Elegant yet economical urine-diverting dry toilets in Ecuador

This paper describes a recent project to build Urine-diverting Dry Toilets, with a new and efficient design, with a ferrocement bench made from readily available materials.

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Abstract

During the summer of 2010, six Urine-diverting Dry Toilets (UDDTs) were built for rural families in the Andes Mountains, in the county of Tisaleo, Tungurahua, Ecuador. These were built with a simple, innovative design that uses conventional, readily available materials, including ceramic tiles on the ferrocement benches and floors to improve aesthetics and ease of cleaning. Each family contributed US$ 80 toward the moderate total unit cost of US$ 390. Of the six toilets, five were built in 16 days (by two experienced masons), as opposed to the sixth toilet in eight days (by the user, a student volunteer and a UDDT consultant). It was learned that quality control must be constant; contribution from the users is crucial for project success; and education and follow-up are essential.

Introduction

The Urine-diverting Dry Toilets (UDDTs) are a very sustainable form of sanitation, as they avoids wasting and contaminating water, while returning nutrients safely to the soil. Urine, in particular, is very good fertilizer that generates high crop yields (Richert et al., 2010). Because of these benefits, many UDDTs have been built in diverse parts of the world in recent decades. In order to adapt to local contexts, many UDDT designs have been developed, which, in addition to adapting to different user preferences, also present trade-offs between cost and quality, while striving to stay within the budget, satisfy users' needs, and ensure successful long-term use. This paper presents a UDDT project that introduced a new technical design that seeks to efficiently balance these factors. The project's context, costs, timeline and results are also discussed.

Project implementation

Context

This project was the second phase of a broader project that aims to promote public health in the county of Tisaleo, province of Tungurahua, Ecuador. It was initiated by Ms. Kawshalya Pathiraja, a United States Peace Corps Volunteer, with the help of Peace Corps Ecuador and her counterpart organization, a non-governmental organization named Fundación Manos Unidas (FMU), based in Tisaleo. FMU supports local disabled children by providing them an education, some financial assistance and preparing them to live more independently as adults. FMU also contributes generally to children's health, maternal health, nutrition and family education.

After a few months surveying the communities' basic public health needs, a great demand for sanitation was identified and Ms. Pathiraja initiated a project to provide toilets to

Technical Data:

- The bench and floor are made of ferrocement, with ceramic tiles placed directly into the fresh concrete. The drop hole is 22 cm x 30 cm. Two small holes are kept open for attaching a standard plastic toilet seat.
- Urine is diverted via a funnel cut from a 4-liter plastic bottle, with a plastic mesh sewn in place to keep solids out. Urine is stored in 20 liter bottles, to later be transported to the fields.
- Feces fall into a rice sack and are covered manually with dry material. Full sacks are stored under the bench for at least 6 months to sanitize their contents.
- A PVC vent pipe (11 cm diameter) removes odors. The top of the pipe is cut at a steep angle (22 cm), to enlarge the exit hole area and so that most of the rain flows down the metallic fly screen to the outside of the pipe.
- Walls are made of concrete blocks and the roof is aluminum/zinc galvanized steel.

individual families. Survey results showed that the users desired toilets that 1) give privacy 2) avoid bad smells, 3) are easy to clean and maintain and 4) are aesthetic. She analyzed different options, taking into account the scarcity of sewer lines and the total absence of wastewater treatment, and arrived at the conclusion that the UDDT would be the best option under these conditions. She then learned, via Peace Corps, of the work of Canaday, a biologist and Ecological Sanitation promoter living in Ecuador, and asked him to help with the technical aspects. Together they presented this concept to potential users during community workshops, where people expressed considerable interest in the free, natural fertilizers that the system provides, in addition to sanitation and privacy.

In the first phase of the project, Ms. Pathiraja organized the building of toilets for seven families and one nursery school. The construction phase lasted over four months. They were all built in the county of Tisaleo. Sites range in elevation from roughly 3000 to 3400 m, with a warmer, drier climate at the lower sites and a colder, mistier climate higher up, although it is very cold at night at all sites. In addition to the actual construction, she held workshops about health, sanitation, and organic farming.

Thibodeau, a PhD student of sustainable sanitation in Canada, was interested in volunteering to build UDDTs in Ecuador and contacted Canaday (via the Ecosanres Yahoogroup), who suggested extending Pathiraja's project. Other residents of Tisaleo had mentioned interest, especially because they only had to pay 25% of the total cost, so a project was conceived to build six more UDDTs and to help teach the users about Ecological Sanitation.

