Terra Preta Sanitation System for Post Disaster Transitional Communities: A Feasible Solution for Low Resource Settings

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Abstract

The frequent occurrence of disasters is a reality which communities all over the world face at present. Mortality and morbidity occur not only as a direct result of the disaster but continue to occur among post-disaster survivors especially when they are settled in evacuation camps. These camps provide temporary dwellings which are often poorly constructed since they are intended as short-term solutions. Often, sanitation and sanitation facilities are the most neglected aspects in the planning of these camps.

Actual experience with several disasters in the last 4 years in the Philippines has led to the realization that existing post-disaster sanitation solutions are often not practical and suitable for use in developing countries since they are expensive to maintain. An example is the Portalet which is often the immediate sanitation solution recommended after a disaster. However, aside from inadequate numbers of these toilets being provided, the budget for cleaning and evacuation is often not provided or is assumed to be the responsibility of the local government unit. As a result, when these toilets are full, people refuse to use them and go back to open defecation, thus defeating their purpose which further leads to outbreaks of sanitation – related infectious diseases. This experience led to the search for a better sanitation solution for communities after a disaster.

This case study is about a sanitation system solution using dry toilets and terra preta sanitation (TPS) for post-disaster evacuation camps which can be constructed and put in place rapidly, will safeguard health and hygiene, at a cost affordable to developing countries. It is designed for a maximum of 300 persons or 60 families (5 members / family). This case study highlights the following:

1. Low-cost, easy to put up facilities;
2. Minimum maintenance since only urine is designed to be collected and re-used;
3. Hygienization of feces through the use of terra preta sanitation;
4. Linking of sanitation and agriculture;
5. Provision of a food source, as well as a source of income for the post-disaster community

This sanitation system has been field tested after several disasters which have occurred in the Philippines namely, Tropical Storm Washi in 2011, the Visayas Earthquake and Supertyphoon Haiyan in 2013.

Keywords: disaster, terra preta sanitation, UDDT

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1. Technical Description

This terra preta sanitation system is designed for transitional post-disaster communities. It can be put in place rapidly, is relatively low-cost, and therefore, applicable and suitable for use in low- and middle income countries after the occurrence of a disaster or an emergency. The system is designed to serve 300 persons (around 60 families) and to be used for 6 months to a year since the intention of this system is temporary, to be used in transitional housing communities after a disaster, while the community is waiting to be relocated to permanent houses.

The sanitation system is composed of the following parts:

a) 6 Arborloo toilets (3 toilets for males and 3 for females) – squat type, with urine separation built over a pit which measures 2 meters in width, 3 meters in length, and 1.5 meters in depth. Additional male urinals are provided at the back of the male toilets. Urine is will be collected in 20 liter jerry cans for urine composting and re-use in agriculture. Since the toilets are not connected to a water system, they are of the urine diversion type. Feces will be collected in the pit and after defecation, each user has to put around 2 handfuls of ash and pour around 20 ml of bacterial mix. This process ensures that processing of the organic waste is started in the pit and that minimal odor is produced. When the pits are full, they will be covered and the toilet will be transferred to a new location.

b) Rainwater catchment and hand washing facilities – rain water will be collected from the roofs of the toilets which will have pipes (PVC 2 inches in diameter) connected to storage tanks to collect rain water. These collection tanks will be in turn be connected to pipes (PVC 0.5 inch in diameter) with taps for hand washing after using the toilet. The hand washing facilities will measure 0.8 m from the ground and platforms will be provided for children.

c) Filtering bed for grey water – This will be connected to the hand washing taps and grey water produced after hand washing will be filtered here. This filtering bed measures 6 meters in length, 2 meters in width, and 1.5 meters in depth. Grey water will feed into this bed from 2 pipes buried in the bed. Filtration of grey water will be accomplished by layers of stones, gravel, charcoal, coconut coir, and soil. In addition, the bed will be planted with papyrus, the roots of which will also help in grey water filtration through the process of bio-remediation. The bed will be covered with impervious lining to prevent seepage.

d) Compost pits (2) – these will measure 2 x 2 x 1.5 meters. They are designed to be used to compost solid waste and urine. Compost produced will be used in the gardens which are also part of the sanitation system.

e) Urine storage tanks – 2 tanks of 1000 liter capacity. Jerry cans from the toilets and urinals when full will be emptied in these tanks. In turn, these tanks will have taps at the bottom so that urine can be easily drawn for inclusion in composting or directly used in the gardens.

