ABSTRACT

The frequent occurrence of disasters is a reality which communities all over the world have to deal with 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 Tropical Storm Washi which devastated the city of Cagayan de Oro in Northern Mindanao, the Philippines in December 2011, 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. A perfect 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 the toilets are full people refuse to use them and go back to open defecation, thus defeating their purpose. It is this experience which inspired the Xavier University team to search for a better sanitation solution for communities after a disaster.

This proposal is for the provision of a sanitation system using 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 proposal 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

Some aspects of the proposal have been field tested after several disasters which have occurred in the Philippines (Tropical Storm Washi in 2011, the Visayas Earthquake in October 2013, and Typhoon Haiyan in November 2013).

Terra Preta Sanitation System

for Post Disaster Transitional Communities in the Philippines

An entry from

Xavier University
Ateneo de Cagayan

Cagayan de Oro City, Philippines

A Terra Preta Sanitation System for Post-disaster Transitional Communities in the Philippines

1. **Technical Description**

The proposed terra preta sanitation system is designed for transitional post-disaster communities. It is designed to be put in place rapidly and to be relatively low-cost, and therefore, applicable and suitable for use in low- and middle income countries after 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 for 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:

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 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.

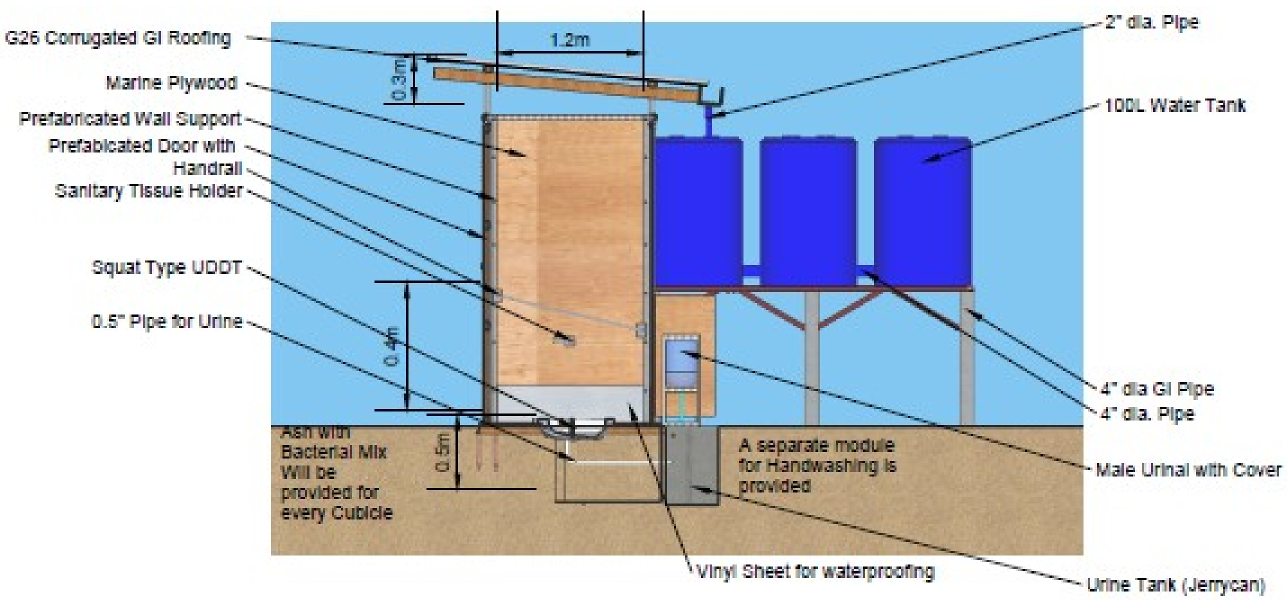
f) Communal gardens – These will be planted with food crops such as bitter melon, cucumber, eggplant, kang kong (swamp cabbage), okra, pechay, sweet pepper, spring onion, string beans, and tomato. These crops will supplement the diets of the community as well as provide them with income.

