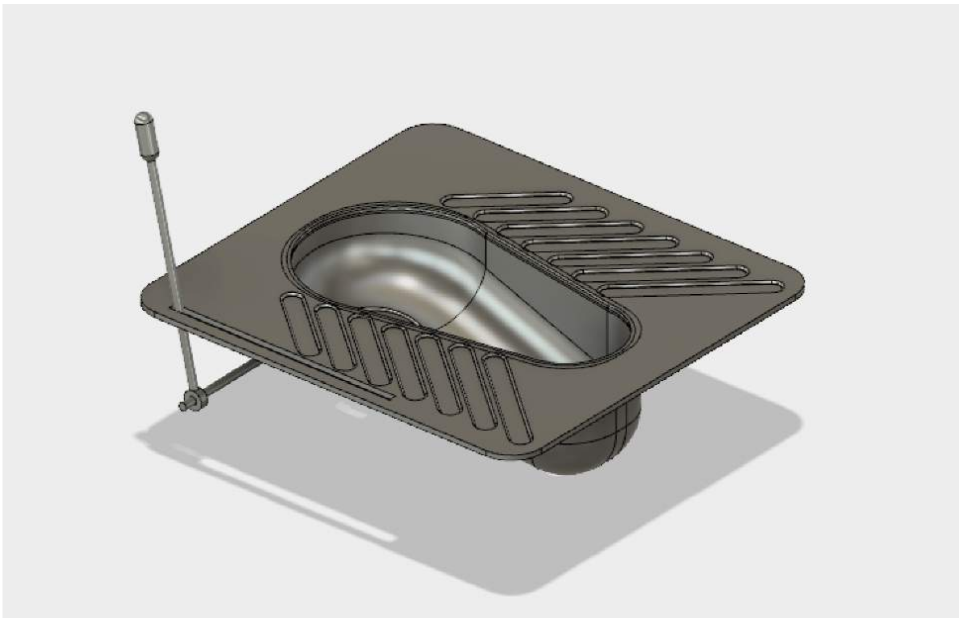

Wash Water-Diverting Squat Toilet

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EXECUTIVE SUMMARY

We were tasked with creating a container-based toilet design for users in rural Bangladesh. In Bangladesh, toilet users squat rather than sit, and use water for anal cleansing instead of toilet tissue. Our design adapts the traditional squatting toilet to allow for separation of liquid and solid waste streams by introducing a user-controlled lever mechanism. During urination and defecation, the lever remains down in the "open" position, allowing feces to remain separate and as dry as possible; when the user prepares to wash after defecation, he or she must pull the lever, triggering a flap which rises to cover the feces hole at the back of the squat plate. This allows for wash water to be diverted into the fluid hole at the front of the squat plate, effectively creating one stream of solid waste and one stream of liquid waste. Our design assumes that the liquid stream can be either chemically purified or directly infiltrated into the ground.

USER / NEED ANALYSIS

We partnered with re.source, an organization that strives to deliver hygienic and aspirational sanitation service to some of the poorest urban households on the planet. re.source recovers resources from waste to finance the delivery of in-home sanitation services. re.source targets extremely poor populations of people who live in urban settings, where sanitation and hygiene especially from human waste have tremendous scope for improvement. In its previous work, re.source has modeled prototypes and systems in Haiti, a country in which people use toilet paper to clean and sit on Western-style toilets. For this project, their goal was to adapt their current toilet design for use in Bangladesh, a country in which people squat rather than sit and use water for anal cleansing rather than wiping with toilet paper. Due to these two major differences, the toilet design had to be modified significantly from what was previously implemented in Haiti. *Our objective was to design a cost-efficient household toilet catered to a "squatting" and "washing" population that can divert feces, urine, and wash water in a manner that keeps feces dry for efficient processing and minimizes pathogen contamination.*

Our users are among the poorest urban dwellers who currently lack access to basic sanitation or waste disposal services. Many simply defecate and urinate in public spaces, and some communities have a communal bathroom. These can often be poorly maintained and dangerous to use at night. Re.source's toilets are for individual households, allowing users to use the bathroom safely and comfortably. Public defecation results in immense sanitation and hygiene problems for a community. Fecal particles can give rise to numerous extremely dangerous diseases and can lead to even greater consequences if particles mix with groundwater. re.source aims to solve these problems by diverting waste into containers that can then be disposed of in a sanitary manner. One of our main goals was to keep feces dry because this makes the disposing and processing significantly easier. Dry feces are easier for waste collection services to transport and can be more cheaply transformed into fertilizer pellets or burned for energy production.

For washing populations, there are three substances that must be disposed of properly: (1) feces (2) urine (3) wash water which may contain fecal particles. We explored two main ways of isolating these particles for purification: a three stream approach and a two stream approach. In the *three stream approach*, each of the three substances would be collected and disposed of separately. The toilet would have three holes for feces, urine, and wash water respectively. Urine is relatively sanitary as is and can be immediately infiltrated into the ground. The wash water, on the other hand, would likely need to be purified as it contains fecal particles. Chlorine is known to be a viable option for this. The *two stream approach*, which is mechanically simpler, involves collecting feces in one container and both urine and wash water together in another. In this case, the toilet would contain two holes instead of three. However, mixing chlorine with urine can create extremely dangerous toxins and therefore should be avoided. For a two stream design, it would be necessary to find a way of purifying the wash water that does not use chlorine.

