THE SUSTAINABLE SANITATION DESIGN CONCEPT FOR SLUDGE TREATMENT FOR CITIES IN AFRICA

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Today, lack of treatment of faecal sludge creates pollution pestering urban life across Africa. In order to upgrade human excreta (HE) from a pathogenic nuisance to valuable and safe agricultural inputs, the urine, faeces and mixed sludge have to be verifiably pathogen free.

In the SuSan Design Secondary Treatment Unit (2nd TU), sludge is handled with a methodology developed in cooperation with the Swedish University of Agricultural Sciences (SLU). The treatment methodology is science based, thoroughly tested and certified by SLU researchers. It proves to be a robust and cost effective method for up-cycling human excreta to a safe natural fertiliser and soil conditioner: Through local entrepreneurs we have the potential of changing the view on human excreta from community cost driver to value creator.

The treatment process is low-tech, cheap, and suitable for decentralisation. Our intention is to create a network of entrepreneur-managed treatment units, organised within the framework of national franchises and /or local cooperatives.

The first SuSan Design 2nd TU was set up in 2011 just outside Kampala, Uganda, supported by the Bill and Melinda Gates Foundation. This test unit has proven that we can turn faeces from pits, septic tanks, and dry toilets into a safe and valuable fertiliser in 45 days. The first unit was built to handle excreta from approximately 2000 people. This 2nd TU is scalable to serve small communities of 5,000 to 25,000 people or a network of units serving large cities.

National Agricultural Research Organisation (NARO/Uganda) are now field testing the volumes of pathogen free sludge produced during the test phase for yield increase in maize production. Our treatment methodology, if scaled up across Africa, can potentially bring enormous volumes of safe fertilizer and soil improvement products to agriculture, flower export and fodder production to sustain the growing urban populations depending on locally produced food.

The main advantage of our treatment system:

- ✓ It can become an integral part of the mix of existing sanitation systems
- ✓ It creates incentives for low water use and safe nutrient recovery
- ✓ There are no bottlenecks in scaling up to units serving millions of users with decentralized treatment units in cities across Africa
- ✓ No external energy is needed to run the process
- ✓ The nutrients in the sludge is well suited for conservation/low till/sustainable agriculture

The treatment unit is central to bridge the current gap between the present sanitation crisis and the goal “Sanitation for All”. The treatment system makes it possible to move towards sustainable sanitation, low water wastage and sustainable food production based on local resources. Our natural fertilizer market research and calculations from Kampala show that nutrient values can provide substantial income to run the sanitation system and treatment since it demands low initial investment. Our calculations show that the daily cost will be well within the Bill and Melinda Gates Foundation 5 US Cents per/user/day.

The SuSan Design treatment unit stands to become a platform assuring value creation through safe reuse. Based on its low investment, off grid capacity, robust treatment process, all size container flexibility and safe end product that is useful to land, based value creation massive dissemination can become a solution that brings sanitation to all across Africa in a sustainable way.

Situation Analysis

Inadequate sanitation is a major problem in the developing world. Unsafe water, the lack of sanitation, and poor hygiene accounted for over 1.5 million deaths from diarrheal disease in low and middle-income countries. Clearly, sanitation has the potential to play a vital role in improving public health and securing economic growth in urban cities, the benefits of which will actually reach the poor[1].

Cities in east African are characterized by slums – or residential areas with only partial sanitation coverage. 200 million people in Africa alone live in urban squalor without access to quality sanitation. A considerable portion of the city dwellers in these countries live in highly congested slums without access to any form of basic sanitation facilities. Most houses in these parts of the cities do not have toilets but only a few shared pit latrines. Public toilets or services are simply unthinkable. Open defecation is the most commonly practiced forms of sanitation. People relieve themselves on streets, road side ditches and surrounding little green areas and gardens. Living environments are highly contaminated; ground water and rivers get polluted during rainy seasons.

To top it off, urbanization is staggering and influx into existing cities is increasing at an alarming rate. As slums are the soft targets for informal squatting, they attract those migrating from rural areas to cities, which make the already bad sanitation conditions worse. This exacerbates quantities and qualities of sanitation facilities that are by far below acceptable standards. Slums' future scenario is deteriorating rather than improving. It is anticipated that by the year 2050, a majority of the world's 9 billion will be living in cities. Since slum areas are going to host the majority of influxes to cities, there is no doubt, unless an earlier planning and intervention are put in place, that this scenario is going to result in unbearable potential health risks to people.