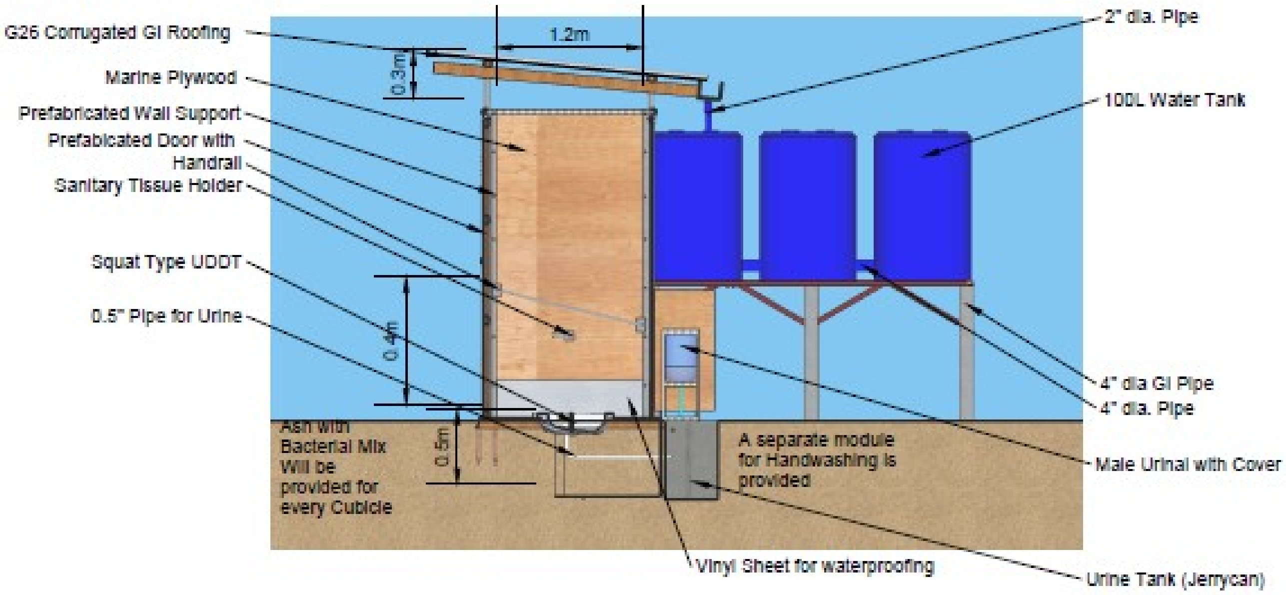
f) Communal gardens – These will be planted with food crops indigenous to the locality. These crops will supplement the diets of the community as well as provide them with income.

Detailed Description of the Toilets

The toilets are arborloo, urine diversion, terra preta, and squat type. 3 toilets will be provided for males and 3 for females. Each toilet cubicle will measure 1.2x1.2 meters per cubicle, will have walls made of marine plywood, a floor made of marine plywood, covered with vinyl and a roof made of galvanized iron sheet. Hand rails are provided designed to be of help for the elderly and the disabled. Urine will be collected in jerry cans with a capacity of 20 liters. Feces will be collected in a pit where the terra preta process will be started to control odor and also to start processing the feces so that pathogens and helminth eggs are destroyed and will not endanger health (see **Appendix 1** for procedure).

These toilets are designed to be put up rapidly and can be assembled in very little time. Kits for the toilets will be always available and at hand and will be designed as part of the Disaster Risk Reduction and Management (DRRM) plan for every city and municipality. The context is a middle income country like the Philippines, where disasters from natural calamities such as typhoons and earthquakes are a very common occurrence.

