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Sanitation in South Africa: A Preliminary Evaluation of Barriers & Opportunities.

Duke PRATT SCHOOL OF Engineering

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About this Report

This report was prepared in conjunction with the Water, Sanitation and Hygiene program of the Bill & Melinda Gates Foundation. Duke University in partnership with the University of Missouri received a grant from the Foundation for the development of a Supercritical Sanitation System to be applied for the neighborhood scale.

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Executive Summary

During June 2013, a team from Duke University undertook a preliminary evaluation as to the economic and technical feasibility to apply Supercritical Water Oxidation (SCWO) as a means to manage pit latrine wastes in the South Africa context. The team visited informal and formal settlements located in KwaZulu-Natal, eThekwini, Durban, Cape Town, Enkanini and Stellenbosch, South Africa.

The goal of the field work was to identify possible opportunities where the application of SCWO would be both an appropriate technology and an economically viable option as compared to existing methods of managing human wastes. Additionally, the team examined the social, environmental and regulatory drivers that impact on the potential utilization of SCWO.

Efforts were made to coordinate on-site activities with existing partners / recipients within the Bill and Melinda Gates Foundation. This included our partnering with the University of KwaZulu-Natal and the municipality of eThekwini. In addition we worked with representatives from the University of Cape Town as well as the University of Stellenbosch and University College London.

The South African context is unique in that national laws in essence require that national citizens have access to sanitation and water for "free." Additionally, there is a significant push in many of the major metropolitan regions of the country to move away from ablution units and pit latrines and instead to increase investments into toilets with urine diversion and in-situ treatment (drying) of fecal matter. Further, as evidenced in multiple public disturbances in the Cape Town region during the project teams field work, South African citizens are increasingly demanding personal household toilets.

Based on our evaluation, it is our preliminary recommendations that:

1. South Africa and specifically the eThinkwini municipality is an ideal setting to "test/pilot" a SCWO unit due to existing infrastructure and abilities to manage the technological and engineering challenges that may arise in the field.

2. Security is a "major" threat to the successful testing of the unit in the field and must be addressed, dictating placement in a secure facility not in an open settlement.

3. Schools, particularly in rural areas appear to be an option for the utilization of SCWO in that there are needs for sanitation, the schools are generally secured compounds and the byproducts of energy and water can be utilized effectively and sustainably.

4. Sizing of the unit and temporal scale of operation need to be refined as schools will generally only have 350-400 users and operate 0700-1700 Monday-Friday which influences the economic model.

It needs to be noted that our recommendations are specific to "testing" the SCWO technology in South Africa. Moving forward, the Duke team will be evaluating how the SCWO technology, including coupled with ablution units, can provide positive value in different settings including India and Ghana.

I. INTRODUCTION

The Water, Sanitation and Hygiene program of the Bill and Melinda Gates Foundation is striving to provide sustainable sanitation facilities to 40% of the world's population in developing countries that lack safe, functional toilets. The health impact of this issue is considerable. Widespread disease caused by contact with pathogens in human waste is the second most common cause of death among children under 5 years old and accounts for roughly 1.5 million deaths a year.

The Gates Foundations is funding numerous investigations into a wide variety of potential technologies by universities and commercial entities worldwide. The sanitation value chain starts with the individual then the toilet which includes the storage, transport and treatment of human waste, and ends with safe, usable byproducts such as fertilizer, fuel or clean water.

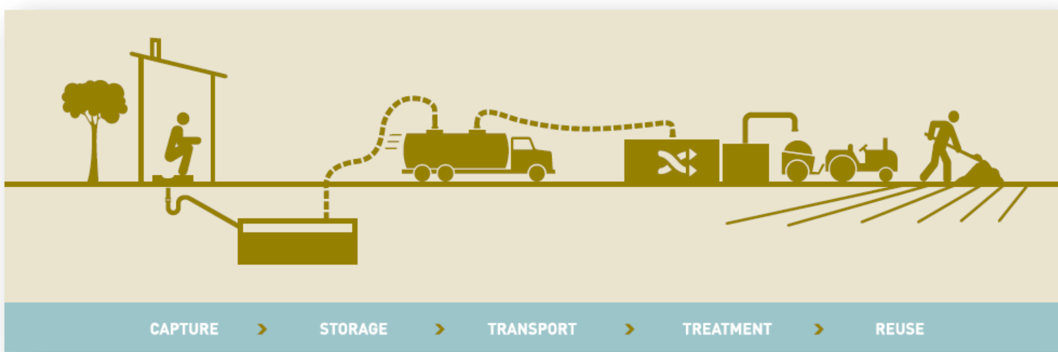

Figure #1: Depiction of the sanitation value chain. Source: Duke University (2013).

A. The Duke-Missouri SCWO Project

Duke University and the University of Missouri are designing a sewage treatment unit that will treat the collected waste of approximately 1,200 people, a neighborhood-scale solution. The goal of this is to produce a demonstration unit that fits into a 20' shipping container and is ready to be tested in a developing country by the summer of 2014. A successful design will have a running cost of less than 5 cents per person per day at commercial volumes.

Supercritical water oxidation (SCWO) is a technology that has already been investigated and employed in several research and commercial applications to treat wastes products including Polychlorinated Biphenyls (PCBs), chemical weapons and sewage waste. It shows promise because it takes very little time to treat waste relative to other treatment methods, produces large amounts of hot water and excess energy in the form of heat and water vapor from the treated human waste. Further, it does not require dewatering or drying of fecal sludge, and it eliminates all types of harmful organisms. Duke and Mizzou seek to demonstrate that supercritical water oxidation and gasification, a related technology, have a role to play in the solution of the world's current sanitation challenge. In addition, we will produce a business model plan that quantifies and optimizes the economic, environmental and social benefits of the treatment unit.