Project description

New UDDT design

Canaday has been building UDDTs for over 10 years, mostly double-chambered models in the Amazon, which work well, but, in this warm, humid and biodiverse environment, users must be very orderly in covering the feces with dry material. In February 2009, two units were built in the Omaere Ethnobotanical Park in Puyo, Ecuador (http://www.fundacionomaere.org, also blog above) for use by visitors, volunteers, and staff. Use as a double-chambered UDDT was frustrating, as the feces form a mound and the new deposit would often roll off and not get covered properly. Also, many of the users did not follow the instructions, thus causing problems with odors and flies. He thought to place a woven polypropylene sack that would contain the feces and cover material, forming an orderly column, while still allowing for water to evaporate out and oxygen to filter in. This provides much more control, as the moment flies are seen to be emerging or there are bad odors, the sack may be changed, thus resolving the problem immediately. By using interchangeable sacks, the structure can also be much smaller and more cost-effective, even to the extreme that it is feasible to not build walls around these sacks (see Canaday, 2011). It also, thus, has an unlimited carrying capacity, as sacks may be stored elsewhere. Presumably, the only fecal pathogens that could actively go through the cloth of the sack would be hookworm larvae (Ancylostoma, Necator) and threadworms (Strongyloides stercoralis), but these only move through moist soil, not the dry cover material used in UDDTs, especially if wood ash is included. Rubber gloves may also be used while handling the bags.

Canaday has also built essentially the same model as in Tisaleo in community tourism projects in the Achuar village of Tiinkias (http://www.communityecotourism.com/tiinkias-ecotourism-center.html) and in the Yaku Kawsay Aquatic Animal Interpretation Center in Yasuní National Park (http://www.yakukawsay.org), where they have been functioning for 6 and 12 months, respectively, with no reported problems, in addition to the toilets in Omaere that have received fairly heavy traffic for the last 22 months with no problems beyond normal maintenance.

The Tisaleo UDDT is a single-vault model made of concrete blocks and a metallic roof (Figure 1). The toilet has two main functional sections: the upper part for the user and the bottom part for collection of urine and feces. Except for the foundation, the entire toilet is above ground. Key features are:

1. Ferrocement floor and bench. In order for these to be strong yet allow for free space underneath, and minimize the area susceptible to being soiled, a 3 cm thick ferrocement slab is made of 15 cm square electro-welded 4mm steel rebar with one layer of hexagonal wire mesh ("chicken wire") above the rebar and another below it (Figure 2). The mix is 3:1, sand:cement, with just enough water to moisten it properly. The bench is 38 cm high, or whatever height is appropriate for the users, thus being an advantage over pre-made pedestals. Other advantages of a bench over a pedestal include less internal soiling, better ventilation, no hard-to-sweep area behind the toilet, and more room for changing and storing sacks.
2. Ceramic tiles. These are put directly into the fresh concrete of the ferrocement floor and bench, including the inner edges of the rectangular drop hole. Tiles, which also extend 10cm up the adjacent walls, enhance aesthetics and are easy to clean, thus contributing greatly to acceptance by the users (Figure 3).
3. Plastic toilet seat. This is affixed on top of the drop hole via its plastic bolts that pass through two small holes that were maintained by placing sticks in the fresh concrete. If the bench is too thick, the corresponding plastic nuts will not fit onto the bolts, but wedges of wood can be jammed in from underneath to firmly hold the bolts in place. The seat contributes greatly to comfort, acceptance, and "normality".