Mechanical filtration or some type of contained infiltration is also a possible alternative to chemical purification. The liquid streams could be purified chemically in the pipes and vessels housed within the toilet as well as mechanically filtered. Alternatively, the streams could be infiltrated into the ground. Harmless materials could be infiltrated while hazardous materials could be contained underground to prevent contamination. Therefore, another design choice to consider was whether the two- or three-stream liquid waste should be handled via purification, mechanical filtration, or possibly even just infiltrated into the ground. This decision requires an understanding of purification and filtration processes along with a good estimation of the amount of pathogens likely to be in the wash water and at what concentration the pathogens become harmful.

INITIAL RESEARCH

We began by looking into different chemical purification processes in an effort to resolve the two-stream vs. three-stream and purification vs. filtration/infiltration dilemma. Iodine and lyme seem to be promising non-chlorine purification chemicals. However, we realized that we do not have enough expertise to determine the amount of purification required. We decided to assume a non-chlorine purification and/or filtration method likely exists and focus on the mechanical aspect of the problem.

Before beginning to design a mechanical solution for diverting wash water, we spent a lot of time talking to different washers and squatters (including one woman from Bangladesh) to make sure we weren't making any incorrect assumptions about washing and squatting methods. We came to the conclusion that washing techniques vary widely, so we've focused on making a design that can accommodate all washing and squatting practices. Specifically, we found that some people splash water from the back while others do so from the front, so our design can accommodate wash water falling either in the back or in the front without mixing with feces.

We also learned more about the context the toilet will likely be used in. One toilet can be shared among a large number of people in one household or even multiple households. We should expect the toilet to be used by children, the elderly, illiterate users, and household guests who aren't familiar with our specific design. Additionally, users will already be very accustomed to washing in a certain way. To ensure user compliance, our design needs to be very simple and intuitive. Specifically, in an effort to not disrupt users' current washing routines, we decided it was important that the user not be expected to rise or shift forward/backward before washing. We also felt it would be ideal for our design to have a familiar aesthetic and size so that it's akin to common flushing porcelain squat toilets.

OUR DESIGN

We came up with many possible designs for both two-stream and three-stream solutions and chose a favorite for each (see Appendix A for sketches). After carefully considering the needs of our users, we came to the conclusion that a two-stream design is highly preferable. Our two-stream design has a cover for the feces hole that is actuated easily using a lever without needing to rise or shift. Based on what we have heard from Kory and Sebastien, users will want to cover the feces hole while washing and urinating to distance themselves from the feces and minimize odor. We therefore think it's likely that this toilet will be used correctly; users are incentivized to cover the feces hole while washing, decreasing the likeliness that we will run into the issue of user non-compliance.

For three-stream, on the other hand, we feel the probability of misusing the toilet is too high. Our most intuitive three-stream design does not allow for users to close the feces hole while while urinating, which we think is an important feature for the reasons mentioned above. Every three-stream design we could think of that allowed for a closed feces hole/open urine hole combination required an extra user-controlled barrier (see Appendix B for a more detailed description of our three-stream solution). It seems very likely a fraction of the users would misuse whatever extra component it is that they control (i.e. forget to close what they're supposed to close, decide they'd rather not shift forward, etc.), especially because this component will not play a role in covering the feces and therefore its purpose is less clear and less important to the user.

In designing our two-stream solution, we aimed to conserve vertical space so that less digging is required to install the toilet. The basin is slanted so that urine and wash water are diverted to a hole at the very bottom. We determined the best slant angle to be in the 20º-25º range, with the ideal number being around 24º (we tested this by attempting to wash hummus off of plastic at various slants). Because of this slant, the feces hole's cover does not take up any additional space when open (see side view in Appendix C).

We also aimed to make the feces cover mechanism as simple as possible. To determine the best way for this to operate, we made a foam core works-like prototype. We ended up going with a plug attached to a round rod at the back which is attached to a lever. The lever can be pulled after defecating and before washing. When the lever rotates the rod, the plug rotates into the feces hole (see Appendices C and D). It has a seal that prevents wash water from falling through. We also simultaneously prototyped the shape and size of the bowl using both CAD and concrete. We looked to existing squat toilets for dimensions and ended up settling on a length of 20", a width of 10" at the widest point, and a width of 8" at the narrowest point.

After our initial prototyping, we began building a medium-fidelity looks-like, works-like prototype out of wood and plastic, which are closer to the actual intended materials (see Appendix D). To make the bowl, we cut the sides out of a large plastic storage tub and glued them into the shape we wanted with a glue gun. We had initially intended to vacuum form our final prototype, but we decided to use lower-fidelity materials instead because the design is still at a very early stage and will likely be iterated on quite a bit.

FUTURE

Our medium-fidelity prototype helped us determine how we would like to further refine the current design in order to improve usability. First and foremost, we encourage the testing of this concept on-site in Bangladesh or another area with a high density of squatters and/or washers. Although we have received positive feedback from the squatters and washers we spoke with in initial phases of our need finding, much greater insight as to the effectiveness of this design could be gained by watching real users interact with it. Specifically, we hope that more extensive user testing could help finalize the following:

-Dimensions and placement of features (footholds, feces hole, etc.)

-Effectiveness of lever mechanism design, i.e.: will users actually use the lever to cover feces hole when they are meant to? Is the incentive of removing odor enough or do we need to find another way to incentivize them?

-What materials are users comfortable or familiar with? Will plastic be successful in Bangladesh like in Haiti based on cultural norms?