UDDT Toilet Detailed Drawings with Specifications and Bill of Materials



Bill of Materials

Toilet Material Cost					
Doors	Door with Panel	6	EA	800	4800
	Door hinges 4"	12	pcs	75	900
	Barrel Bolt	6	set	60	360
Steel Works	2.6mmx25mmx6m angle bar	24	h	270	6480
Roofing Works	1.5mm flat sheets	4	LM	120	480
	GA 26 corrugated GI sheet	4	sheets	320	1280
	1.5mmx2.44m gutter strap	1	piece	70	70
	2-1/2" umbrella nail	1	kls	75	75
Carpentry	2x3x8 coco lumber	6	pcs	67	402
	2x2x8 coco lumber	8	pcs	45	360
	# 1.5 common nails	1	kls	60	60
	# 3 common nails	0.5	kls	60	30
	# 4 common nails	0.5	kls	60	30
	3/4" Marine Plybboard	9	pcs	400	3600
	12x50mm Tekscrew	150	pcs	3.2	480
	12x35mm Steel Tekscrew	45	pcs	3.3	148.5
Electrical	CFL 18W bulb	2	pcs	220	440
	Porcelain receptable	2	pcs	55	110
	#14 CU wire	5	LM	176	880
	Electrical tape	2	rolls	45	90
	Panel board	1	pcs	720	720
	Switch 2 gang	2	pcs	120	240
Plumbing	UDDT toilet	6	lot	1000	6000
	1/2"-DIA. POLYTELENE PIPE	5	LM	150.00	750
Painting Works	Red Oxide Paint	1	pail	13250	13250
	Enamel Paint	1	pail	2500	2500
			Total	PhP	44535.5
Labor Cost					
Carpenters		10	250		2500
Laborers		20	200		4000
			Total	Php	51035.5

2. Economic Aspect of the TPS Sanitation System for a Post Disaster Community – Cost Benefit Analysis of Establishing a Terra Preta Sanitation System

A. Provision of Sanitation Facility - Link to Health and Economic

In analyzing the economic potential of this system we begin by a looking at the basic connection between the availability of proper sanitation system and health. Provision of proper sanitation facility in a post-disaster community does not only provide privacy and maintain human dignity, it also avoids the cost of treating water-borne related diseases. Disaster survivors are so vulnerable to diseases most especially to water-borne diseases like diarrhea, gastroenteritis, and amoebiasis. These diseases are avoidable through provision of potable water and proper sanitation systems.

Our experience in Cagayan de Oro, Philippines after Tropical Storm Washi, taught us that immediate provision of proper sanitation system to the post-disaster community can indeed minimize the incidence of water-borne diseases, and therefore avoid the additional burden of treating these diseases.

Assuming a post-disaster community with 300 individuals (60 families x average 5 members), if 10% of the population falls ill with diarrhea because of poor sanitation, there will 30 sick individuals. In the Philippines, it will cost around PhP 60,000 (Euro 1032.00) to treat them. The simple act of providing basic and proper sanitation is life-saving, as well as economically beneficial.

B. The Potential Value of Urine in the Philippines according to its Nutrient Content

The monetary value of the nutrients in urine can be calculated by determining the synthetic fertilizer equivalent of the basic macronutrients (N, P, K) in urine times the current local synthetic fertilizer prices. Commonly used fertilizers in the Philippines are Complete fertilizer (14/14/14), Urea (46/0/0), and Muriate of Potash MOP (0/0/60).

To calculate the nutrient value of Philippine urine excreted per person and year, the average Philippine nutrient content of urine can be translated into the equivalent amount of synthetic fertilizers (see Table 1). Since the nutrient ratio in the urine does not fully correspond with the Complete fertilizer (14-14-14) nutrient ratio, the first row only reflects the necessary amount of Complete fertilizer (14-14-14) based on the total P content in the urine because P is available in the least amount in human urine. The following 2 rows reflect the amount of Urea and Potash to be added to compensate the remaining Nitrogen and Potassium amount.

