the one set up by the SDA church has been broken down on the left. It should be noted, however, that this cost exceeds what could be built with similar functionality (e.g. using thatch and not bricks). Also, the materials are pooled and so do not distinguish between toilet structure and composting pit structure, despite the composting pit costs being shared by multiple families.

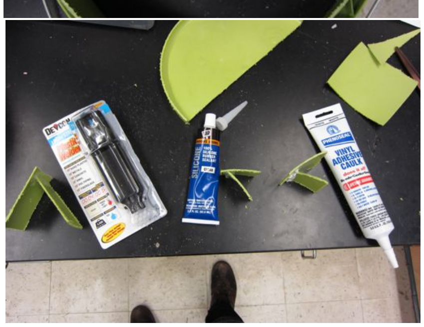
This does also not take into account the potential savings from fertilizer. A bag of fertilizer costs 25 cedis. An acre of land requires two bags of fertilizer.

Ideation and Concept Selection:

We chose to focus on keeping the current form factor and lowering the price of the seat by exploring various material options: wood, metal, plastic, ceramic, concrete.

All of our initial ideas considered a single material for the separating bowl. We eliminated composite materials for this iteration of our project to reduce the scope. However, we realize that for future iterations, composite materials may be a viable way forward.

Wood was eliminated early on due to its porous nature and being difficult to mold to our specifications at low cost. Given its local availability, clay seemed a viable option. However, we consulted with a clay expert and calculated that the required 2 cm thick separator would weigh about 50 lbs and still be brittle and prone to cracking.



PLASTICS

Plastic seemed the best option given our functional requirements. We considered both injection molding and vacuum forming as possible ways forward, but found that facilities were not available for low-cost manufacture. Given the results of a recent IDDS project (2009) on plastic recycling, we decided it was outside our scope to successfully design and construct a low-cost vacuum former. However, we continue to see this as a potentially powerful option.

Instead we shifted our focus to using plastic in its already existing form, choosing two readily available mediums: plastic water sachets and plastic buckets.

The plastic bucket.

We constructed a plastic prototype from a plastic bucket that we cut up. The advantages of this design were low cost (~$15), lightweight, and robust to being dropped. Furthermore, plastic buckets are found everywhere.

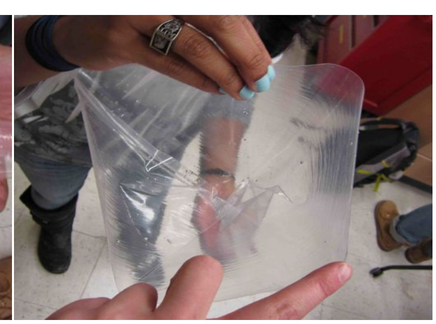
An earlier iteration had been made in Ghana, but the pipe outlet joint had been very unstable. However, even with the outlet tube being doubly reinforced in this second prototype, the joint was not strong enough to give the separator a particularly long lifetime if the tubing is removed and attached frequently. A possible solution to this, however, might be to construct a lightweight plastic tube to divert the urine into the jerry can. Such a tube could be made from plastic sachets and would thus reduce stress on the pipe joint.

We tested various glues to see which would be strong enough to hold together the bucket, and found that epoxy was the only viable adhesive. Unfortunately, however, it turns out that epoxy is very difficult to come by in Ghana.

These compounding factors led us to abandon this prototype. It traveled with Amy and Kofi to Ghana in April, however, and so is currently on-site.

The plastic sachet funnel.

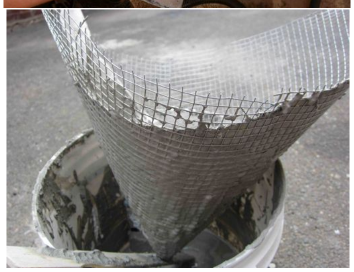
We considered making a urine-diverting funnel out of plastic water sachets. Given the wide availability of sachets, this would have been an extremely low cost solution of only labor cost and the investment of a heat sealer. The prototype, however, was abandoned because it would need more frequent replacement and it does not look appealing to the user.