-Correct placement of the lever mechanism (which range of motion is comfortable for users while squatting? current mechanism is placed for convenience on prototype but not for usability)

Additionally, more work needs to be done in refining the mechanism. Once the desired materials for the basin have been determined (the type and thickness of plastic), it would be helpful to build a higher fidelity prototype out of that material and use it to refine the mechanism. We were limited by the materials we had available; the actual mechanism will be smaller and less clunky and will be built to exact specifications so that the seal is watertight. It would also be useful to spend more time researching and experimenting with different options for the seal to determine what will be the most effective. Depending on the thickness of the material, using a slightly different lever mechanism may be appropriate. Another design we considered had the feces cover hinged at the top end (an elephant hinge on the backside would likely work well). The lever would then attach to the bottom end of the feces cover with a similar L-shaped rod, but would pivot about the point where the cover is hinged rather than rotating.

Some features of the design, namely those regarding implementation and installation, depend on the preferences of re.source partners. For installation, our recommendation is to dig holes the size of waste buckets in the ground on site. Although this slightly increases the need for upfront labor needed per installation, we believe this method will a) make the squatting toilet more similar to those currently in use in Bangladesh by keeping the surface flush to the ground rather than raised, b) help accommodate users with lesser mobility like the elderly, and c) avoid the necessity of designing supports below the squat plate that allow for significant load-bearing. If most of the squat plate can rest directly on the ground, users will be stable while defecating or urinating, and we avoid the risk of the squat plate buckling or breaking. This also enables the use of a thinner sheet of plastic during manufacturing; thus, a model in which the plate sits directly on the ground reduces overall costs substantially by eliminating the need for a sturdier squat plate or supports beneath it. Finally, our intent was that the squat plate be attached at the back or side with a hinge, allowing it to swing open and closed when waste must be removed.

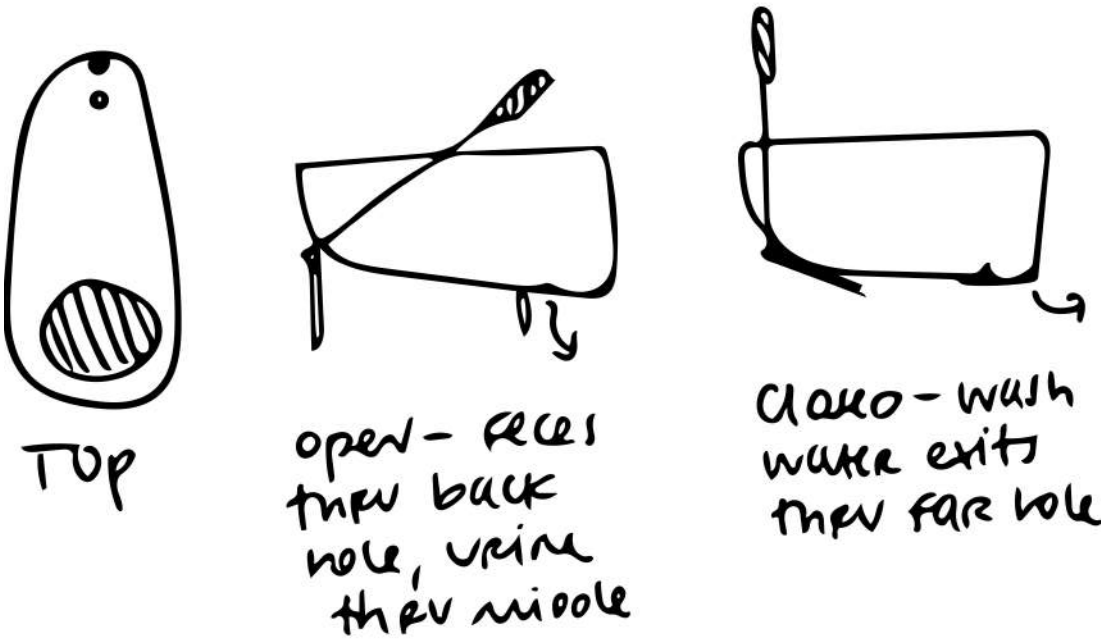
The process for disposal and/or purification of the wash water and urine mixture requires further research. Our advisor, Elise Guinee Cooper, suggested that the amount of feces in the wash water may be small enough that purification isn't necessary. According to Elise, such a small quantity of fecal matter likely will pose a negligible threat if infiltrated directly into the ground:

> "As a quick back-of-napkin calculation, we can estimate that for every 100L of waste water you produce, there are roughly 100g of feces mixed in. Assume that before reaching humans, a given batch of 100L of wastewater will mix with 200L of groundwater as well, and we're approaching a combined groundwater concentration of 0.33g feces/ L. While it's certainly possible that harmful bacteria/ viruses could be present, my guess is that they would not be especially dangerous at that concentration."