On the other hand, Governments don't have the capacity to provide basic public sanitation facilities for all, despite the fact that sanitation is widely recognized as an element of human rights. In most east African countries, sanitation is not properly dealt with, either by regional or national governments. Governments should provide incentives based on their health savings that stimulate innovation and action to get service delivery functioning and assuring that the population is not in contact with their excreta. The incentive mechanisms can make it possible for massive roll out of low cost, quality sanitation service delivery.

Currently, there are signs of an emerging private sector that can supplement the governments' provision of services and products for sanitation. Sanitation is generally seen as the main responsibility of Government, a task which the Government is unable to provide. However, it is Government that is the main benefactor of sanitation results, as measured by lower health costs and higher GDP growth through higher work participation and children finishing school being more productive later in life. In addition, the possibility of creating urban tourism increases, a sector that today is hampered by cities unfit for tourism due to pollution and undignified living areas.

In addition, nutrients recycling can be viewed as a form of reducing losses of nutrients in the food chain and helping the development of self-sufficient communities, not dependent on external sources of fertilizer.

Therefore, there is a clear need for sustainable sanitation solutions in this part of the world in order to achieve one of the goals of millennium development goals, which is sanitation for all.

Principle of business idea, and basic safety:
Sustainable Sanitation Design (SuSan Design) is a business oriented foundation that aims to: Deliver innovative service concepts and products to form a sanitation value chain providing low-income countries with quality sanitation systems. SuSan Design seeks to develop scalable implementation strategies of sanitation services based on local entrepreneurship, management

[1] www.sanitationfinance.org/blog/economic-rationale-key-driver-scalable-sanitation-say-susan-design-and-fivas

incentives and value creation through the transformation of human excreta into a safe and hygienic soil improvement product and fertilizer for agriculture. In Uganda, SuSan Design partners with Government through the National Agricultural Research Organization (NARO), the private sector i.e. Uganda Cooperative Alliance (UCA) and a local NGO Sustainable Sanitation and Water Renewal Systems (SSWARS). The SuSan Design model is based on local entrepreneurship and local value creation and consists of four interdependent main parts: Toilet product, Business Model with its logistics, Treatment and Agriculture. This case focuses on the treatment unit for the production of a safe fertilizer to be used in agriculture. The valuable outputs from the system act as incentive for setting up and operating sanitation facilities. According to SuSan Design, the human, financial and dignity cost of faecal sludge pollution in cities across Africa will not be tolerated in an evolving economic climate. Our solutions will be attractive investments to provide dignity to the urban population and secure economic development.

Background of business case:
SuSan Design has been searching for a solution to scale up sanitation service delivery since 2007, with the founder's background from UNICEF during the 90's and working with the Norwegian Organization "Design without Borders" (DwB) until Sustainable Sanitation Design was founded in 2009. The motivation of venturing into sanitation solutions, especially those which link it with agriculture, has been largely a result of SuSan Design's understanding and belief that bad sanitation is the root of urban misery and quality sanitation services is a prerequisite for prosperity. According to SuSan Design, well-functioning societies have, if not rational[2] and sustainable, at least functional and safe sanitation systems. Further, bad sanitation may, and does cause pollution of ground water, surface water and streams, contamination of local environments, and stimulates vector breeding. Consequently, SuSan Design believes that improved sanitation has a vast potential to give dignity and save lives directly and indirectly. Due to the above, SuSan Design has focused on trends that point in the direction of increased attention and investment in sanitation, driven by the following:

i) Raising energy prices;
ii) the linkage of industrial fertilizer prices to cost of fossil energy resources thereby suggesting that the peak phosphorus will put pressure on the current low prices (still inaccessible to most African farmers) of artificial fertilizer;
iii) increasing population growth thus supporting the willingness to make investment in soil improvement;
iv) the need to adopt sustainable agricultural practices that makes use of natural, safe and locally produced fertilizer;
iv) the fact that treated urine and faeces will promote a sound ecological and low impact agriculture;
v) the need to decrease CO2 emissions from agriculture.

The rapid increase in urban population and the need to feed huge populations in urban areas motivated SuSan Design to search for innovations and scaling-up strategies of activities that can produce a high quality fertilizer from human excreta.

