# Design of a Portable Ecological Sanitation Toilet for Disaster Relief

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## Executive Summary

A portable toilet appropriate for disaster response is presented in this report. The urine is diverted and the feces undergo a lactofermentation process. Biochar is added also to the feces to eliminate odor and facilitate the reuse of the excreta as a soil additive. The design, costs, logistics and expected challenges are discussed.

## Introduction

In a disaster, large portions of a population may be left without proper access to sanitation infrastructure. Addressing this need is one of the pressing matters for an emergency response team. Several standard sanitation solutions exist for immediate, short-term and long-term response, yet there are many situations where these solutions are not appropriate.

Ecological sanitation (sanitation technologies which promote the safe reuse rather than the disposal of excreta) is currently implemented in disaster relief (DR) for difficult situations such as flood-prone areas and locations where excavation is not possible. Unfortunately, these solutions have been rather expensive and time-consuming to construct. Thus, a need is still present for rapidly deployable and less expensive solutions in these situations. Additionally, there is a need to increase the portability of the sanitation solutions to increase the ease of access for disabled and elderly people as well as ensure that more women and children have access to sanitation option at the household level to decrease the security risk of nighttime toilet use. In addition to meeting the sanitation needs of the affected population, ecological sanitation can be implemented to allow added benefits such as nutrient recovery, reforestation and to help begin post-disaster recovery and the transition to peaceful and sustainable development.

## Design Overview

The proposed solution should be able to meet the needs outlined above, in an inexpensive, simple and portable design. This design should provide some hygenization of the excreta, significantly reduce odors, and facilitate the reuse of the urine and the excreta. To achieve these objectives, the separate collection of urine and feces is incorporated into the design, as seen in Figure 1 below.

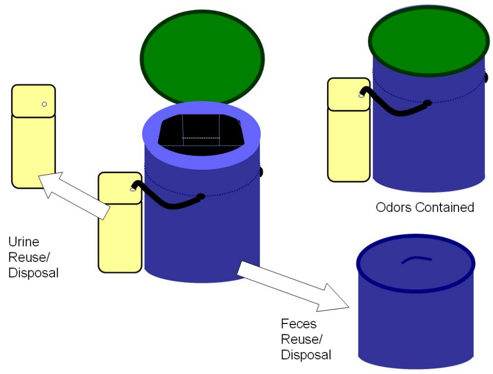


**Figure 1: Separate Collection in a Portable Toilet**

Anal hygiene material (either water or paper) should be collected in a separate bucket. The dry material can be burned, and the wash water can be treated in a soak-pit. The feces are collected in the rear portion of the chamber and are conveyed to container below using a lever.

In order to achieve hygienization of the excreta and minimalization of odor, the toilet is based off of the Terra Preta Sanitation (TPS) concept. TPS requires inputs of charcoal and lactofermenting bacteria. The LAB mixture should be added before use. The outcome of this process is the production of Terra Preta which aids in the production of very fertile soils.

The feces should be covered with charcoal before they are deposited in the bottom receptacle. A little charcoal can also be used to slightly cover the receiving surface of the toilet (to facilitate the transfer of the feces). This process is highlighted in Figure 2 below.

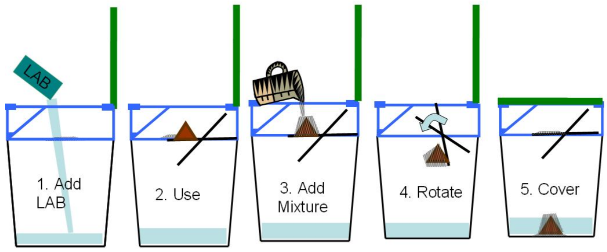


**Figure 2: Operation of the Porta Preta** The outcome

The lactofermentation process must be carried out under anaerobic conditions, so it is important that the collection chamber is closed after each use.
The volume of the receptacle can hold the feces produced by five individuals over one week's period.

After the receiving bucket is full, the bucket can be covered and collected by a local laborer. The material can then be composted to produce rich terra preta. If the composting step is forgone, the lactofermented feces can be stored indefinitely until they can be further utilized.