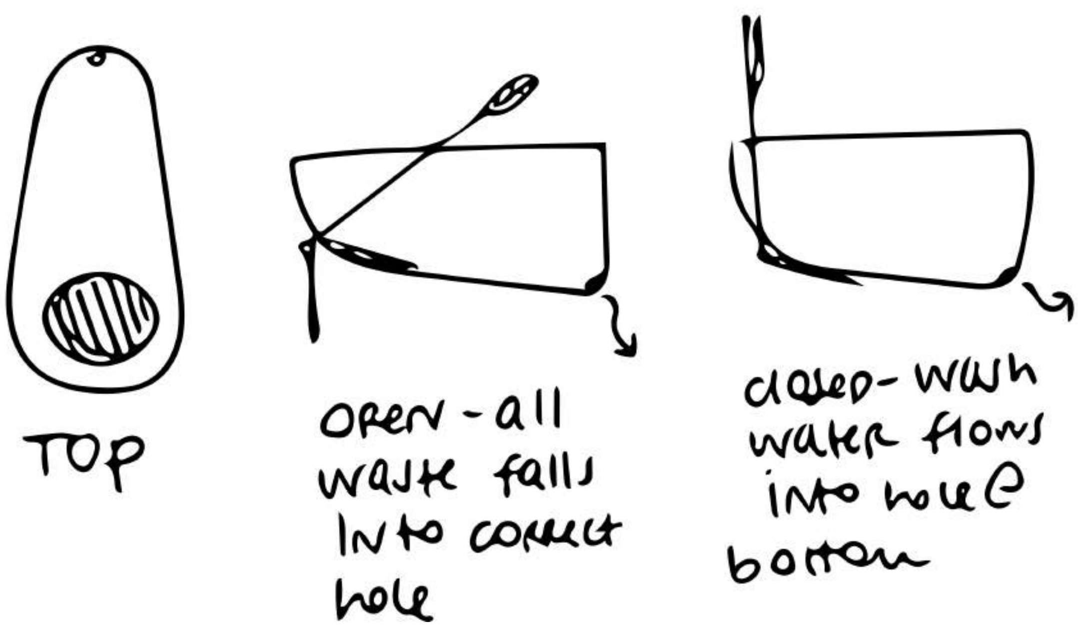
Further research is required to verify this and to determine whether some level of filtration is appropriate before infiltrating the mixture. If so, we thought of two possible mechanical filtration options. The pit or pipe used for infiltration could be lined with a fine mesh that collects any larger fecal particles but lets liquid pass through. Ideally the mesh would line a large enough area that it would need to be replaced very infrequently. When it does become full, the waste collector would just need to dump the fecal matter into the feces container. The mesh could be collected and cleaned or simply replaced. Another option is to have a smaller, biodegradable filter in a section of the infiltration pipe that is easily removable (almost like coffee filter but stronger and less fine). This filter could be replaced weekly by the collector; the dirty filter can be thrown in with the fecal matter and a new one could be put in its place. Both these ideas are just initial jumping-off points and would need significant further refinement.

APPENDIX A: Design Sketches (2-Stream and 3-Stream)