Figure #2: Illustration of the Duke-Missouri SCWO Technology. Source: Duke University (2013).

B. Project Team

Primary research is being done by Duke University's Department of Civil and Environmental Engineering in collaboration with University of Missouri's Biological Engineering Department. In addition, industrial partners with experience in commercial scale SCWO will be providing valuable consulting on the unit's design and development.

The Center for Sustainability and Commerce at Duke University will be leading the environmental and socio-technological investigations of the value proposition and create a business model for the SCWO solution. Many factors affect the ultimate success or failure of the technology on location including the ease of operation and maintenance, the market value of the byproducts produced, the reliability and the cost. The sustainability experts at Duke will help ensure the treatment unit is not only technically sound, but viable from an economic, cultural and regulatory standpoint.

C. Project Timeline

The experimentation and design phase using prototype development units at Mizzou will take place in the spring and summer of 2013. Construction of the demonstration unit in an actual shipping container will take place at Duke beginning late summer and extending through the fall of 2013. In the winter and early spring of 2014, the demonstration unit will be tested at a local sewage treatment plant near Duke University in North Carolina. By summer, 2014, the unit should be ready for on-site testing in a developing country. Throughout the project, possible locations in South Africa, India and Ghana will be evaluated, and an optimum on-site testing location for the follow-on, field-testing phase of the project will be identified.

II. NATIONAL & REGIONAL OVERVIEW

A. South Africa

The Republic of South Africa is located at the southern most edge of the African continent. It held its first universal elections in 1994 with the African National Congress winning a majority. The country is one of the BRICS and is the twenty-fourth most populous country in the world with over fifty-three million citizens. Approximately one-quarter of the population lives on less than $1.25/day.

Millennium Development Goal 7, Target 7C calls on countries to "Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation". According to the United Nations, as of 2006, 17 percent in South Africa live without improved sanitation.

			URBAN Percent				RURAL Percent				TOTAL Percent			
Year	Total Population Millions	% Urban	Improved	Shared	Unimproved	Open Defication	Improved	Shared	Unimproved	Open Defication	Improved	Shared	Unimproved	Open Defication
1990	36,577	52	64	25	10	1	45	18	14	23	55	22	12	12
2006	48,282	59.8	66	26	5	3	49	19	11	21	59	23	7	10

Table #1: Sanitation Coverage in South Africa 1990 & 2006. Sources: WHO/UNICEF, (2008).

The Constitution of South Africa requires free access to water and sanitation. This includes:

- South African Constitution (Act 108 of 1996) Chapter 2 – Bill of Rights
    - Section 27.1 "everyone has the right to have access to water."
    - Section 24: Everyone has a right to an environment that is not harmful to health
- Water Services Act and Regulations 1997 and 2001
    - Everyone has a right of access to basic water supply and basic sanitation.
    - Basic sanitation: "appropriate health and hygiene education" plus "a toilet which is safe, reliable, environmentally sound, easy to clean, provides privacy and protection against the weather, well ventilated, keeps smells to a minimum.

B. KwaZulu-Natal

KwaZulu-Natal is a province in South Africa about the size of Portugal located on the southeast part of the country. It is the home to the Zulu monarch. The province has eleven municipal districts including eThenkwini, which includes the major port city of Durban.

C. eThenkwini

eThenkwini is the largest municipality in the province and the third largest in the country. The population of the municipality is approximately 3.5 million persons in a geographic region of 2,297 km2. In Durban, eThekwini Water and Sanitation (EWS) is the authority responsible for providing water and sanitation. In the urban and peri-urban areas of Durban, 1 million people live in informal settlements, densely populated areas characterized by different soil types, generally floodplains and dolomitic lands (Eales, 2008). A 2010 case study on sustainable sanitation projects (sustainable sanitation alliance, 2010) indicates that approximately 150,000 families (~500,000+ persons) are estimated to occupy 417 informal settlements in eThekwini, living in basic shacks and experiencing low sanitation standards. Standpipes and water tanks are the main sources of water supply, with open defecation, pit latrines or Ventilated Improved Pit (VIP) latrines being the most common sanitation options.

According to personal interviews (Golden, 2013) with government officials, the municipality estimates there are approximately 40,000 "formal" pit latrines in eThenkwini. In 2011, the municipality began a process to empty pit latrines – approximately 35,000 formal pits, which had been identified by over flights and mapped using GIS. Informal settlement pits were not emptied due to the risk of collapse. Much of the pit wastes according to government officials were found to be relatively dry. There are over 640 informal settlements housing over 1M persons. There are 27 wastewater treatments plants (WWTP) serving eThekwini municipality, which treat 500 ML/d and serve 498,341 people approximately. The WWTPs produce approximately 95 tons (dry) sludge per day. By 2020 this quantity is expected to increase to 120 ton/d. Of the sludge currently produced, 50% is disposed together with pre-treated effluent through the two sea outfalls, 20% is incinerated and 30% is stockpiled at treatment works sites.

Over the last few years eThenkwini has built 16,000 to 20,000 new homes per year for families living in informal settlements. Additionally, the municipality is looking not to construct new POTW's but rather move towards the installation of smaller units / technologies. The officials emphasized that in the South African context any charge / fee for sanitation services is a *"non-starter."* Additionally the government is seeking to reduce pit latrines and is advancing the use of urine diversion toilets.

D. Cape Town – Stellenbosch

Cape Town is the second most populous city in South Africa and is the capital of the country. The metropolitan population is approximately 2.9M. Stellenbosch is a suburb of Cape Town located about 50 kilometers to the east with a population of about 125,000. It is known for its wineries.

While attempts were made to meet with officials from the Cape Town government, we were unsuccessful in securing such a meeting. Prior to our team's visit and during our field work in Cape Town, there were numerous front page stories in the Cape Town newspapers as a result of significant disturbances by residents over the lack of proper sanitation services. One of the key issues being complained about by residents was the lack of "in-house" toilets and the governments promotion of porta-toilets.