## Lactic Acid Fermentation

With the addition of the LAB mixture, lactic acid fermentation occurs, and the pH of the mixture is significantly lowered, providing hygienization of the feces as well as odor control. Additional odor control is provided in the collection phase by the addition of charcoal or biochar (about 1.00 kg/user/month) so that no ventilation is necessary.[1]

The LAB mixture can be formed with water, lactic acid bacteria (such as the Rankin Mix) and the appropriate amount of sugar (3%). 500 mL of this mixture can be added to the bottom of the container at the beginning of the week. Additional sugar, between 5-10% of the weight of the feces, about 0.25 kg/user/month. The additional sugar can be added after each use, daily or weekly.

## Local Production of Charcoal

The charcoal can be produced from local feedstocks on site at the camp. A model camp has been proposed based on a population of 2000 inhabitants. The sanitation needs of half of the inhabitants will be met with 200 Porta Preta toilets. In addition to the Porta Preta, it is assumed that there maybe various materials available in the camp which could be used to produce biochar, summarized in Figure 3.

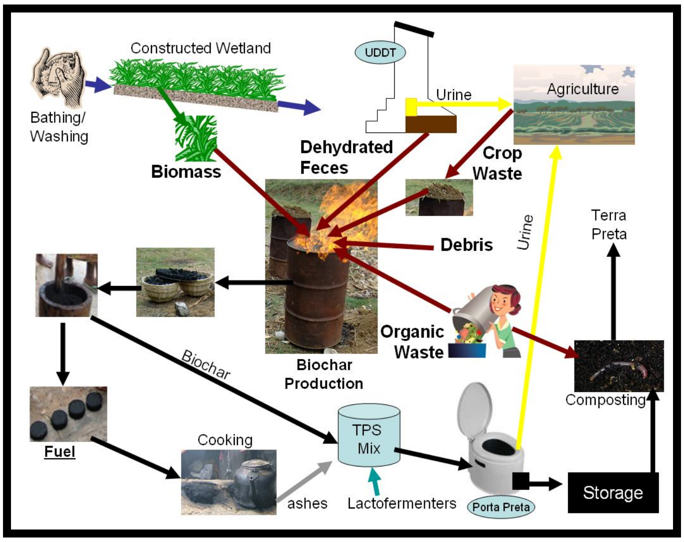


**Figure 3: Integrated Biochar and TPS System for DR**

This scheme shows how biochar production can be integrated into a relief camp using currently available materials.

For a camp of 2000 individuals one or more of the following four situations may be present:

a) Organic waste (0.5 kg per person per day)
b) 1000 people (half of the camp) use urine diverting dehydration toilets (UDDTs)
c) 1400 $m^2$ of constructed wetlands
d) Local crops are grown for the camp producing 4-40 metric tons of crop waste and residues

The expected quantities of biochar produced per month based upon these assumptions are listed in Table 1 below along with the percent of the need met for the operation of the 200 Porta Preta systems in the camp.

| Situation | Description | Total Biochar Produced (kg) | % of Biochar needed for Porta Preta |
|---|---|---|---|
| A | Organic Waste | 1172 | 117% |
| B | Dehydrated Feces | 500 | 50% |
| C | Wetland biomass | 500 | 50% |
| D | Agricultural Waste | 400-4000 | 40-400% |

**Table 1: Production of Biochar from Different Feedstocks**

The extra biochar not used for the Porta Preta can be used for cooking fuel, providing added value.

## Costs

The Porta Preta sanitation system is designed to be low cost. The target fixed cost of the Porta Preta is $25 for the toilet unit. Additional costs which must be considered such as processing equipment would be another $3-23. The monthly costs are targeted to be $3.50 for consumables and $0.50 for collection and treatment. More details and a further break-down of the fixed and monthly costs can be seen in the Attachment.

Given these costs, the monthly cost per user for the Porta Preta used over one year would be between $1.20 (if urine is reused and biochar is locally produced) to $1.80. This would be less expensive or comparable to a pit latrine (assumed to cost $100[2] or $1.70/person/month). At the current design stage, the Porta Preta seems to offer promise as a feasible ecological sanitation alterative to the standard pit latrine for disaster response.