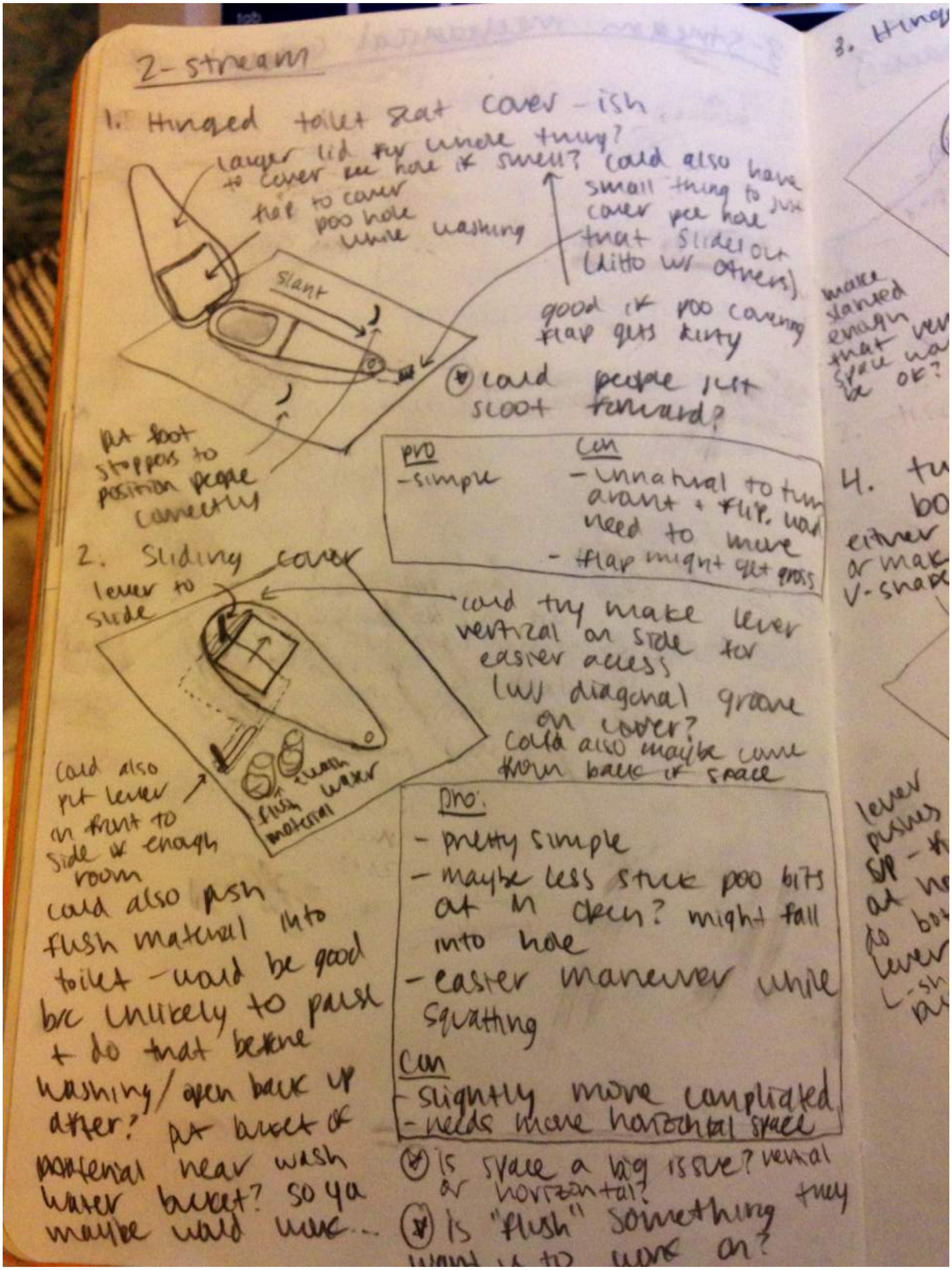
3-stream conceptual design



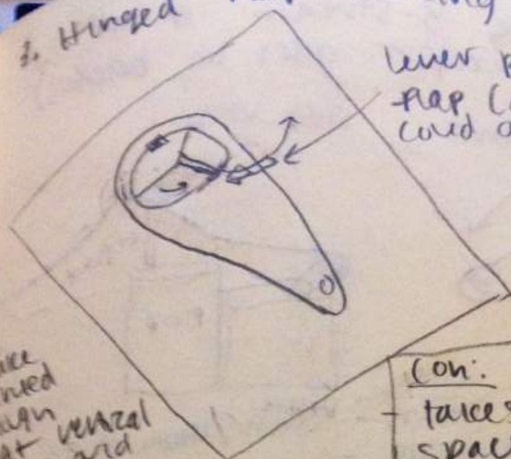
2-stream conceptual design



Additional sketches and explanation



3. Hinged flap coming from bottom



lever pull up flap (design better)
could also push from back

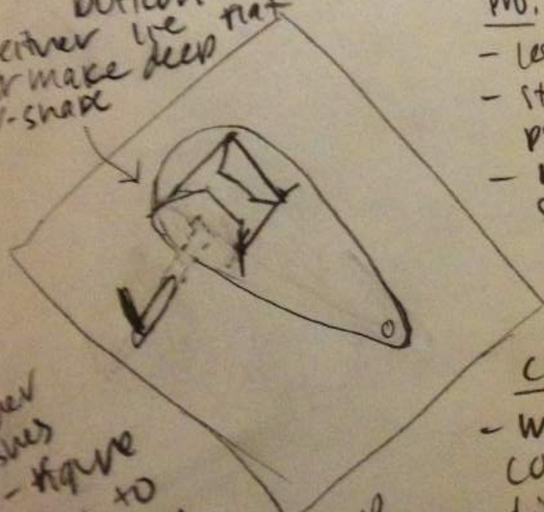
pro:
- pretty simple
- poo bits fall into poo container

con:
- takes up more vertical space (too much?)
- more complicated mechanism (think more)

make slanted enough that vertical space would be OK?

4. two hinged flaps coming from bottom

either use flat or make deep V-shape



pro:
- less vertical space
- stuck bits fall into poo bucket
- more concentrated stream - faster, less gross, less sticking?

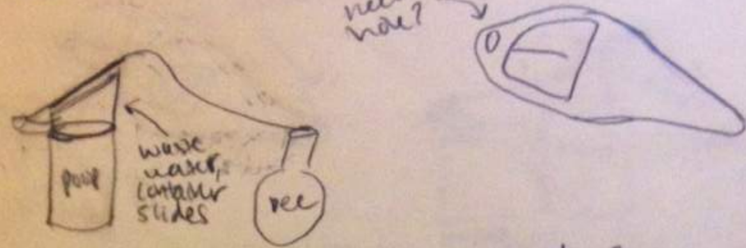
con:
- more mechanically complicated
- difficult to prevent leakage?

lever pushes up - figure out how to do both w/ one lever

L-shaped so just push in + nods edge up

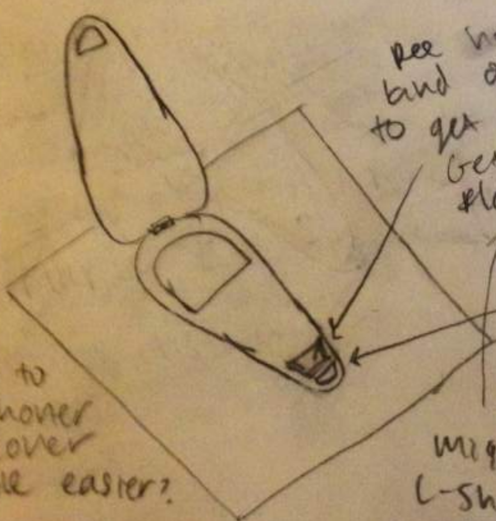
3-stream (see 2-stream #5 too)

1. Slant #2 w/ moving bucket ?



2. 2-stream #5, assuming dirty water lands in back (maybe b/c has to touch butt! check...?)

3. 2-stream #1 w/ pee hole cover



might be hard... add L-shaped ledge cover @ end? idk

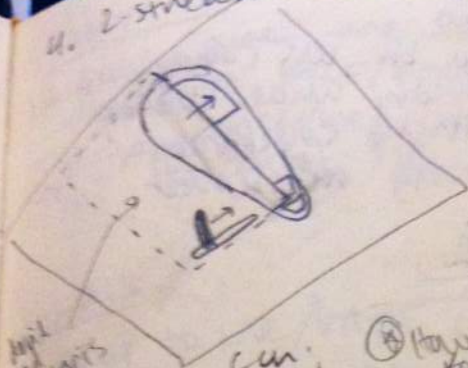
how to have shower one + cover pee hole easier?

pro:
- simple, easy
- 2 or 3-stream
- no surface contamination

con:
- might be hard to divert flow?
- unnatural to turn around + flip, would need to move

if does get gross, could spread poo when flipped over → top might get gross. make really steep? Have people clean it?