Detailed Description of the Toilets

The toilets are arborloo, urine diversion, 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. **Business Model**

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

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

This system is a closes the loop by trying to link sanitation and agriculture. In order to present the economic potential of this system, we attempt to present the economic value of the nutrients found in Philippine urine. Based on the study of Gensch, et. al. in 2011, average annual per capita (kg/person/year) nutrient content of urine excreted in the Philippines is around (2.18N-0.20P-0.87K). The figures describe the total percentage of available Nitrogen (N), Phosphorus (measured in % of P_2O_5), and soluble Potassium (measured in % of K_2O) in each of the fertilizers.

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).

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.

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

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 $300m^2$ 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 $5m^2$ x 60beds ($300m^2$)
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 300m^2 Community Garden in a Post-Disaster Community in one year. Although each family will not be paid for maintaining their gardens, however for the sake of getting the economic valuation, labor is also accounted for here. As presented on this table**, PhP 97,611.78 (Euro 1677.00)** is the annual cost to incur. 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 from the family, water for irrigation will be reuse from the greywater filtration, and fertilizers will be from the urine and urine compost, it is then assumed that only seed cost (**around PhP13,385.6**) is the direct cost for this community garden plus the initial PhP5000 garden establishment cost. Due to the reuse principle, it is conservatively assumed that benefit is outweighs 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, Thus, the system has 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.

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. **Additional Questions**

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. Our 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 and 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.

Reference

Gensch R, Miso A, Itchon GS. *Experimental study on the use of human urine for selected Philippine Crops: Assessment of macronutrient content in Philippine urine and determination of appropriate application rates, 2010-2011*. Xavier University Journal of Medicine vol 7, 2011, p10-21.

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Appendices

Appendix 1 Urine Composting Method

Appendix 2 Additional Technical Diagrams and Specifications

Appendix 3 The Effectivity of the Terra Preta Sanitation (TPS) Process in the Elimination of Parasite Eggs in Fecal Matter: A Field Trial of Terra Preta Sanitation in Mindanao, Philippines (Itchon GS, Miso AU, Gensch R)

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 (based on RECKIN, 2010). 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.

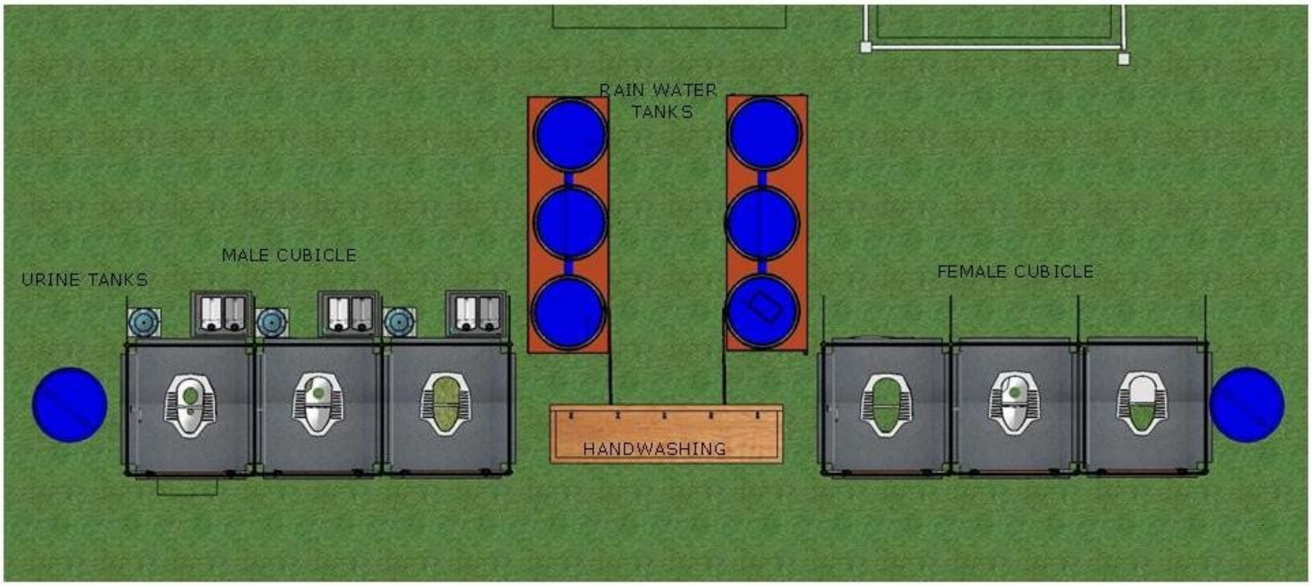
The addition of charcoal (coming from carbonized rice husks, coconut shells, tree clippings, etc.) aids in the absorption of nutrients. The wood source provides lignocellulose and increases the C/N ratio needed for the composting process. The desirable C/N ratio for humification lies between 21 to 24 (RECKIN, 2010).