III. SANITIATION TECHNOLOGIES REVIEWED

VIP: Ventilation Improved Pit. This design provides a continuous airflow through the ventilation pipe which helps to control odors, flys and promotes the drying of the pit wastes. This is achieved by continuous air movement across the top of the vent pipe resulting in a venturi effect and by sunlight heating the vent pipe causing a convection effect.

CAB: Community Ablution Blocks are shared water and sanitation facilities of brick construction (older) or prefabricated containers, modified to meet acceptable standards by adding ventilation and appropriate plumbing. Generally, the facilities are characterized by female and male blocks, provided with toilets (and urinals for men), showers, hand wash and laundry basins. A block should serve 100 housing units; in reality, however, a single block may serve up to 200 dwellings (each composed of an average of 5.5 people).

UDT and UDTT: Urine diversion toilets and urine diversion dry toilets are designed to separate urine from feces. This is done since urine is mostly sterile and the urine can be used by the homeowner as a fertilizer.

Pit Latrine: This is a dry toilet system used to collect feces and urine. The slit trench latrine is the simplest type pit latrine. In many instances CAB's are connected to a pit latrine (in the back).

LaDePa: Latrine Dehydration and Pasteurization treatment technology being piloted in Durban to treat VIP wastes.

III. FIELD INVESTIGATIONS – DURBAN REGION

A. University of KwaZulu-Natal

The project team coordinated activities with the assistance of Dr. Chris Buckley, director of the Pollution Research Group (PRG) at the University of KwaZulu-Natal in Durban, South Africa. Field work initiated the week 17 June, 2013 with an initial kick-off meeting at the PRG with Susan Mercer and Tina Velkushanova serving as our hosts. In addition to discussing a set of pre-meeting questions prepared by Duke, the team completed a tour of the various laboratories at the University. The University is a recipient of the Bill and Melinda Gates Foundation and has a strong history and reputation in the area of sanitation.

A review of regulatory, societal, economic and technological drivers that will influence the deployment of an SCWO technology was undertaken through literature research and on-site investigations. A summary of the deployment and anticipated expansion of sanitation programs is provided below as Table # 2.

	Within Urban Edge					Peri-Urban and Rural				
	VIP/VIDP	Unimproved Pit Latrine	CAB	Pour-Flush	UDT/UDDT	VIP/VIDP	Unimproved Pit Latrine	CAB	Pour-Flush	UDT/UDDT
Technology Increasing / Decreasing in eThekwini	no due to costs/ groundwater, odor	No	Yes, container type	not in urban	No due to plot constraints	no due to costs/ groundwater, odor	No	Yes, container type	in evaluation	limited growth
Connected to Municipal Sewer	yes within 500m to sewer	N/A	yes within 500m to sewer	N/A	N/A	No	N/A	No	No	N/A
If not connected, is waste removed from pit	Yes ~ every 5 years by municipality	only if safe	Yes ~ every 5 years by municipality	N/A	N/A	Yes ~ every 5 years by municipality	only if safe	Yes ~ every 5 years by municipality	dual chamber not a pit	N/A
Primary waste management method / not connected to sewer	LaDePa	LaDePa	LaDePa	in-situ	N/A	LaDePa	LaDePa	LaDePa	on-site fertilizer	on-site fertilizer
Alternative waste management	N/A	N/A	biodigester, septic/leech	N/A	N/A	in-situ dual chamber	in-situ	biodigester, septic/leech	N/A	N/A
Cost to Resident w/ property value R120,000+ for structure	various fee schedules - prorated.					various fee schedules - prorated				
Cost to Resident w/ property value < R120,000+ for structure	free	N/A	free	NA	n/a	free	N/A	free	N/A	free
Cost to Resident w/ property value < R120,000+ for disposal	free	free	free	free	n/a	n/a	free	free	free	n/a
numer of active units in eThekwini <u>combined</u> rural and urban	30,000-35,000 in and out of urban edge combined	Unknown	579	600 trial under way	Not used in urban setting	30,000-35,000 in and out of urban edge combined	Unknown	579	600 trial under way	Used in rural setting where on-site disposal of solids is feasible
	35 constructed share block VIPs		63 constructed inhereted from Health Dept			Numbers provided combined				
			446 container types							
			70 Pre Fab							

Table #2: Analysis of Sanitation Technologies deployed in greater Durban region.

B. Newlands-Mashu DEWATS Demonstration Plant

This is a 40kL/d decentralized wastewater treatment (DEWATS) domestic wastewater treatment plant in Newlands-Mashu, Durban. The facility is a joint effort between the eThenkwini Water and Sanitation, Kanyisa Projects and the Pollution Research Group at the University of KwaZulu-Natal) that was launched in the fall of 2010. As presented in figure #3, the facility is located in a residential area and is adjacent to an on-site constructed wetland. The wastewater is treated via a biogas settle, an anaerobic baffled reactor, anaerobic filters and both vertical and horizontal flow wetlands.

Figure #3: The DEWATS Demonstration Plant

In addition to the DEWATS project, a doctoral research student (Sarah Rhoton) from the University of KwaZulu-Natal was leading a project on urine diversion.

It is becoming more commonplace for toilets in developing regions to include a urine diversion capability. This has the benefit of diverting a resource of value (urine) which is generally pathogen free and high in nutrient value, specifically phosphorous. Additionally, by eliminating the liquid, it is easier to accomplish in-situ treatment of fecal matter by drying the materials in isolation for an extended period of time (approximately six months). As presented in Figures #4 & #5, Ventilation Improved Toilets (VIP's) are an economic solution providing individual family units with a sanitation solution that eliminates the need for an ablution unit and connected pit latrines. Rather, the VIP operates by diverting the urine (Figure #4) allowing the solids to drop into a retention container directly under the toilet. After six months the resident will move the toilet to the second opening in the VIP which will then allow feces to drop into a separate container. The first container is allowed to dry during the six months while the second container fills up. After six months, research has shown that the now dry fecal matter is pathogen free and can be used as a soil additive. This now eliminates any "off-site" treatment and is a relatively economical solution.