Table 1: Synthetic fertilizer equivalents (in kg) of annual nutrient excretion with the urine (person/year)

Average N,P,K content in PH urine (kg/pax/year)		
N (2.18 in total)	P (0.20 in total)	K (0.87 in total)
0.49	0.2	0.38
1.69	0	0
0	0	0.49

Equivalent amount of synthetic fertilizer (kg)	
Complete (14-14-14)	3.27
Urea (46-0-0)	3.67
MOP - Muriate of Potash (0-0-60)	0.98

The equivalent amount of synthetic fertilizer can then be multiplied by the current local market prices for these fertilizers and extrapolated per person, per household or even for the entire country (see Table 2).

Table 2: Monetary value (PhP/person/year) of N, P, K nutrients found in Philippine urine

Equivalent of synthetic fertilizer (kg/year)		Market price PhP/kg	Subtotal per year (PhP)	Subtotal per year (Euro)
Complete (14-14-14)	3.27	37	121	2.07
Muriate of Potash (0-0-60)	3.67	40	147	2.50
Urea (46-0-0)	0.98	35	34	0.58
Total per person			302	5.18
Total per family with average 5 family members			1510	25.94
Total for the whole Philippines: current (2014) population around 99 million			29,906,910,000	513,857,000

(Adapted from Gensch et.al. 2011); Note *Exchange rate 1 Euro = PhP 58.20

The annual per capita value of urine for Filipino is estimated around PhP302 (Euro 5.18). For a family of average 5 members, it can be estimated that the annual nutrient value they excreted from urine is around PhP1510 (Euro 25.94)

Consequently, estimating value of the nutrients from urine excreted of the whole country of the Philippines current population in 2014, it be around PhP29,906,910,000 (Euro 513,857,000).

This conservative estimate will vary over the year depending as the price of the fertilizers increase and population also depends on the population growth rate.

C. *Economic Potential of the TPS System for Post Disaster Community through closing the loop between sanitation and agriculture: Establishment of a Community Garden*

This approach is trying to sell the idea that it is not impossible to provide proper sanitation as well as a reuse opportunity for organic waste in the post disaster community. It is as well to raise awareness in the community that it is possible to close the loop between sanitation and agriculture. This system is trying to provide good and proper sanitation and creating the opportunity to get healthy diets from the community garden and to reduce their vulnerability to malnutrition and incidence of water-borne diseases. The community garden in this system will measure around 500 square meters and the 60 families (with 5 average members) will share the community garden. The garden will be subdivided into 1m x 5m ($5m^2$ per bed), and every family maintains one bed ($5m^2$). However, they share their produce from the garden. The beds will be planted with 10 vegetable crops rotationally depending on the life span of the vegetable, in order to get diverse nutrients from the garden. Whether the gardeners consume or sell the vegetables produced from the garden, the following table presents the conservative economic valuation of the expected outputs from the garden. Based on the conservative estimates Table 3 shows that there will be at least around PhP 152,520 (Euro 2,076.00) revenue from the community garden if the reuse oriented sanitation system will be established in the post-disaster community.

Table 3: Annual Revenue from the 300m² Community Garden in a Post-Disaster Community

Vegetable and description		Harvest per cropping/season (kg) (1mx5m =5sq.m)	Price (kg)	Revenue per cropping (1mx5m =5sq.m)	Revenue per cropping (6 beds x 5sq.m =30sq.m)	Annual Revenue from the 5m² x 60beds (300m²)
1. Bitter gourd *Note: 50cm between hills; 10hills per row; 20hills all	1.5	30	35	1050	6300	**18,900**
2. Cucumber *Note: 50cm between hills; 10hills per row; 20hills all	1.5	30	12	360	2160	**64,80**
3. Eggplant *Note: 25cm between hills; 20hills per row; 40hills all	1	40	30	1200	7200	**21,600**
4. Kangkong Note*2rows (5m per row x 2rows)		10	50	500	3000	**24,000**
5. Okra *Note: 50cm between hills; 10hills per row; 20hills all	0.5	10	35	350	2100	**63,00**
6. Pechay *Note: 25cm between hills; 20hills per row; 40hills all	0.3	12	40	480	2880	**23,040**
7. Pepper *Note: 25cm between hills; 20hills per row; 40hills all	0.3	12	80	960	5760	**17,280**
8. Spring onion *Note: 25cm between hills; 20hills per row; 40hills all	0.3	12	90	1200	6480	**19,440**
9.String beans *Note: 25cm between hills; 20hills per row; 40hills all	0.25	10	50	500	3000	**9,000**
10. Tomato *Note: 25cm between hills; 20hills per row; 40hills all	0.5	20	18	360	2160	**6,480**
Total Annual Revenue						**152,520 (Euro 2,620.63)**