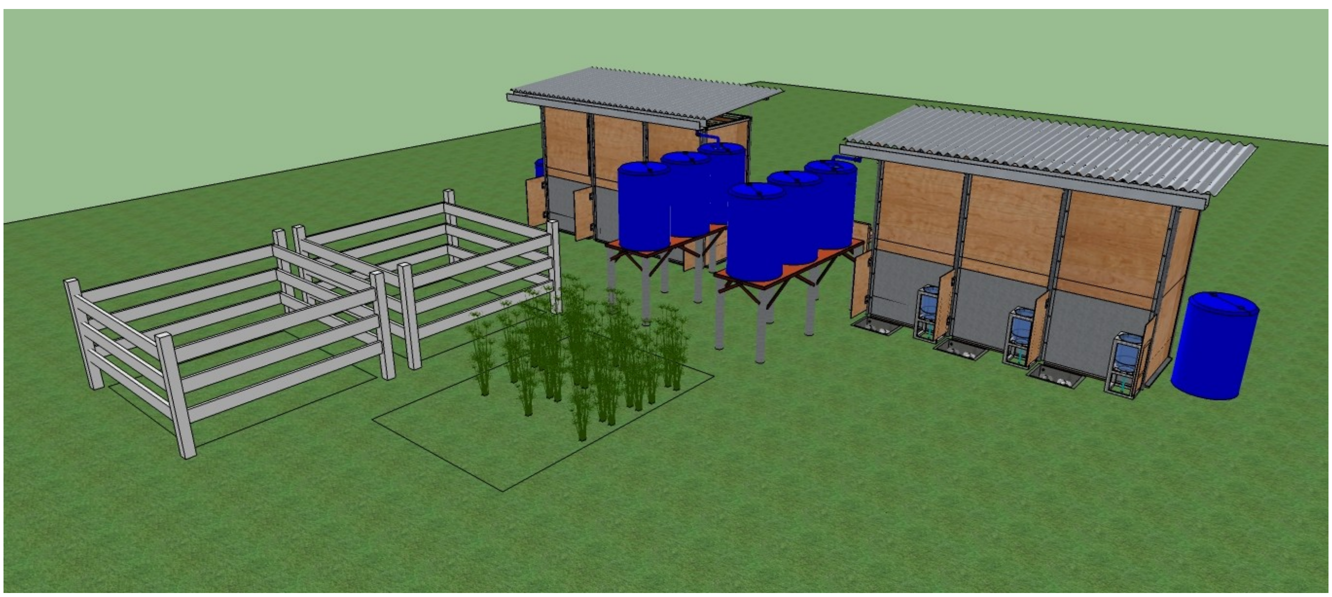
The microbial mix added to the urine contains selected microbes that aid in the formation of humic acids and helps inhibit the bacterial urease process that hydrolyses urea into Ammonia and bicarbonate, thereby avoiding significant losses of Nitrogen through volatile Ammonia (RECKIN, 2010). As a positive 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). The mix can be obtained free of charge from the XU SUSAN Center (see contact details at the end) and can be easily propagated by adding water, milk, and a sugar source to feed the microbes regularly.

Appendix 2
Additional Technical Diagrams and Specifications

TOP VIEW



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Appendix 3

The Effectivity of the Terra Preta Sanitation (TPS) Process in the Elimination of Parasite Eggs in Fecal Matter: A Field Trial of Terra Preta Sanitation in Mindanao, Philippines (Itchon GS, Miso AU, Gensch R)

Abstract

Earlier studies have shown that *Ascaris lumbricoides* ova persist in dried human faeces from urine diverting dehydration toilets (UDDT) vaults even up to 10 months without secondary treatment. To address gaps in the knowledge for effective secondary treatment methods, this study aimed to determine the effects of a bacterial mix (obtained from Dr Jurgen Reckin) as a fermenting medium, in combination with charcoal (Terra Preta Sanitation process) on parasite egg reduction.