Ideation and Concept Selection:

METAL

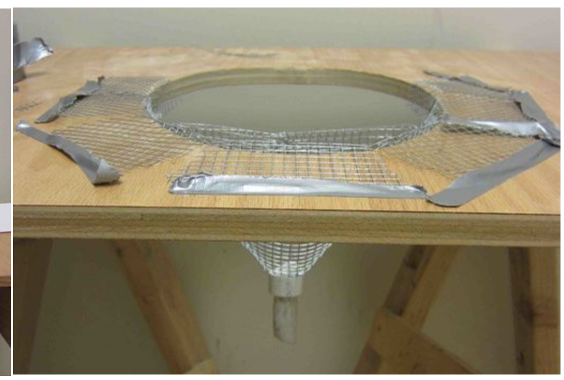
A sheet metal prototype was constructed in Kumasi, Ghana, in January. This had the advantage of being robust, not particularly heavy, and easily constructed in Suame Magazine. At approximately 56 cedis ($37), however, it was slightly expensive, particularly due to the welding involved. Furthermore, there were concerns about the sound of liquid hitting metal negatively contributing to the user experience, as well as corrosion of the metal and splash back from the urine diversion funnel.



CONCRETE

We were introduced to a lightweight concrete technique in April (George Nez, nezgeorge@gmail.com) that adds latex to the concrete mix. This adds to the concrete an element of flexibility that allows for a very thin shell of concrete while still retaining the durability of concrete.

We saw the potential for lightweight concrete to be able to meet all of our functional requirements, and so this is the material that we decided to go forward with.



The commercially available Ecovita separator. Cost is $115. Not depicted is the toilet seat which attaches on top.

Lightweight Concrete: Method

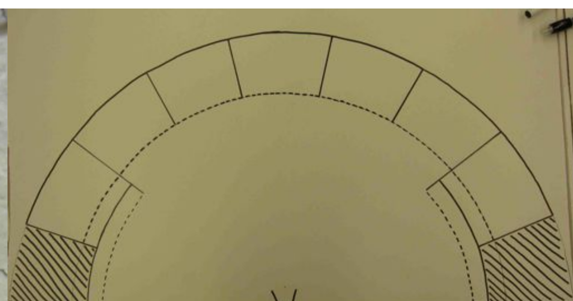
A stencil (see picture below) is provided to form the mesh into the desired shape. Cloth is overlaid the mesh, and the concrete mix is painted on top. The concrete should have a very runny consistency—only a thing layer is applied at a time. Let layers dry before applying a new one, up to approximately six layers. Fewer layers did not produce a robust enough seat, and a less runny consistency made a less compact concrete. Because the concrete does not have a smooth finish, the dried seat was sanded and finished with acrylic paint (the same we had used in the concrete).

We used latex primer as our source of latex, and thinned it to a 10% latex mixture (this required about 50/50 water to latex).

The stencil.

We decided to use a stencil rather than a mold for the production of our seats for reasons including:

- Using very wet concrete and painting it on increases the latex content and makes the concrete more compact. This is difficult to do with a mold.
- Mesh is needed to reinforce the concrete, and a mold makes it difficult to lay on mesh consistently.
- A mold limits the process to one seat per mold, while a stencil can be replicated as many or as few times as desired. It is easily transported.
- While we need a smooth inner surface of the bowl—easily achieved using a mold—we found that sanding the surface still keeps cleaning time less than five minutes.



Cost breakdown:

(approximate cost per seat, excluding labor cost)

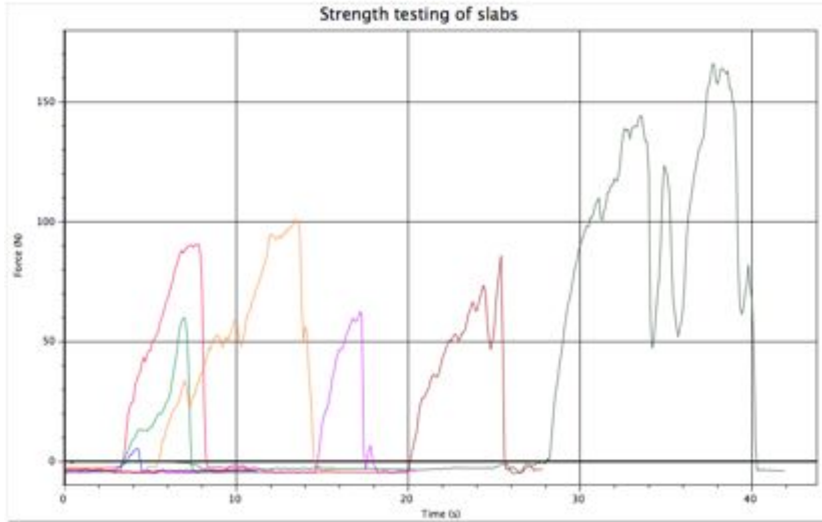
7 dl Latex Paint:	0.5 GHS*
6 dl Water:	n/a
4 dl Cement:	0.5 GHS **
4 dl Sand:	negligible
Wire:	2 GHS***
Cloth:	1 GHS
Pipe:	2 GHS
Tubing:	2 GHS
Seat:	7 GHS
TOTAL	= 15 GHS