Table 4 below presents the most basic investment cost for the establishment and operation and maintenance for the 300m² Community Garden in a post-disaster community in one year. Although each family will not be paid for maintaining their gardens, for the purpose economic valuation, however, labor is also accounted for here. As presented in Table 4, PhP 97,611.78 (Euro 1677.00) is the annual cost incurred. Looking at the Total Annual Revenue we can say that they have some savings from the garden if we convert it to monetary value.

Since in the community garden, labor is free, water for irrigation will be from the greywater filtration, and organic fertilizers will be from the urine and urine compost, it is then assumed that only the cost of seeds is needed (**around PhP 13,385.6**), which is the direct cost for this community garden plus the initial PhP 5000 garden establishment cost. Due to the reuse principle, it is conservatively assumed that benefits will outweigh the investment costs. As observed, the benefit cost ratio (BCR) here is positive even during the first year of establishing this TPS System in the Post-disaster community:

Benefit= 152,520/97,611.78=1.56BCR, clearly showing economic benefits

Table 4: Expected Direct Investment Cost for the Community Garden

Item/Subject	Unit	Quantity	Unit/Quantity	Amount
A. Establishment of Community Garden (land preparation, garden tools)	no	1	5000	5000
B. Inputs				
Seeds	**set for a year**	**1**		**13,385.6**
Labor (assumed 1man/day for the 300sq.m)	day	300	250	75,000
Water 200pesos/10 cubic meter	cubic meter	54	200	1080
Fertilizer	year	1	3146.18	3,146.18
Total Annual Cost				**97,611.78**

With the assumed 300-person population (60 families with 5 average members), the monetary equivalent of the nutrients excreted from urine is presented on Table 5. When urine is collected and utilized as fertilizer, this community would save PhP 453,135 (Euro 7790.87) which would have been the cost of synthetic fertilizer if these had been purchased.

Table 5: Synthetic fertilizer equivalents (in kg) of annual nutrient excretion with the urine (person/year) for the 60 Families Post-disaster Community

Equivalent of synthetic fertilizer (kg/year)		Market price PhP/kg	Subtotal per year (PhP)	Subtotal per year (Euro)
Complete (14-14-14)	3.27	37	121	2.07
Muriate of Potash (0-0-60)	3.67	40	147	2.50
Urea (46-0-0)	0.98	35	34	0.58
Total per person			302	5.18
Total per family with average 5 family members			1, 510	25.94
Total for the whole 300 individuals			**PhP453,135**	**7,785.82**

3. Conclusion

Most parts of this sanitation system have been field tested from December 2011 to the present, after 3 major disasters were experienced in the Philippines; Tropical Storm Washi, which devastated the city of Cagayan de Oro in December 2011, the earthquake which hit the island of Bohol and many other provinces in the Visayas in October 2013, and finally Super typhoon Haiyan, which affected again the Visayas in November 2013.

Xavier University played a major part in the relief operations after TS Washi. The university's experience with providing terra preta sanitation systems for evacuation centers was a result of need and creativity, since international aid agencies were providing portalets, which, after a few days would be full and had to be evacuated. The process proved to be very unhygienic as well as expensive and resulted in outbreaks of diarrhea and other sanitation-related diseases.

The parts which were field tested were the arborloo urine diversion toilets, with urine collection and composting; the grey water filtration beds; composting of urine with solid biodegradable waste, and the gardening component. Xavier University donated land for transitional and permanent housing after TS Washi in Cagayan de Oro City and we were able to field test these components in that community.