Figure #4: Inside of a VIP toilet. The toilet has a urine diversion partition in the front (red arrow) which drains into a bucket partially buried to the rear of the VIP. As presented the second chamber opening connection is shown to the left of the toilet. After six months the toilet is moved to the new port by the resident.

Figure #5: The rear of the VIP showing the fecal matter collection containers.

Observations and Key Findings

1. The DEWATS demonstration plant was established as a potential sanitation solution to treat wastewater in dense informal settlements, schools and clinics that are outside the reach of the current sanitation network for the municipality.

2. The DEWATS system does NOT remove nitrogen or phosphorous from the wastewater thus serving as a sustainable solution by providing nutrient values to local agriculture.

3. VIP's are emerging as a preferred household solution.

4. Urine diversion is increasingly being promoted in connection with the VIPs.

C. Frasers Settlement

Frasers is located near Tongaat, in the northern section of eThekwini. It is a peri-urban informal settlement that is located beyond the sanitation infrastructure for the municipality. The settlement has a population of approximately 400 households / 1,600 persons. The community is divided into two sections (north and south) by a major railroad line. There are five (5) community ablution blocks (CABs) which utilize anaerobic baffled reactors or septic tanks with evapotranspiration fields (secondary treatment). The CABs are constructed so that there are pair units for each of the 5 blocks. Both are standard shipping (intermodal containers). The pair includes a male unit and a female unit placed side by side and located based on work discussed in Gouden and Kee (2012). The CABs are designed to serve 50-75 households within a distance not exceeding 200m. The CAB's we inspected (Figure #6) were across from the Saravasti Primary School included:

- Hand wash basins
- Showers
- Toilets
- Urinals (men) and,
- Laundry facility located in between the two units (note also used for cooking).

Figure #6: Pair of CABs at Frasers settlement with a child doing laundry adjacent to provided basin.

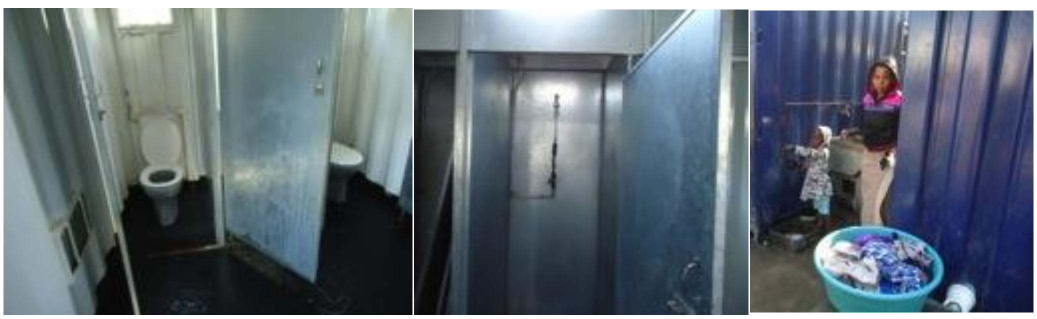

Figure #7: Interior of CAB (toilet, shower and laundry/potable water).

Crous et al. (2013) undertook a water demand study for community ablution blocks in the Frasers community. The findings of this research is summarized in Table #3:

Average CAB water demand per household $(\ell * HH^{-1}d^{-1})$	
Toilet	13
Urinal	2.3
Shower	14
Hand wash basin	4.4
Laundry	48
Blackwater *Water supplied toilets & urinals*	15
Greywater *Water supplied to showers, basins and laundry*	67
Total Combined Water Supplied to CAB	82

Table #3: Water demand for a CAB per household in the Frasers Settlement. Source: Crous et al., (2013).

Observations and Key Findings

1. The ablution blocks are subsidized by the regional government.
2. Cleaning crews are hired by the government to maintain and clean the units.
3. Pit latrines are not employed, rather the government is using treatment technologies on-site.

D. Saravasti Primary School

Located within the Frasers settlement is the Saravasti Primary School which has a student population of 340 student primarily comprised of children from the age of six up to fifteen years old. Until recently the school had only 1 toilet to serve all the students and a separate toilet for faculty and staff. Recently, an NGO (Hering South Africa Engineering PTY Ltd) has teamed with the school and with eThekwini to provide sanitation services at the school. As presented in Figure #8,

Figure #8: Newly constructed school toilets with four male individual stalls and four female private stalls. Note: the school employs a cleaning crew.

The Department of Water Affairs and Forestry has released recommendations to departments when planning schools. For schools the department recommended between 15 and 20 litres per learner per day, while boarding schools needed between 90 and 140 litres per learner per day. Schools have to install one water supply terminal per 130 persons within 200m of the main building. In terms of toilets, DWAF recommended Toilet planning one toilet seat per 25 girl learners and one toilet seat per 40 boys plus 1 Urinal per 40 boys[i]. Water used for flushing the toilets (4-6L/flush) comes from harvested rain water collected and stored on-site in one of six units. Per the principal of the school, they would benefit from additional electricity generation.

Observations and Key Findings

1. Schools provide a potential user for the SCWO technology.
2. However, the size of the SCWO (1,000/persons/day) would be too large for the average school.
3. Schools have further limitations in that they operate generally from 0700-1700 hours M-F only.
4. Schools would benefit from the any energy and water produced by the SCWO.
5. School will lack the financial resources to pay for a SCWO and due to security concerns connected community ablution units would not be permissible.