## Logistics

The portable nature and rapid assembly of the design make the Porta Preta appropriate for both urban and rural disaster response as soon as the first humanitarian supplies have arrived. The dimensions of the units are optimized to facilitate transport. All components of the system should fit within the dimensions of 30x32x40 cm. In this way, 36 units can fit on a pallet, and 22 pallets can fit in a 40 foot high cube container. Given these assumptions, the estimated cost of delivery per unit is $7-10 depending on the location. The compact design is seen in Figure 4 below.

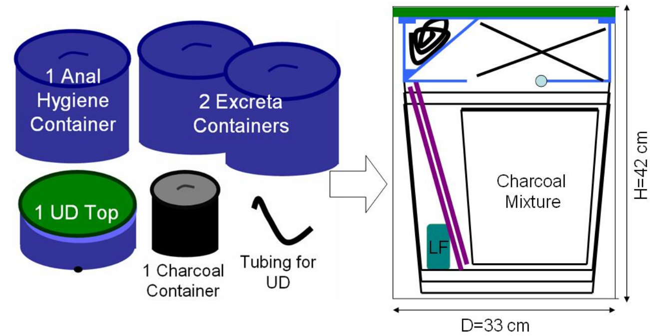


**Figure 4: Easily Transportable Porta Preta Kit**

## Expected Challenges

There are some challenges expected to be encountered in this design which must be addressed:

**1. Training:** the users must be quickly and effectively trained how to use the system. This can be facilitated by diagrams present on the lid or the side of the system. The negative odor feedback with improper use is also expected to help encourage proper use.

**2. Ergonomics**: the bucket must be designed to support the weight distribution of the user during defecation and anal cleaning. This can be improved by local materials (rocks, concrete or bricks) as well as user precaution.

**3. Lactofermenting bacteria:** work must be carried out to deliver the bacteria in a reliable, transportable way. One approach may be freeze-drying and encapsulating the bacteria as done for many probiotic supplements for human and animal diets.

**4. Squatters:** this design is not particularly suitable for individuals which prefer to defecate in the squatting position. Further development is required to tailor the design to these needs.

**5. Stirring:** Intermittent stirring by the user may be required for proper functioning of the system. If this is the case, then a stirrer can be added to the design for about $1 per unit.

## References:


1. Factura, H et al. "Terra Preta Sanitation: Re-discovered from an Ancient Amazonian Civilisation – Integrating Sanitation, Bio-waste Management and Agriculture." *Water Science & Technology*61.10 (2010): 2673.
2. Choe, KC. "What Does It Take to Put Together a Latrine Project: A Practical Guide for NGOs." Web. <http://www.watersanitationhygiene.org/>.

## Attachment: Additional Information for Calculations

### Assumptions for Biomass Production

These quantities are based on the assumption that 25% mass to biochar conversion would be achieved during the carbonization process which can be carried out in one location using the process developed by the D-labs of MIT.[3]

The wastewater for the constructed wetland is from the bathing and cloth washing facilities and/or the urine from the urine diverting dehydrating systems.
The charcoal produced from biomass is calculated assuming the production of papyrus biomass at a rate of 1.4kg/m$^2$ per month.[4]

It is assumed that organic waste is produced at a rate of 0.08 kg (by dry weight) of organic waste per inhabitant per day.[5]

Another assumption is that the UDDTs will be emptied after one year at a staggered interval in the camp (therefore not all of the dried fecal matter would need to be carbonized at the same time). This resource would thus not be immediately available at the start of the camp, but after more than one year's operation, and thus only appropriate for semi-permanent refugee camps.