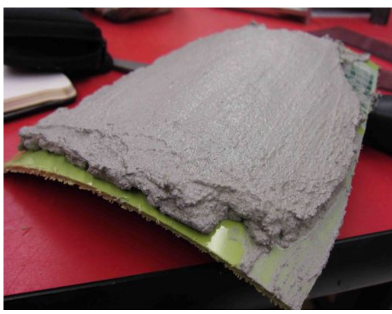
*1 gallon of Leyland emulsion paint ~ 3.5 GHS
**1 bag of cement = 14 GHS
****based on US value

Lightweight Concrete: Experimentation

Wire mesh.

In our first prototype we used a very fine wire mesh but found that it did not have the necessary strength, especially at the pipe outlet joint. In our considerations of whether to use a mold, we also wanted to test the difference between using no mesh to see whether we could get by with concrete alone as this would make the mold easier. We prepared small samples of concrete with and without mesh and applied pressure until they broke. The graph on the left shows the biggest (last) peak as the stronger wire that we decided to use for our next prototype; a purple peak (just before 20s) corresponding to the finer mesh; and the tiny blue peak at the very beginning, which is with no mesh.





Concrete consistency.

A one-part mold would require a thicker concrete being applied to it: the runny consistency would not be able to keep its shape. We thus made samples of concrete of a thicker consistency to compare, and found that to reach the same strength the thicker concrete mix resulted in a thicker end product. When painting on the concrete, a much more compact shell is acquired. One could potentially use a two-part mold and thus still be able to keep the concrete at a fluid consistency.

We found that using a mold, however, resulted in a surface much smoother than without a mold.

Lightweight Concrete: Experimentation

Testing our functional requirements.

- It took removing and attaching the tubing 308 times for the joint to come loose and break off. When we were using finer mesh the joint held up for 42 iterations, so this is a significant improvement.
- There was little to no splashing when water was poured from different heights and angles into the separating funnel. Earlier tests had shown that angles greater than 45 degrees would splash very little, which is in agreement.
- A 500 N force applied down the central axis of the seat cracked the rim. This corresponds roughly to a young teenager jumping on it.
- Dropping the separator from human height cracked the bowl after 6 drops. Prior to this it was damaged but not irreparably so: applying a new coat of concrete to the damaged area sealed it for continued use. The concrete tends to not break apart, but merely shatter in place.

We decided to remove the back rim for our final product because this was the weakest part of the separator and the most prone to breaking off when dropped or otherwise manhandled.

Conclusion and Future Recommendations

Dissemination strategy: two potential options.

1. The stencil:

> A stencil (pictured on a previous page) is distributed with an instruction manual. Seats will be centrally made by masons and sold to families in the area. Families can also learn how to make their own seats and buy stencils if they wish.

2. A mold:

> A mold is distributed and used by masons to construct seats.
>
> A mold would have to be constructed that makes it easy to cast wire mesh into the concrete. We would recommend a shape similar to that our stencil creates, as there are no soft curves and so a mesh can be more consistently overlaid. This mold could be made using a sheet of plastic that is cut and joined together according to the stencil.
>
> The pros of a mold are greater consistency and a smoother finish, however it also limits the manufacturer to constructing one seat at a time. Mesh consistency in the concrete is also a potential problem that would need to be tested.

Further suggestions.

Our final product met our functional requirements. However, three main issues might limit its impact: (1) it is not quite as robust as is perhaps necessary, as it will break when dropped a few times; (2) the production time of the separator is fairly long (~4 days) because the concrete is painted on in layers that have to dry and the final surface must be sanded; (3) quality control is difficult.