E. LaDePa

The Latrine Dehydration and Pasteurization (LaDePa) technology is a containerized technology that takes pit latrine wastes and removes the detritus then pasteurizing and drying the sludge producing a useful agricultural fertilizer pellet as presented in figures # 9-12. The technology was developed as a partnership between eThenkwini and Particle Separation Solutions (Pty) Ltd.

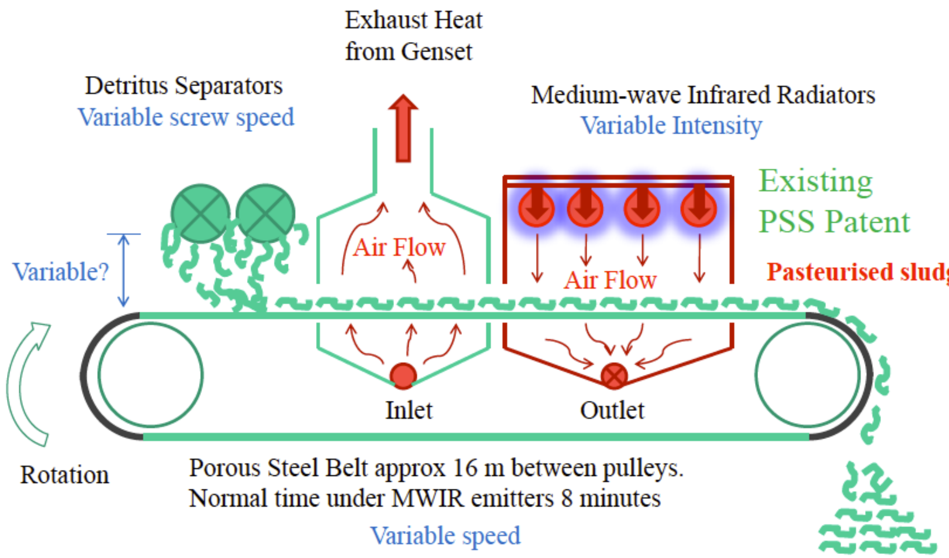

Figure #9: Simplified process flow chart for the LaDePa technology.

According to Harrison and Wilson (2013) the technology separates the detritus from the sludge by compressing the combination of sludge and its associated detritus in a screw compactor with lateral ports, through which the sludge is ejected, and is then deposited in a 25 to 40 mm thick layer of open pored matrix, onto a porous, continuous steel belt, while the detritus is ejected through the end of the screw conveyor.

After pre-drying (~8 minutes), using the waste heat from the internal combustion engine of the drive plant, the sludge on the belt is conveyed through PSS's patented Parceps Dryer where it is subjected to pasteurization, which also provides sufficient drying to take the sludge through the "sticky" phase (another ~8 minute process).

The dryer technology uses Medium Wave Infrared Radiation and a vacuum to draw air through a porous material or one with an open matrix.

Figure #10: LaDePa Technology, Tongaat, eThekwini Municipality

The end product is a low-grade organic fertilizer, with about three percent active ingredients. It is free from gross detritus as the holes through which the sludge is extruded are 6 mm diameter; it is free of pathogens and is consequently suitable for all edible crops. When leaving the machine the moisture content is generally in the order of 60 % solids, but is dependent on the influent moisture content. At this moisture content the material is friable, and is well past the sticky phase of sludge.

Figure #11: The grinder removes garbage from the solid waste before it is processed in the LaDePa.

Figure #12: The infrared treatment for LaDePa.

The technology is being utilized at a POTW owned by the municipality. The government is utilizing the technology to treat pit latrine wastes as part of the five year pit latrine clean-out program. In discussions with management of the facility (D. Wilson), traditional sewer treatment in the municipality runs 8R per person where they believe the total costs using LaDePa will meet R6/person/year. There will be four machines in eThenkwini. The municipality used to pay R500 to clean out a pit to contractors, they are now paying R550/m3 to bring in sludge – but the municipality inspects the pit latrine wastes to ensure low sand and garbage. The machine has a total capacity of 2,000m3/year.

Because rural citizens usually do not have toilet paper, there is generally a large amount of debris – therefore LaDePa will only accept pit latrine wastes from schools located in rural areas. The by-product of the technology are pellets with N,P,K pathogen free. The fertilizer is only 3% active as compared to traditional fertilizer at 22%. However, traditional fertilizer costs approximately R6,000/m3 while LaDePa will have a positive cash flow at R1,000/m3. Preliminary but un-quantified results indicate that the LaDePa fertilizer is at least as effective as traditional according to small farmers. In part this "may" be explained that the pellets are not as prone to storm water runoff.

Based on Harrison and Wilson (2013) a cost benefit analysis is presented as Table # 4.

Disposal Cost Savings	
2,000 tons at R1,012/ton	R2,259,000
Less 20% detritus	R 404,800
Income fro sale of fertilizer product	
Input=1,600 m3 at 20% solids	320 m3 solids
Output = 320 m3 at 80% solids	400 m3 (ton) product
Income – 400 cu m @ R500 m3	R200,000
Total Income and Savings	R2,054,000
Additional Operating Costs / annual	
Foreman at R10,000/month	R120,000
Laborer at R135/day at 260days/year	R140,000
Diesel fuel	R250,000
Pick up truck	R117,000
Total Additional Operating Costs	R627,000
LaDePa Annual Cost	
Annual established costs	R500,000
Maintenance and Royalty	R600,000
Total Annualized LaDePa Costs	**R1,100,000**
Net	**R327,000**

Table #4: Cost Benefit Analysis of LaDePa. Source: eThenkwini Municipality Data

Observations and Key Findings

1. Alternative technologies are being developed in large part due to the low liquid content of pit latrine wastes and the lack of economic and operational benefits to treating at a POTW.
2. The eThekwini Municipality piloted disposal to a sewage treatment works with disastrous consequences.
    a. Loading of 1.5 cubic meters of VIP sludge per day is approximately equivalent to a capacity increase of one mega liter of wastewater per day on the sewage treatment works.
    b. VIP sludge is virtually stable by the time it is removed from the pit, so little further beneficiation to the sludge occurs at a wastewater treatment works:
    c. Passing it through the POTW increased the load on nitrification and the sludge handling facilities.
    d. Further, it also makes little sense in adding water to a relatively dry sludge if the ultimate intent is to dewater it again for landfill.