The study was conducted using twenty (20) UDDTs in Lumbia, Cagayan de Oro City, in Mindanao, Philippines. The users of 10 UDDT toilets were told to add powdered charcoal and 20 ml of the bacterial mix after using their toilets for defecation, while owners of 10 different UDDT toilets were told to just add charcoal after defecation. The study was conducted for three (3) months after which the collected faeces from all the UDDT toilets were collected, stored for another 3 months, and were then vermicomposted separately for six (6) weeks.

Results showed that after 3 months of undergoing the terra preta sanitation (TPS) process (addition of powdered charcoal and bacterial fermenting mix), fecal material was virtually free of parasite eggs, especially that of *Ascaris lumbricoides* which proved to be very difficult to eradicate in earlier studies, when compared to faecal material to which only charcoal was added. Nitrogen, Phosphorus and Potassium (NPK) values for both experimental groups were also comparable after undergoing vermicomposting.

Therefore, the TPS process is an effective secondary treatment method for eliminating parasite eggs from dried human faeces in a country with a tropical climate like the Philippines. It is capable of rendering faeces safe for re-use in a shorter time compared to just drying or using no secondary treatment. This is of particular importance in developing countries like the Philippines where the parasite load in the population is extremely high. Furthermore, NPK values after vermicomposting showed that there is no significant difference between the two experimental groups.

It is therefore recommended that the TPS process be used as a secondary treatment method for faeces collected from UDDT toilets particularly in countries like the Philippines, with a tropical climate and where re-use of faeces poses a risk to health and hygiene because of a high parasite load in the population.

Keywords: terra preta, terra preta sanitation, urine diverting dehydration toilets

Introduction

"Terra Preta de Indio" (Amazonian Dark Earths; earlier also called "Terra Preta do Indio" or Indian Black Earth) is the local name for certain dark earths in the Brazilian Amazon region. These dark earths occur, however, in several countries in South America and probably beyond. They were most likely created by pre-Columbian Indians from 500 to 2500 years B.P. and abandoned after the invasion of Europeans (Smith, 1980; Woods et al., 2000). However, many questions are still unanswered with respect to their origin, distribution, and properties.

The global carbon cycle has been brought to wide attention due to its importance for the global climate. The Intergovernmental Panel on Global Change (IPCC, 2001) recently confirmed that the anthropogenic greenhouse effect is a reality, which we have to deal with in the future. The atmospheric CO2 has increased from 280 ppm in 1750 to 367 ppm in 1999 and today's CO2 concentrations have not been exceeded during the past 420,000 years (IPCC, 2001). The release or sequestration of carbon in soils is therefore of prime importance.

Soil organic carbon is an important pool of carbon in the global biogeochemical cycle. The total amount of organic carbon in soils is estimated to be 2011 GtC, which constitutes about 82% of the global organic carbon in terrestrial ecosystems (Watson et al., 2000). Amazonian Dark Earths have high carbon contents of up to 150 g C/kg soil in comparison to the surrounding soils with 20-30 g C/kg soil (Sombroek WG et al., 1993; Woods and McCann, 1999; Glaser et al., 2000). Additionally, the horizons which are enriched in organic matter, are not only 10-20cm deep as in surrounding soils, but may be as deep as 1-2m (average values probably around 40-50cm). Therefore, the total carbon stored in these soils can be one order of magnitude higher than in adjacent soils.

The potential of terra preta soil as a means to enrich soil and make it more productive is important for an agricultural country such as the Philippines. Furthermore, the potential of creating terra preta from bio-waste such as human excreta is a possibility which needs to be investigated further. Of particular interest for investigation, is the potential of the terra preta sanitation process to eliminate parasite ova, particularly of *Ascaris lumbricoides*, which have been proven by a number of studies (Itchon G et al 2008; Sanguinetti G et al 2009) to persist for extended periods in dried fecal material. These studies have shown that *Ascaris lumbricoides* ova may persist in dried human faeces from UDDT vaults even up to 10 months without secondary treatment (Itchon et al, 2008). To address these gaps in the knowledge, this study aimed to determine the effects of a bacterial mix (obtained from Dr Jurgen Reckin[*]) as a fermenting medium, in combination with charcoal, as well as the influence of time on parasite egg reduction.