4. 2-stream #2 w/ pee hole cover



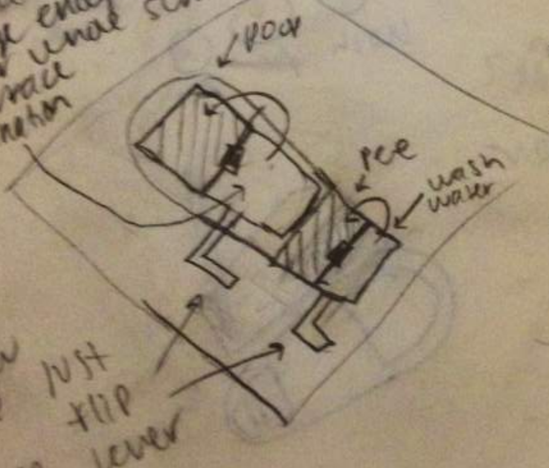
pro:
- grossness more covered, not topped over
- easier/more intuitive maneuver
- 2 or 3 stream
- separate surfaces (no contamination)

con: (*) How could we make this work for 3 scenarios. pooping: all holes open
- more complicated
- gross part still exposed - have separate cover?

might need this all material, can be 2 pieces connected

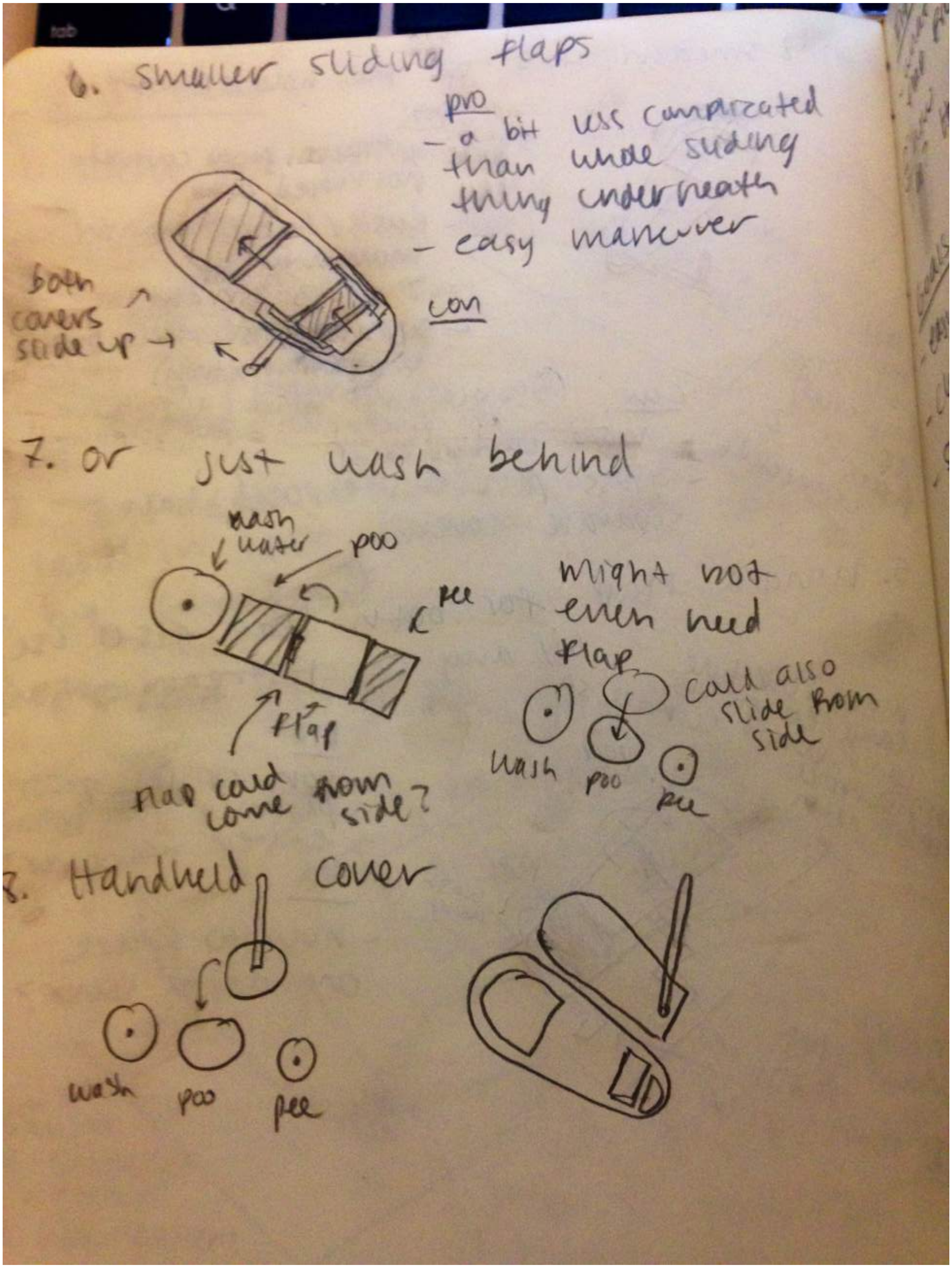
5. hinged flap for both (can also use w/ any of 1-stream options