### Detailed Costs of the Porta Preta

The target fixed costs for the Porta Preta, delivery, training costs and processing equipment are listed in Table A1 below. The cost of the urine Soakaway patch could be reduced if the urine was reused in a garden or in agriculture.

| **Fixed Costs** | |
|---|---|
| Porta Preta Unit | $25 |
| Logistics (delivery) | $10 |
| Labor (distribution and user training) | $0.60 |
| Processing Equipment Cost | $2.00 |
| Urine Soakaway patch | $20 |

**Table A1: Total Fixed Costs**

The further breakdown of the cost of the Porta Preta unit with the materials for one month of operation for five people is listed in Table A2 below. The different parts described are seen in Figure 4.

| Component | Target Cost |
|---|---|
| Plastic Urine Diverting Top | $8.00 |
| Buckets (3) | $4.50 |
| Lids (2) | $1.00 |
| Charcoal Bucket with lid (1) | $2.00 |
| Urine Jerry Cans (2) | $3.00 |
| Tubing | $1.00 |
| Charcoal (5.0kg) | $3.00 |
| EMA + Sugar (1.25 kg) | $2.50 |
| **Total:** | **$25.00** |

**Table A2: Target Cost of Porta Preta Parts**

The initial labor per unit is expected to cost $0.60 assuming local hygiene promoters can be trained (and paid at $4/day), and train approximately 6-8 families each day.

The terra preta processing equipment cost for one unit would be $2, assuming the following collection scheme was followed as presented in following Collection and Processing Section.

### Monthly Cost of the Porta Preta Operation

The monthly costs are targeted to be $3.50 for consumables assuming 5.0 kg of charcoal and 1.25 kg of sugar are used. The cost of charcoal is estimated at $0.50 from an average of the prices given on charcoalproject.org. The cost of sugar is estimated to be $1/kg. The cost for collection and treatment is estimated at $0.50/Porta Preta per unit per month (described below). Thus, the total monthly operation cost would be $4.00 per unit or $0.80 per person. This can be further reduced if biochar is produced on-site.

### Collection and Processing

Assuming a person produces 1 liter of feces per week, and that the volume is not affected significantly by the small addition of the biochar and lactofermenters. Each unit, assuming five users, would have five liters contained after one week. If 40 buckets were collected in a day, then the treated feces from one day of collection could be treated in one 200 liter oil drum (estimated to cost $15). Thus, one laborer could handle the input from 200 units, or 1000 people. This is summarized in Figure A1 below.

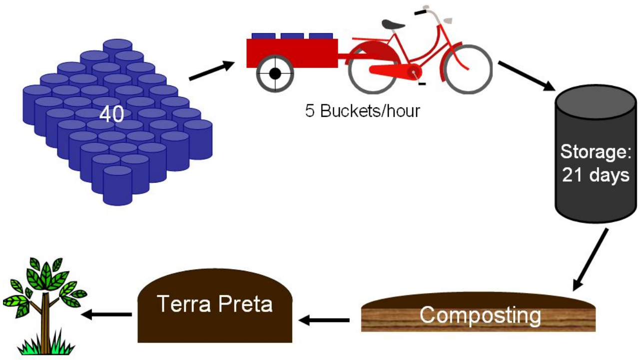


**Figure A1: Porta Preta Collection Scheme**

At a centralized collection area, the feces should be stored for three weeks to allow further sterilization before being composted. Thus, assuming a residence time in the drum of three weeks to allow further hygenization, 21 units would be required. Thus the initial equipment costs to process the feces from 200 Porta Preta units, would be $395, or about $2 per unit. Details of the cost breakdown are shown below.

| | |
|---|---|
| 21 Holding Drums | $315 |
| 1 bike | $40 |
| 1 wagon | $40 |
| Total | $395 |
| **Cost/unit** | **$1.98** |

**Table A3: Porta Preta Collection and Treatment Costs**

The cost of the composting materials is not included because it is proposed that the pallets from the TEU be used for this purpose. The terra preta which is produced can be used for crop production (for non-food production for the first two years) or reforestation. The added value of these benefits is not included in the cost analysis.

### References Continued:

3. "Fuel from the Fields Charcoal Background." MIT D-Lab. <http://d-lab.mit.edu/sites/default/files/Charcoal_BG.pdf>.
4. Perbangkhem, Thaneeya, and Chongchin Polprasert. "Biomass Production of Papyrus (Cyperus Papyrus) in Constructed Wetland Treating Low-strength Domestic Wastewater." *Bioresource Technology* (2009).
5. Davis, Jan, and Robert Lambert. Engineering in Emergencies: A Practical Guide for Relief Workers. London: ITDG, 2002. Print.