Specifically, it aimed to achieve the following objectives:

a) to determine the optimum Carbon: Nitrogen (C:N) ratio suitable for vermicomposting;
b) to investigate the potential of terra preta (TP) as a source of nutrients to plants.

Materials and Methods

Type of Study: Analytic Observational

Study Location: Lumbia and Palalan, Cagayan de Oro City, Philippines

Study Procedure:

Phase 1

*[*] This bacterial mix contains the following bacteria: *Bacillus subtilis*, *Bacillus mesentericus*, *Geobacillus stearothermophilus*, *Azobacter croococum*, and *Lactobacillus sp.*

Twenty (20) toilets were initially identified for the first phase of the study. 10 urine diverting dehydration toilets (UDDTs) from Lumbia, and 10 from Palalan, Cagayan de Oro City. The 10 UDDTs in Lumbia were designated for use with the microbe fermenting mix and powdered charcoal; while the 10 UDDTs in Palalan, were designated for use with powdered charcoal only. This was to ensure that comparison could be made regarding the effect of the bacterial mix on the reduction of pathogens and parasite eggs in the collected faeces contained in the toilet vaults.

Toilet owners in both Lumbia and Palalan were oriented on the proper use of UDDTs and the addition of material after defecation. Designated toilet owners in Lumbia were told to add around 20 ml of bacterial mix and a cup of powdered charcoal after defecation; while designated toilet owners in Palalan were just told to add a cup of powdered charcoal. Residents were told to use their toilets for a week before the observation period was started and before addition of bacterial mix. Fecal samples were then taken from all toilets for baseline data. Additional samples were then taken 30 days after and 60 days after the start of the observation period. Bacterial mix and powdered charcoal was provided to all toilet owners

Phase 2

At the end of 60 days, 6 toilets were discarded as experimental sites in Palalan because of a number of problems. Among the problems identified were the following: wet fecal material in the UDDT vaults due to improper use of the toilets; charcoal was not added adequately; identification of other discarded material in the toilet vaults (food scraps). The faeces collected from all the experimental UDDTs were put in separate black plastic garbage bags and transported to the storage shed of the community in order to undergo drying for 6 weeks. There were 10 bags from Lumbia (with bacterial mix) and 4 bags from Palalan (without bacterial mix).

After 6 weeks of drying, the faeces from Lumbia and Palalan were put in 2 separate beds for vermicomposting. 44 k of faeces with bacterial mix and 44 k of faeces without bacterial mix were placed in 2 beds. C:N ratio of 70:30 was used and 1 k of African nightcrawlers were used for composting for each of the beds. Standard vermicomposting procedures were used. Fecal samples were then taken at monthly intervals to further monitor for presence of parasite eggs for the next 3 months during the vermicomposting phase. Samples were also taken for N P K analysis after 3 months. Vermicast analysis was done at the Regional Soil Testing Laboratory of the Department of Agriculture Regional Office 10.

Results

The tables below show the results during Phase 1 and Phase 2 of the study. Table 1 and 2 show the results during Phase 1while Table 3 and 4 show the results for Phase 2.

Table 1. Number and Type of Parasite Ova in Fecal Samples with Bacterial Mix

	Baseline	After 30 days	After 60 days
Ascaris	5-6	Irregular 2-3	0 (none seen)
Taenia	0-1	0 (none seen)	0 (none seen)
Trichuris trichura	2-3	0 (none seen)	0 (none seen)

Table 2. Number and Type of Parasite Ova in Fecal Samples

without Bacterial Mix

	Baseline	After 30 days	After 60 days
Ascaris	3-4	Irregular 1-2	2-4, Irregular
Trichuris	2-3	1-2	0 (none seen)
Enterobius vermicularis	0-1	0 (none seen)	0 (none seen)

Table 3. Number and Type of Parasite Ova in Fecal Samples with Bacterial Mix During Vermicomposting

	After 30 days	After 60 days	After 90 days
No parasite ova	0 (none seen)	0 (none seen)	0 (none seen)

Table 4. Number and Type of Parasite Ova in Fecal Samples Without Bacterial Mix During Vermicomposting

	After 30 days	After 60 days	After 90 days
Ascaris ova	Irregular 0-1	0 (none seen)	0 (none seen)

Tables 5 and 6 show the assay results for vermicasts, specifically testing for Nitrogen, Phosphorus, and Potassium content.