Figure 1: UDDT Design. Interior dimensions were 120 cm long by 90 cm wide

4. Collection and storage of urine. Urine is collected in a funnel made from a carefully cut 4 liter white plastic bottle (which may have once contained chlorine). A plastic mesh is sewn with fishing line, 5mm below its sloped opening, to prevent feces and solids from going in. The mouth of the bottle fits into an elbow of a 5 cm PVC pipe which passes through the side wall and is inserted into a 5-cm hole in a plastic beverage bottle, with a hose glued into its mouth that goes to the bottom of a 20 liter plastic bottle for storage, thus avoiding ammonia emissions in the direction of the user (Figure 4).
5. Collection and storage of feces. Feces are collected in a rice sack that is held open by four elastic strings attached to the walls (Figure 4). Dry material (e.g., wood ash, sawdust, rice hulls) is added manually, using a cup, after each use. When it is full or starting to get heavy, the user ties it shut, marks it with the date, and puts it under the floor for six months in order for any pathogens present to die (given the tropical location; the rule of thumb for temperate countries is one year). Dried feces, which may be periodically examined under the microscope for ameba cysts and helminth eggs, can be used to improve soils or to cover new deposits of feces. Advantages of rice sacks include: concentrating feces and cover material so that feces are covered better; gas exchange through the cloth of the sack allowing water to evaporate out and oxygen to penetrate in; accessibility; and low cost. Nonetheless, if users prefer, buckets or other containers may replace the sacks.
6. Measurements. The inside dimensions are 0,8 m wide, 1,2 m long, and 1.9 m high (entrance door). This small space is sufficient for user comfort, and also allows for 5cm clearance on each side of the roof to prevent rain damage to the walls, given that the roofing was 1.1 m wide.
7. Doors. The front and back doors are made of painted wood and are 0.8 m wide, in order to fit directly in between the two side walls.
8. Ventilation. Front and rear windows, made with wooden frames and mosquito screen, let light and air into the room. A PVC vent pipe (0.11 m x 3 m) creates a flow of air away from the user, removing any odors. The top of the vent pipe is cut at a steep angle and covered with a metallic mesh. (In other locations, with warm, humid climates, a 0.16 m pipe is used.) The chamber should be as air-tight as possible, so that the draft pulls air consistently into the drop hole.

Figure 2: Ferrocement floor and bench before adding concrete. The brown plank forms have no need for holes. (Photo: C. Thibodeau)

Figure 3: Seat, funnel and sack. The yellow plastic mesh keeps solids out of the funnel. Note that the rice sack, in this case, is too high. (Photo: C. Thibodeau)

Figure 4: View of back door. Note the plastic bottle that collects urine and that the spaces around the door frame should be filled. (Photo: C. Canaday)

Overall, this new UDDT model has various advantages over other single-vault models. First, the urine and feces collection system is made largely from reused, post-consumer waste (chlorine bottle and rice sack) that have little or no cost, are easy to get, and can be replaced whenever needed. Moreover, rice sacks allow for gas exchange and are easily carried to farmlands when ready. Ceramic tiles are aesthetic and ease cleaning, compared with other, rougher materials. The ferrocement floor and bench allow for space underneath for storing sacks that are full. The large back door enables easy access underneath. Finally, the entire structure is made with easily obtained materials.

Costs

Table 1 shows the building costs, including materials, labor and transport of the masons. It does not include food for the masons (which was provided by the users), transport of material, quality-control visits, water and electricity fees, and final layer of paint. The presented costs are in line with the study made by Rosemarin et al. (2008).

The two doors cost US$ 90 (23 % of the total), while the material for the walls cost only US$ 70 (18 % of the total). These wooden doors could have been less expensive, but a more aesthetic and durable finish was desired. The 35 solid blocks (below floor and bench) and the 90 hollow blocks (above the floor and bench) needed for each toilet cost respectively US$ 0.28 and US$ 0.23 each. The excrement collection system is very inexpensive, since no costly molded inserts were used. Since the users contributed a significant part of the costs (24 %), it is worthwhile for a family to build on its own, with the help of neighbors or friends, as was the case for the sixth toilet. Finally, this model is aimed to have a long lifespan, therefore more durable and costly materials were selected. If a family wants the same functionalities at a lower cost, other materials could be used (see Canaday, 2011).

Timeline

Table 2 shows a generalized building timeline, indicating that each UDDT requires eight days. Each phase of construction represents a division of work that allows time for the concrete to attain sufficient strength before beginning the next phase. The number of man-hours used in each phase, by the experienced masons, was recorded. For example, if two masons work on Day 1, it will take them 2.5 hours to carry it out.

Preparation includes recruitment of families and procurement and delivery of materials and equipment. Day 1 starts with the determination of precise location, foundation building and placement of blocks up to the level of the floor and bench. Day 2 includes formwork for the floor and bench, placement of rebar and chicken wire, positioning strips of ceramics around the drop hole, mixing and placement of concrete, and installation of ceramic tiles. Day 3 involves building walls and installing the plastic hose conduit for electric wires. Day 4, the roof and screened windows are installed, plus the front step is made. Day 5 is dedicated to plastering the walls and installing the urine pipe. Day 6 is for painting on the primer, installation of the toilet seat, and placement of the grout between the ceramic tiles. Day 7, the electrician installs the light fixture and the carpenter places the custom-made doors. Day 8, the system for separately collecting urine and feces are installed, and installation of the toilet seat.