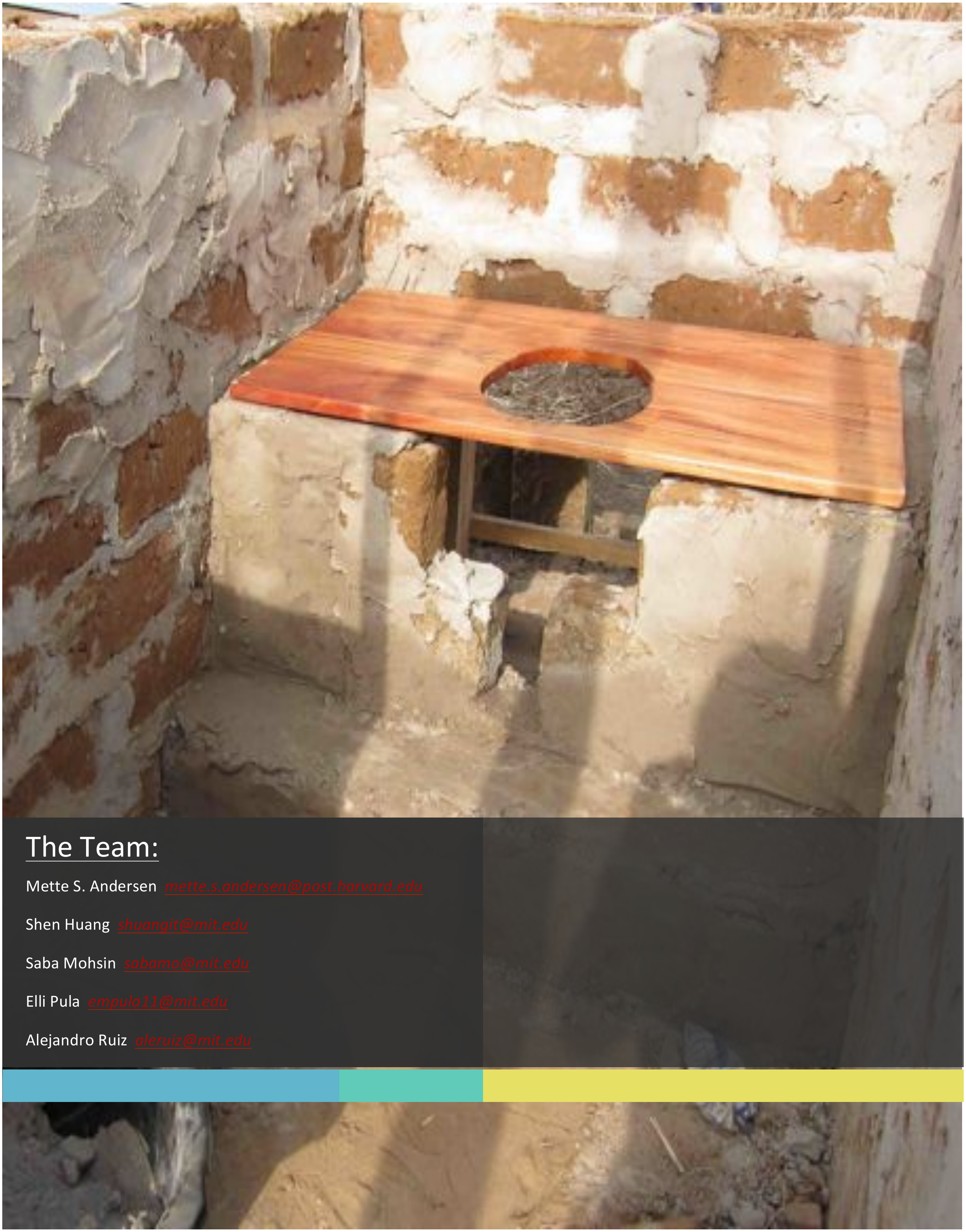
We anticipate the need for teaching material surrounding the proper use of a urine-diverting toilet, how to handle and store feces and urine safely, and how to clean and upkeep the seat.

The production of shea butter is common in Ghana and has a latex-based byproduct. Testing out the lightweight concrete with this might have potential benefits.

Using recycled plastic is still a potentially viable option if a vacuum former can be constructed. An IDDS project was started on this, but was never quite successful. Continuing this work might be valuable.

User testing.

The urine-separator is coming to Ghana on IDDS in July and will be installed there alongside a commercial Ecovita separator. Based on user feedback, the design can be improved.



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