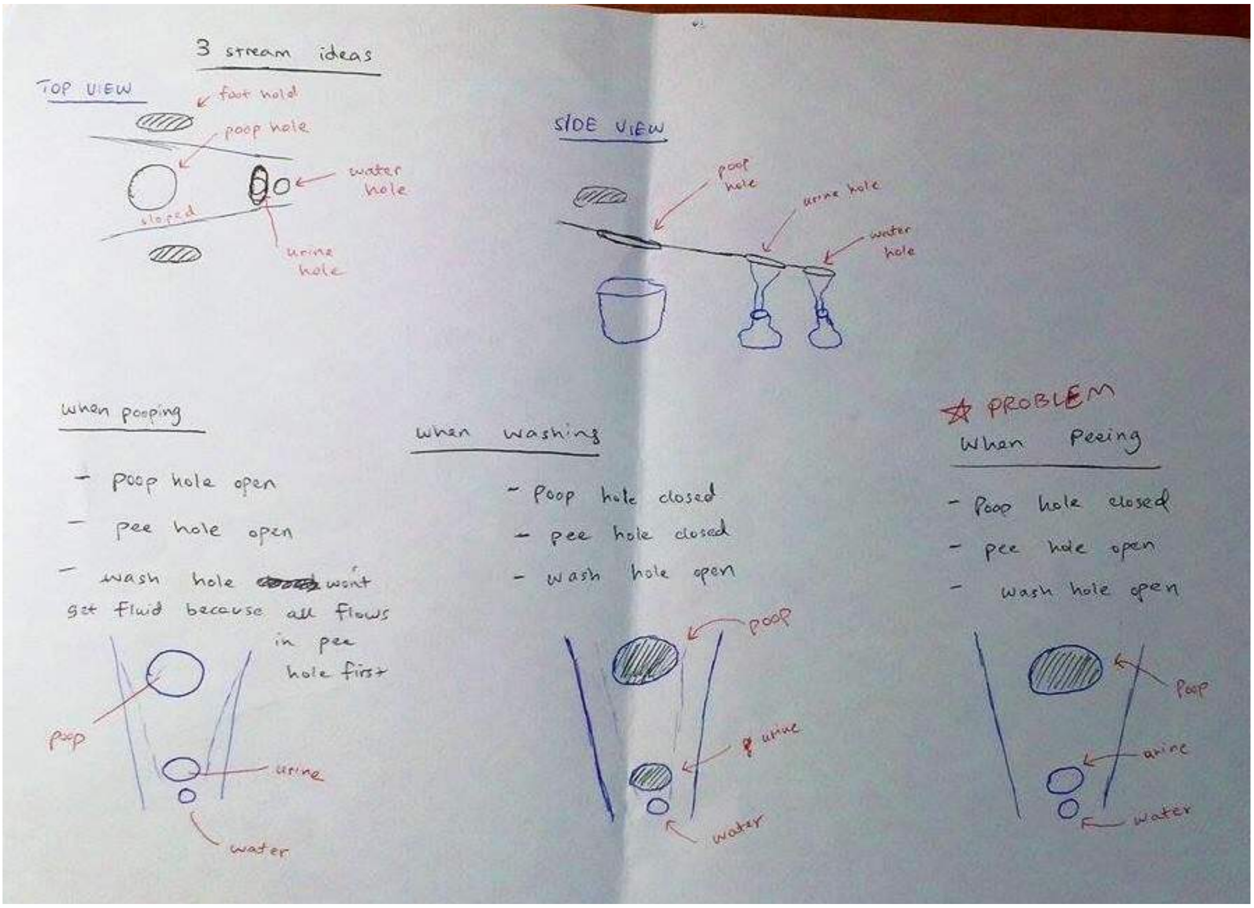
make flap/hole large enough to cover whole surface so no surface contamination



pro
- sort of less gross particles (for bottom)
- easier maneuver?

con
- how to make one action lever?


6. smaller sliding flaps
pro
- a bit less complicated than whole sliding thing underneath
- easy maneuver
con
both covers slide up
7. or just wash behind
wash water
poo
pee
flap
flap could come from side?
might not even need flap
could also slide from side
wash
poo
pee
8. Handheld cover
wash
poo
pee


3 stream ideas
TOP VIEW
foot hold
poop hole
water hole
sloped
urine hole
SIDE VIEW
poop hole
urine hole
water hole
when pooping
- poop hole open
- pee hole open
- wash hole won't get fluid because all flows in pee hole first
poop
urine
water
when washing
- Poop hole closed
- pee hole closed
- wash hole open
poop
urine
water
PROBLEM
When Peeing
- Poop hole closed
- pee hole open
- wash hole open
Poop
urine
water