Five of these toilets were built by two masons with experience from the previous phase of the project and were supervised by Thibodeau. The sixth toilet was built by the family, a neighbor who is a mason, Thibodeau and Canaday.

Table 1: Budget for Building One Toilet

Materials and labor	US$	%
Walls (concrete blocks, mortar and plaster)	70	18
Ferrocement floor and bench	10	3
Ceramic tiles	15	4
System for collecting urine and feces	25	6
Vent pipe	10	3
Doors[1]	90	23
Roof	20	5
Electricity and light[1]	40	10
Miscellaneous equipment and materials	10	3
Primer (pre-painting)	10	3
Masons wage	80	21
Masons transportation	10	3
Total	**390**	**100**
If self-built :	300	77

[1] Made and installed by a subcontractor

Table 2: Normal Timeline

Day	Activity	Man-hours
Day 0	Preparation	variable
Day 1	Foundation and first rows of blocks	5
Day 2	Ferrocement floor and bench	10
Day 3	Walls and electricity	9
Day 4	Roof, windows and front step	7
Day 5	Plastering	12
Day 6	Painting (primer) and accessories	5
Day 7	Install doors and lighting	5
Day 8	Excrement collection system	4
	Total:	57

Figure 5: Finished UDDT in use. Mrs. Mélida T. is one of the most enthusiastic users. She and her family of four filled 2.5 sacks in six months, fertilize vegetables and fruit trees with the urine, and look forward to using the soil conditioner. (Photo: C. Canaday)

Follow-up

On December 19, 2010, Canaday visited and/or received first-hand reports of the use of 10 of the 14 toilets (including both phases of the project). Surprisingly, half were essentially not being used, despite the users' investment and training. This seems to be a case of old habits dying slowly, calling for more guidance, although in a couple of cases the adjacent house was not yet being lived in. The sacks were also positioned higher than is best. Ventilation was generally working well and only in a few cases were there problems with rain entering the pipe. Those who are using the toilets are very satisfied.

Lessons learned

During this two-month volunteer project, several lessons were learned:

Family contribution

Families were asked to contribute about 25 % of the total construction cost, which amounts to US$ 80 and is roughly equivalent to the cost of labor. In addition to this financial contribution, they helped with the handling and transport of material (e.g. sand and rocks) and offered lunches to the workers. For the sixth toilet, the family had to pay only US$ 20, but built the UDDT by themselves, with our help. Whether the contribution is financial or physical, it is considered fundamental, so that each family has the sense of ownership and investment that is essential to long-term use.

Quality control

Quality control during construction is crucial. One cannot simply depend on the hired masons to do everything correctly on their own. Therefore, supervision must be constant. The main things to watch are: measurements, proper mixture of concrete, position of the holes for attaching the toilet seat, and secure installations overall. All of these have an impact on user comfort, functionality, durability and aesthetics, and therefore on user acceptance and long-term use. Therefore critical elements should be done by the project leader or a trusted expert.

Figure 6: Final UDDT with beneficiaries. See a video about the project at http://www.youtube.com/watch?v=xzFONCN3YDY (Photo: C. Thibodeau)

Education and Monitoring

More than just a matter of construction, this project aimed at capacity building in Ecological Sanitation. Even with the best infrastructure, if families are not aware of infectious disease transmission via fecal contamination, sustainable public health cannot be achieved. During all stages of the work, we discussed sanitation, the proper use of these UDDTs, and the application of the fertilizers that will be generated with families, neighbors and visitors. There were also talks given at the local high school and at meetings of the parents from nursery schools. Even so, there needs to be a process of monitoring, answering of questions, and demonstration to eliminate any doubts the users may have. As this system is new to them, sometimes no one dares to be the first user, so organizers may make (or simulate) the first use. A new Peace Corps Volunteer, who wants to build UDDTs in another community, has offered to do a round of fine-tuning and education, which will include better positioning of the sacks and group visits to successful UDDTs and well-fertilized farms. In future projects, it would be recommendable to loan families portable UDDTs (see Canaday, 2011) as part of a process to train and screen them before investing in the construction of elegant, permanent units.

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Acknowledgements

We wish to thank Kawshalya Pathiraja for her true commitment throughout the project, Viron Solis for his technical help, Aníbal Yankee for the organic farming workshop, and Fundación Manos Unidas for its steady support. Funding came from the Peace Corps, École de Technologie Supérieure, Fonds de Développement Durable de AÉÉTS and Office Québec-Amérique pour la Jeunesse.

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