The terra preta component was used after research from the School of Medicine showed that the addition of ash and a bacterial mix was effective in getting rid of pathogens and helminth eggs, thus rendering feces collection safe.

In the actual communities, water supply for hand washing proved to be difficult since the community had no piped water and had to rely on water being supplied by trucks. Therefore, in this sanitation system, we are advocating rain water catchment and its connection to hand washing facilities to make the system complete.

References

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4. Appendices

Appendix 1 Urine Composting Method

Appendix 2 Additional Technical Diagrams and Specifications

Appendix 1
Urine Composting Method

Another alternative urine use is to add urine as a nutrient source in compost production. While the direct use of urine as a liquid fertilizer only mimics conventional agricultural practices by adding mere mineral nutrients to the plants, the production of urine-enriched compost offers a way of improving the soil condition as a whole.

Adding of Urine to the Compost Heap

Urine can be added to regular compost heaps as an additional source of Nitrogen (as well as other macro- and micronutrients). For compost heaps with a high carbon/Nitrogen (C/N) ratio, the urine helps to add the missing Nitrogen element and can therefore be considered a good compost activator. During the composting process, however, considerable amounts of Nitrogen might get lost through volatile Ammonia in the composting process. The adding of urine usually increases the temperature in the compost, which is also beneficial to destroy any remaining pathogens and unwanted seeds in the heap.

Urine Composting

Here, the urine together with a microbial solution is added to a mix of around 10% of garden soil, around 10% of ground charcoal, and around 80% of a finely sliced wood source (e.g. woodchips) and left for (vermi-)composting for a period of 1-2 months with occasional watering of the compost heap. The final (vermin-composted product is a nutrient-rich, humus-like substance with a high organic carbon content that allows for improved water retention and a longer lasting fixation of essential nutrients.

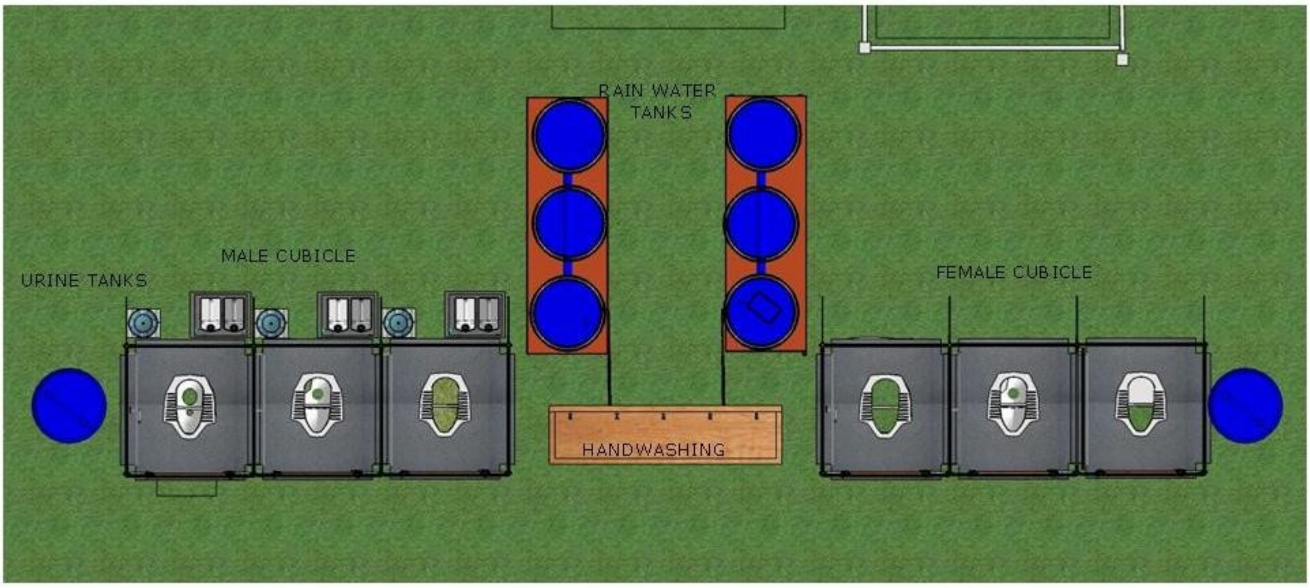
The addition of charcoal (coming from carbonized rice husks, coconut shells, tree clippings, etc.) aids in the absorption of nutrients. The wood source provides lignocellulose and increases the C/N ratio needed for the composting process. The desirable C/N ratio for humification lies between 21 to 24.