F. Besters Camp (VIP)

The history of the Besters camp[ii] dates back to race riots in Durban during January 1949 between Africans and Indians mainly in Cato Manor, a mixed race, dense settlement of shacks behind Berea and only a few kilometres from the colonial CBD. The National government systematically implement Apartheid planning. Africans were relocated to a new township, Kwa Mashu, to the north and Indians to Chatsworth in the south of the city. During the mid 70's another Indian township, Phoenix was located further to the north. A Pretoria based construction company, Bester Construction, was retained to construct Phoenix. They set up a blockyard on this vacant land, on the city boundary. As the spatial control of Apartheid began to diminish in the 80's the steep hillside behind became settled by a dense informal settlement of makeshift shacks known as 'Bester's Camp' as presented in figure #13.

The site is highly dense with an estimated 436 people /ha and 6.33m^3 available per person in shacks (one quarter at 2m^2). The city attempted to install sanitation services in the Camp in part due to the very poor stormwater management and limited space to manage pit latrines.

Figure # 13: Besters Camp.

To install services it was determined that 10% of the resident shacks would have to be removed / relocated with the costs absorbed by the municipality. The residents refused the offer.

As the Duke project team toured the site, we were advised that the total population of Besters has been growing. We located a VIP that was designed for five persons but now serves 14 persons which is indicative of the overutilization of toilets. In addition, due to the density of the settlement and the informal placement of additional shacks, access to the pit latrines used by the VIPs is extraordinarily difficult to access as presented in figures #14 and #15.

Figure #14: VIP toilet in Bester's Camp.

Figurer #15: Access to the pit latrine to the rear of the VIP, which as an opening of approximately less than 1m.

Observations and Key Findings

1. Great difficulty in urban settlements to access pit latrines.
2. Residents would prefer sewer hook-ups but don't trust government to relocate due to property rights regulations in South Africa.

F. Mzinyathi Village, Rural District North Community

Mzinyathi is a rural / tribal area of KwaZulu-Natal north of the Inanda Dam. It directly serves the Imbozamo, Mgangeni and Matabetule tribal areas with the total estimated population of 50,000. The community is provided urine diversion VIPs as well as 200L water tanks. The water supply has been increased to 300L per day. There is no off-site management of the wastes as it is managed in-situ. Historically, there were difficulties encountered by residents using the technologies. The municipality then undertook a program where each resident is provided and must complete 5 meetings / visits with trainers regarding health and safety, water tank management, toilet maintenance etc.

Figure #16: A urine diversion VIP at a single family residence in Mzinyathi

Figure #17: A 200L above ground water tank supplied by municipality

G. Johanna Road Informal Settlement

According to local government officials, the Johanna Road settlement is one of the "more challenging informal settlements in the City of Durban". The settlement is situated on a steep slope of a hill next to the Sea Cow sewerage works north of Durban. During our drive up to the settlement we observed electricity being illegally diverted from a pump station to shacks in the settlement. The settlement has two community ablution blocks and water. There are over 500 residents of Johanna Road. Our visit was primarily focused on the upper Ablution Block, which is unique CAB in regards to its social enterprise.

Figure # 18: A six-year-old ablution block that hosts 81 families. The block is run by a caretaker who transformed it into a social gathering place. The caretaker implemented a billiards table (covered by white cloth) and runs a store from his shack, just across from the block.

As presented in figure #18, the CAB is maintained by a caretaker who not only keeps the CAB's clean but who also has been active in attempting to make the upper CAB a social gathering location. He has added a pool table and on weekends when families do laundry, he has music. Additionally, adjacent to the CAB, he has a small container which he uses as a store selling household supplies and food (figure #19).

Figure #19: Caretaker and his shed in the upper community ablution block.

Observations and Key Findings

1. Entrepreneurial activities seem to be supported by the residents of informal settlements.

IV. CAPE TOWN / STELLENBOSCH FIELD VISITS

A. Enkanini Informal Settlement

Enkanini Informal Settlement is the largest information settlement in Cape Town region with between 8,000 to 11,000 persons mostly Eastern Cape immigrants. It is located nearby to Stellenbosch. There are different toilet designs utilized in the settlement. The toilets in the green blocks are regular flush toilets and connect to the municipality's centralized POTW. According to our research guides from the University of Stellenbosch, pit latrines in urban informal settlements in the Western Cape are not utilized, rather the toilets are connected to the POTWs.

Figure #20: Enkanini Informal Settlement.

With approximately 10,000 residents in the settlement there is an average of one toilet per 150 people (70 toilets). There are 36 water taps scattered throughout the area, with one tap for 250 people. It costs 2,500 Rand to clean one toilet for one month.

The research team from the Sustainability Institute at Stellenbosch University have placed toilets in the settlement which they have connected to an anaerobic digester at their on-site research center. Presently the AD discharges into the municipal sewer, but they intend to incorporate secondary treatment to foster a decoupling from the POTW. They did not utilize urine diversion toilets because the waste urine has no market and there is insufficient demand for it by food gardeners in Enkanini. In addition, they purposely wanted the phosphorous from the urine in the sludge in the digester, so that the sludge compost has high soil conditioning value (ie in addition to just adding organic matter).