Table 5. Assay for Vermicast of Fecal Samples with Bacterial Mix

Contents (Constituents)	Air Dry Basis (%)	Oven Dry Basis (%)
Total Nitrogen (N)	1.61	1.79
Total Phosphoric Acid (P_2O_5)	0.80	0.89
Total Potassium (K_2O_5)	1.27	1.41
TOTAL N,P,K =	**3.68**	**4.09**
Available Phosphoric Acid (P_2O_5)		
Calcium Oxide (CaO)		
Calcium Carbonate ($CaCO_3$)		
Magnesium Oxide (MgO)		
pH of the Sample		
Moisture Content (as received - 73.5)	10.00	

Table 6. Assay for Vermicast of Fecal Samples Without Bacterial Mix

Contents (Constituents)	Air Dry Basis (%)	Oven Dry Basis (%)
Total Nitrogen (N)	1.24	1.33
Total Phosphoric Acid (P_2O_5)	0.80	0.86
Total Potassium (K_2O_5)	1.03	1.11
TOTAL N,P,K =	**3.07**	**3.30**
Available Phosphoric Acid (P_2O_5)		

Calcium Oxide (CaO)		
Calcium Carbonate ($CaCO_3$)		
Magnesium Oxide (MgO)		
pH of the Sample		
Moisture Content (as received - 73.5)	7.00	

Discussion

The most important finding of this study is that it has been able to demonstrate the effectiveness of using the terra preta sanitation process as a secondary method of eliminating parasite ova from faeces collected in the vaults of urine diverting dehydration toilets. Aside from the advantages of creating terra preta to enrich soil and complete the carbon cycle, the fact that the process also shortens the time required to render human faeces safe for agricultural re-use is a very important finding for a developing country such as the Philippines. Earlier studies have illustrated that in developing countries, the issue of safe re-use of human excreta is often one of the principal barriers to completing the sanitation cycle primarily because of the high parasite load in populations (Itchon et al 2008; Phasha 2005).

The study was also conducted in an actual community where a number of UDDT toilets have been installed and are in use. Thus, this study has also been able to highlight several problems in the use of dry toilets. As mentioned earlier, some toilets were later discarded for data collection since a number of problems were identified. Among other factors, toilet design and proper training and orientation of users were the most important. However, the field trial was also able to demonstrate very clearly, that addition of a bacterial mix and charcoal to faeces after defecation is a very feasible secondary treatment method in humid environments such as what is normally found in the Philippines.

Another important finding of this study is the use of 70:30 C:N ratio during vermicomposting after 6 weeks of drying the collected faeces. The slightly higher Carbon content ratio was necessary to make vermicomposting possible because of the use of charcoal. A C:N ratio of 60:40 was not possible and killed the earthworms after 1 week. This problem was avoided when Carbon content was raised to 70%.

It is also noteworthy that after vermicomposting, assay of the vermicompost from both batches of vermicomposted dried faeces (with and without addition of bacterial mix and charcoal) showed remarkably similar macronutrient and moisture content. Both sample assays also showed that both samples conformed to organic fertilizer standards set by the Philippine National Standards for Organic Fertilizer (Department of Trade and Industry, Bureau of Product Standards, Republic of the Philippines 2008).

Conclusions

Three (3) important conclusions can be drawn from the results. These are:

1. The terra preta sanitation (TPS) process is an effective secondary treatment method for human faeces collected in UDDT vaults;

2. Vermicomposting of dried human faeces that have undergone the TPS process requires a slightly higher C:N ratio (70:30 instead of 60:40);
3. Assay of vermicompost from dried human faeces which have undergone the TPS process conformed to Philippine standards for organic fertilizer in terms of NPK and moisture content.

Recommendations

It is therefore recommended that the TPS process be used as a secondary treatment method for faeces collected from UDDT toilets particularly in countries like the Philippines, with a tropical climate and where re-use of faeces poses a risk to health and hygiene because of high parasite load in the population.

It is further recommended that a larger scale field trial be conducted in order to validate the findings of this study.

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