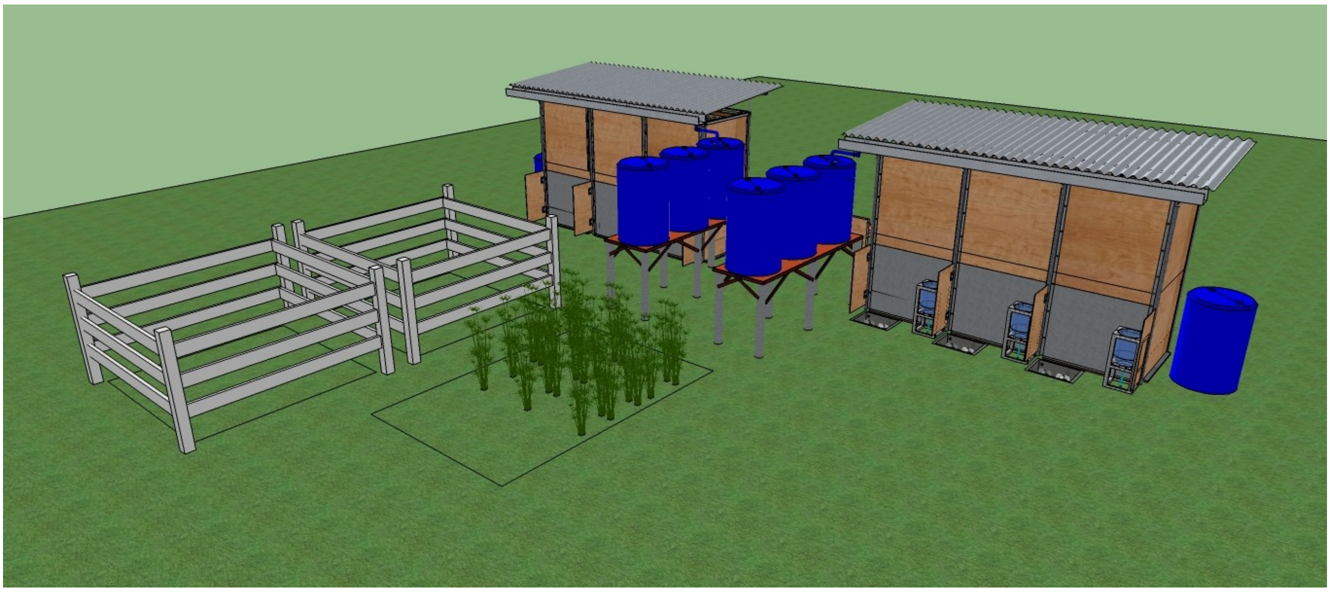
The microbial mix added to the urine contains selected microbes that aid in the formation of humic acids and helps inhibit the bacterial urease process that hydrolyses urea into Ammonia and bicarbonate, thereby avoiding significant losses of Nitrogen through volatile Ammonia. As a positive effect, the characteristic smell of urine coming from the Ammonia is considerably reduced as well.

The microbial mixture contains 5 key microbes (Bacillus subtilis, Bacillus mesentericus, Geobacillus stearothermophilus, Azotobacter croococcum, Lactobacillus spec). This mixture is easily propagated and kept alive by adding a little milk and sugar every week.

Appendix 2
Additional Technical Diagrams and Specifications

TOP VIEW



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A medical doctor whose passion is public health, Doctor Gina has been working and doing research in post –disaster communities in the last 3 years. Her academic background includes degrees in Biology, Medicine, and Community Medicine. She currently holds the rank of Associate Professor at the Xavier University School of Medicine, and since 2012, is also the Director of the Sustainable Sanitation Center.