V. PRELIMINARY ANALYSIS & DISCUSSION OF FINDINGS

A. Empirical Data

The project team undertook to acquire "preliminary" data on the various economic, regulatory, environmental and social factors that influence the implementation of the SCWO technology in South Africa. This was undertaken as the team also quantifies the by-products of the SCWO technology.

Resident Sanitation Availability & Costs

1. Fee to local government for basic municipal services:
    a. Only for dwellings with value above R120,000
2. Fee to local government or others for use of ablution block:
    a. No Fee
3. Costs to residents for emptying of pit latrines:
    a. No Fee
4. Costs to residents by government for a VIP:
    a. No Fee

Access & Costs for Ancillary Primary Services

1. Fee to government for potable water:
    a. No Fee but volume regulated (300L/day)
2. Access and costs for CAB laundry:
    a. Full Access and No Costs
3. Access and costs for CAB showering:
    a. Full Access and No Costs
4. Informal settlement access to electricity:
    a. Limited to none
5. Desire for electricity:
    a. High

Costs to Municipality

1. Fee to contractors for emptying pit latrines in eThenkwini: approx. R450 per m^3 plus travel costs.
2. Additional costs are presented in table #3 of this document.

Pit Latrine Wastes Characteristics

1. Loaded and transported to municipality in sealed drums
2. Generally the sludge is about 25% solids and contain about 20% detritus
3. Any water (which is very low as a %) is being fed back into the treatment works
4. eThenkwini has characterized that the average person produces 40 kg of sludge per year so a family of six would produce approx. 1.24 m^3 per 5yr cycle.

Observed Trends / Sanitation

- Potential for increased use of community ablution blocks: Very low
- Potential for increased construction of VIP's: High
- Potential for increase of in-situ waste treatment: Very High
- Potential for increased use of urine diversion: Very High

As discussed in the early sections, South African policies dictate that water and sanitation be accessible and free. Additionally, local / regional governments are pursuing pathways that will reduce off-site treatment at POTW's. However, low technology solutions are gaining great momentum including the use of urine diversion VIP's.

Schools in rural areas do represent a potential opportunity where SCWO would provide a valuable service in-lieu of no treatment or investment into a POTW. The economics are such that the technology must be competitive with in-situ treatment technologies such as anaerobic digestion, septic/leech fields as well as emerging technologies such as LaDePa.

VI. REFERENCES

Campos, L.C. Jain, V., and M. Schuetze (2012). Simulating Nutrient and Energy Fluxes in Non-Networked Sanitation Systems. *a paper presented at the second conference on developments in faecal sludge management in Durban, South Africa, October 29 -31, 2012*

Chowdhry, S and D. Kone (2012). Business Analysis of Fecal Sludge Management: Emptying and Transportation Services in Africa and Asia. Draft final report.

eThekwini Municipality (2012). Policies and Practices of the eThekwini Municipality Water and Sanitation Unit.

eThekwini Municipality (2011). Water Services Development Plan 2011.

Gounden, T. (2008). Sustainable Sanitation in the eThekwini Municipality. A Powerpoint Presentation.

Graham, J. And M. Polizzotto, (2013). Pit Latrines and their Impacts on Groundwater Quality: A systematic Review. *Environmental Health Perspectives* 121:521-530.

Schütze, G., Robleto, G., León, C., & Rodriguez, I. 2011 Modelling and scenario building of urban water and wastewater systems – Addressing water shortage in Lima. 12th International Conference on Urban Drainage. Porto Alegre, 11 – 16.09.2011

Sustainable Sanitation (2012). Case Study of Sarasvati School. eThekwini Municipality.

Thye, Y., Templeton, M., and M. Ali. (2009). Pit Latrine Emptying: Technologies, Challenges and Solutions. EWB-UK Research Conference. February 20, 2009

Tilley, E., Lüthi, C., Morel, A., Zurbrügg, C., & Schertenleib, R. 2008 Compendium of Sanitation Systems and Technologies. Dübendorf, Switzerland, Swiss Federal Institute of Aquatic Science and Technology / Water and Sanitation in Developing Countries: 158.

WHO/UNICEF (2008). Joint Monitoring Programme for Water Supply and Sanitation, 2008A Snapshot of Sanitation in Africa A special tabulation for AfricaSan based on preliminary data from the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation

APPENDIX A

ADDITIONAL PHOTODOCUMENTATION

Photograph 1: One of 3 ablution blocks in the Fraser Settlement. eThinkwini Municipality in the Province of KwaZulu-Natal.

Photograph 2: Bioreactor chambers across the street of ablution blocks (photograph #1) in the Fraaser Settlement. eThekwini Municipality in the Province of KawZulu-Natal.

Photograph 3: Toilet amenities in the Fraser ablution blocks (photograph #1)

Photograph 4: The school toilets and accompanying cleaning crew provided by the school (located within Fraser settlement). There are four stalls for boys and four stalls for girls, with a separate block for teachers.

Photograph 5: LaDePa technology removes garbage from the solid waste, heats the waste and effectively removes all pathogens, and turns the waste into pellets used as fertilizer.

Photograph 6: The back of the urine diversion toilet. Each panel on the back represents where the waste for each hole goes to.