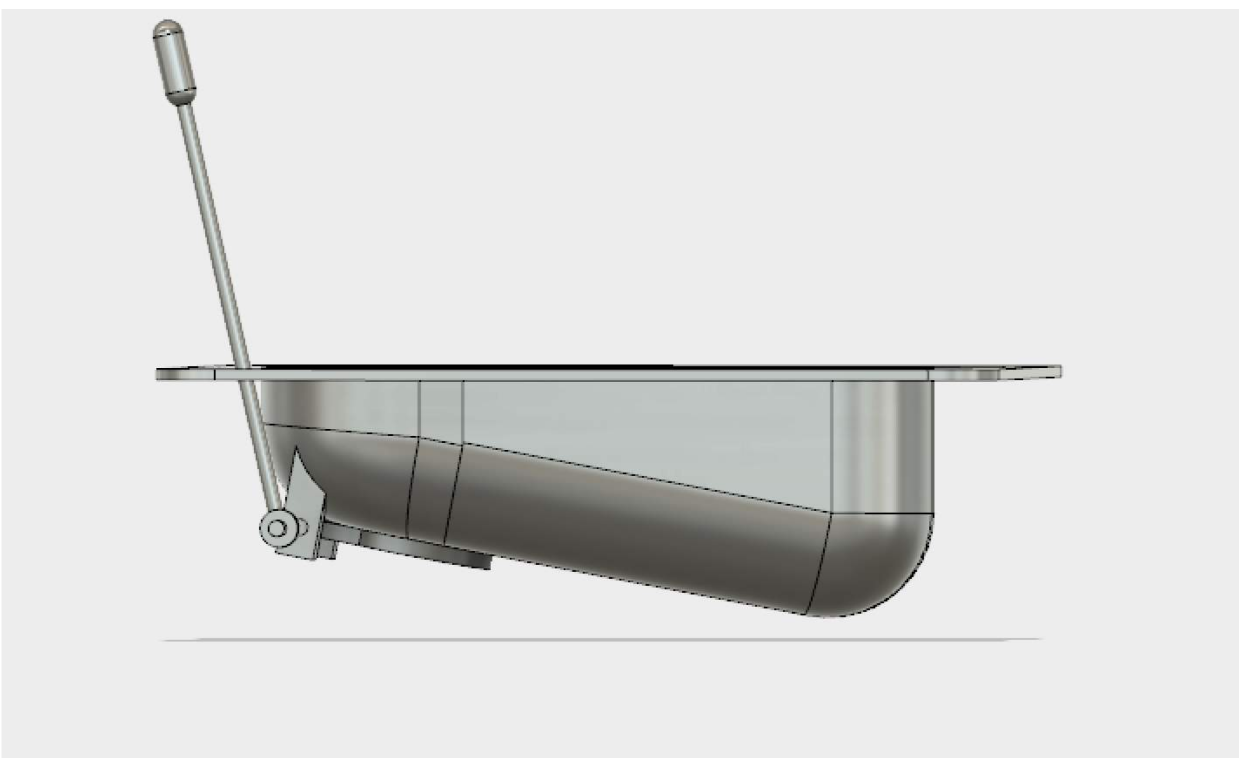
APPENDIX B: 3-Stream Solution Details

Our 3-stream design had a squat plate basin that included two separate holes for urine and wash water as well as the hole for feces. With this design, we struggled to find a balance between simplicity and functionality. In one option, the lever used in our 2-stream design controls two flaps; when the user pulls the lever, both the urine hole and fecal hole are covered. This model allows for every possible kind of waste to successfully be diverted into its proper stream, but does not allow users to cover the feces hole while urinating. Another option involves two separate levers so that the urine and feces cover can be operated individually. While this allows users to distance themselves from the feces while urinating, it relies on a high level of user compliance with a relatively unintuitive system. These ideas could be explored further if purification constraints change and a preference for a 3-stream solution emerges down the line.

APPENDIX C: CAD

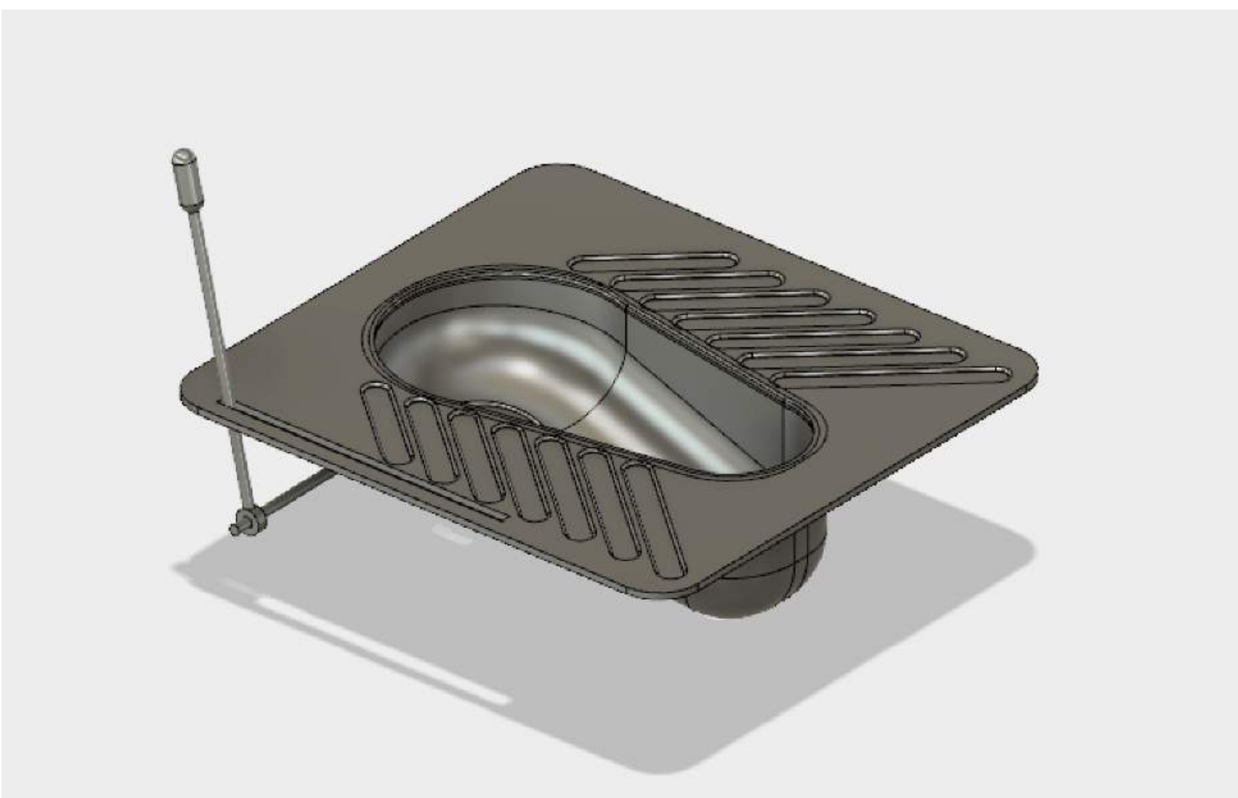
Top view

Side view



Back view

Isometric view



APPENDIX D: Medium-Fidelity Prototype Photos

Top: open (urination or defecation); bottom: closed (washing)

Prototyping in concrete for shape of basin