Section 2: Pit Latrine Operations

2.1 How much is generated in day		☐☐
2.2 How many families / persons per pit		☐☐
2.3 How many total pits		☐☐
2.4 What do residents pay for the use?		☐
2.5 What are the storage capacities	What is design of the pits	☐☐
2.6 How do residents pay?	Cash, phone? Frequency?	☐
2.7 What are the environmental impacts for this location		☐☐
2.8 What are the human health impacts for this location		☐☐
2.9 How are they currently emptied?	where, potential impacts and distance	☐☐
2.10 Where does the waste currently go from latrines		☐☐
2.11 How is the waste transported		☐☐
2.12 How frequently emptied?	Who will prepare	☐☐
2.13 Odors	From Whom and timelines	☐☐
2.14 Material composition of the wastes?	% solids	☐
2.16 Are there apparent materials of concern?	Materials which can harm the SCTP unit?	☐
2.17 Vector		☐☐
2.18 Human Health impacts	any reports	☐☐
2.19 What is in the pits	materials than can impact our unit	☐☐
2.20 How many people empty the pits?		☐☐
2.21 Are they different "companies" ie. Individuals		☐☐

Section #3: Transportation

3.1 How is latrine wastes currently transported?		
3.2 Could it be upgraded?		
3.3 Can the government provide a tanker?	What size	
3.4 How much would the govt charge?		
3.5 If private would it be the same as those who empty latrines	Ie is this a turn key	
3.6 Are there already established liquid waste haulers?	Who and how much do they charge / who do they charge?	
3.7 How many runs can they make in a day?	Capacity	
3.8 Can they help to identify a central location from a logistics standpoint for a SCWO unit	where	
3.9 Do they need to be cleaned after each emptying run	Where and how much water	
3.10 What permits do they need	Would we have to check their permits before each emptying?	

Section #4: Potential SCWO Siting

4.1 Size of SCWO Unit		
4.2 Do we need a pad	What is design	
4.3 Do we need electricity		
4.4 Storage tank(s) & how many	Sizes and do they need pads	
4.5 Do we need an area for eq storage	How large	
4.6 Who can do survey	How much	
4.7 Who can do construction	How much and bonding	
4.8 Timelines for construction	fees	
4.9 Permitting costs and timelines		
4.10 What type of approval is needed	who, how long, etc.	
4.11 Can we get free land	If we put an ablution unit on site?	
4.12 If no, how much land is needed and costs	Who would own land? Do they need a loan	
4.13 Micro financing options		
4.14 Will we have AsBuilts	Who will prepare	
4.15 Are we transporting unit or building on-site	Costs to ship turn-key and timelines + insurance	
4.16 Do we need permits?	From Whom and timelines	

Section 4 continued

4.17 Capacity by hour		
4.18 Material Restrictions		
4.19 How many persons to operate		
4.20 Start up time to operate/day		
4.21 Technical skills of operator		
4.22 Can we design with Lead & back up operator	back up person or trainee	
4.23 How much electricity is required / day in kWh		
4.24 Odors from Unit	What is required to manage	
4.25 Byproduct #1 (steam)	units	
4.26 Byproduct #2 (water)	units and quality	
4.27 Byproduct #3 (salts)	units and lab results	
4.28 Byproducts #4	what might it be	
4.29 Can we close loop water byproduct if used	consider ablution unit with laundry, bathrooms etc	
4.30 Noise of unit	in db	
4.31 What type of equipment materials would we expect we would need for on-going maintenance?	availability	
4.32 Do we need a pad for trucks when delivering?		
4.33 Do we need emergency equipment		

4.34 Do we need to be connected to potable H20		
4.35 Do we need natural gas?		
4.36 Do we need washing station for trucks once off loaded		
4.37 Do we need EHS equipment		
4.38 Should we expect theft	What type	
4.39 What type of security is required	fencing?	
4.40 Do we need perimeter lighting and operational lighting?	Do we risk theft of electricity?	
4.41 Do we need insurance	How much and costs and brokers	
4.42 If unit breaks and we need to dispose of contents how?	Where do they go and how much?	
4.43 What do we do with solids we can not process	Where do they go and how much?	

Section 5: Business Operations

5.1 Who is the legal entity owning the business(s)	Do they need to incorporate in some form	
5.2 What legal / regulatory requirements	Permitting, Type, frequency, costs	
5.3 Legal support	Is there a clinic that can do this	
5.4 Are there occupational health needs	Medical exams, signage etc.	
5.5 Are there medical clinics	State owned or private, fees	
5.6 What insurance is needed	Transport, fixed facilities, selling by products	
5.7 Are we allowed to sell water	check with local utility	
5.8 Are we allowed to sell electricity	check with local utility	
5.9 Permitting costs and timelines	Types of permits required	
5.10 What type of approval is needed	who, how long, etc.	
5.11 Who owns the land	If we put an ablution unit on site?	
5.12 If no, how much land is needed and costs	Who would own land? Do they need a loan	
5.13 Micro financing options		
5.14 Who are the lenders	What are their rates and ability to finance micro loans?	
5.15 Will we have AsBuilts	Who will prepare	
5.16 Are we transporting unit or building on-site	Costs to ship turn-key and timelines	+ insurance
5.16 Do we need permits?	From Whom and timelines	

Section 6: EH&S for Proposed SCWO Unit

6.1 Do we need to manage stormwater		
6.2 Do we need secondary containment	Designs and costs	
6.3 Any byproducts not beneficially re-used?	What, potential impacts & how managed	
6.4 What are the emissions?		
6.5 Noise in db?		
6.6 Safety hazards	What are they and how do we mitigate / train?	

Section 7: Ablution Units

7.1 Are their currently units in place	Where, capacity, services	
7.2 Can you identify with NGO's potential sites?	Where, what are the local users, whom do we need to work with?	
7.3 Do we need permitting?	From whom?	
7.4 What service(s) would they provide that are not currently being provided?	Water, showers, laundry, toilets etc...	
7.5 How much do / would people be willing to pay?		
7.6 What sizing would we need?		
7.7 How do we collect the money?		
7.8 Who would be able to connect to the SCWO units?		
7.9 Would we need pads?		
7.10 Security?		
7.11 Signage	What kind?	
7.12 Hours / days of service?		
7.13 Additional "value-add" services we can provide?	Energy via solar, personal care products?	

[i] http://www.health-e.org.za/2013/05/02/school-toilets-in-shocking-state/