The secondary treatment unit
In order to scale up sanitation delivery we need to create income from the nutrients collected. Urine is safe when leaving the body so our strategy is to create urinals and logistical structures that maintain urines fertilizer value and assures no contact with contamination. Since a product has to be safe and effective to be sold at a good price it has been very important for SuSan Design to establish the safety of the HE based fertilizer product. SuSan Design uses a secondary treatment unit, in which faeces/faecal sludge are treated to produce a high quality fertilizer product. In the SuSan Design Secondary Treatment Unit faeces and mixed sludge are handled with a methodology developed in cooperation with researchers of the Swedish University of Agricultural Sciences. The treatment system is science based and thoroughly tested by SLU researchers, in which the method proved to be safe for treating human excreta. When implementing the system in

[2] Water based flush is by no means rational but as a personal service wonderful giving "flush and forget" experience to its privileged users

new countries, the method is tested to secure safety when adding new variables such as temperatures and variations in pathogens in excreta. The treatment process is low technology based, inexpensive and is suitable for decentralization. The smaller tanks are easy to handle by hand, larger tanks can also be implemented and the secondary treatment unit can be operated as a business by trained local workforce.

The secondary treatment unit produces valuable natural fertilizers for farmers, changing the view on human excreta from waste to resource. The first SuSan Design secondary treatment unit was put up in 2011 just outside Kampala, Uganda in a village called Kakiri supported by Bill and Melinda Gates Foundation. This pilot has proved that the SuSan Design secondary treatment unit turns faeces from problem waste to safe and valuable fertilizer in 45 days. The treatment kick starter for the faeces is a widely available nitrogen rich fertilizer while for urine[3] the ammonia content in the urine treats it when stored for two weeks at a temperature of about 20^0C. If urine comes from higher risk units or if there is a known contamination from faecal matter in the urine storage time will be increased.

The unit is operational and built to handle excreta from approximately 2000 people. The test phase confirms that it can be scaled up and decentralized to cities across Uganda and Africa. SuSan Design is doing a test now with the National Agricultural Research Organization (NARO) in Uganda in order to check yield increases in maize production using the natural fertilizer products from HE.

Results of the field testing to check the maize yield increases will be available around the 25th of October 2012. SuSan Design intends to create a network of entrepreneur managed treatment units organized within the framework of a franchise and/or local cooperatives. SuSan Design representatives will regularly monitor the operators to assure that the end product from the secondary treatment unit is safe and has strong agricultural value.

Waste = Value – how cleaning up is everybody business

Resource supply and availability of faecal matter

In the city of Kampala, about 250 m3/day of faecal sludge (FS) is collected and deposited to the Bugolobi wastewater treatment plant for treatment. The amount of FS deposited at the sewage treatment works in Kampala represents only about 30% of the collectable FS in Kampala. There is no data that shows where the uncollected FS in Kampala is deposited. However, a large proportion of the uncollected FS stays within the slums, especially the volume generated by pit latrines. Pit latrines are normally abandoned upon filling, and when there is space, new ones are constructed. When there is no space, the people will share latrines with neighbors where this is possible, and where it is not, they defecate in a polyethylene bag in the house, which they throw out on garbage, a practice referred to as flying toilets. Only about 6% of Kampala City is served with sewage systems. The sewer coverage is at present only in the Central Business District (CBD) and some few affluent areas within close proximity to the CBD. In other municipalities and towns, the situation is the same or even worse. There is therefore a large quantity of faecal sludge from pits and septic tank systems which can be used in any business case dealing with Resource Recovery and Recycling in Kampala or its immediate surroundings.

Demand for natural fertilizer needs to be enhanced

The demand for fertilizers produced from HE is not immediately obvious, so it is important to develop marketing strategies that give farmers value for money and an inoffensive product delivery. There is still need to convince people to purchase the HE fertilizer products. The flower industry is very positive to alternatives to industrial fertilizer – in particular urine. There is a need in the flower industry to use low CO2 natural fertilizer alternatives. This statement is based on the interviews that SuSan Design conducted when performing the market research on the use of urine in agriculture in Kampala and neighboring areas prior to 2011. The urine market study was done by GIZ in cooperation with SuSan Design.

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[3] http://www2.gtz.de/Dokumente/oe44/ecosan/en-ppt-marketing-human-excreta-2010.pdf

Unfortunately SuSan Design has not been able to do a specialized market research for the faecal sludge based soil improvement product that we will produce. Our product is pathogen free and enhanced with additional nitrogen so it would also be an effective fertilizer. A study was done by EcosanRes Uganda knowledge node with ordinary sludge from water works that indicates that there was some willingness to pay. In order to avoid the heavy metals and the industrial waste that is in the volumes from sewage water purification units we will not try to attract this volume to our units – with our non-toxic, pathogen free, nitrogen enhanced and cleaner soil improvement product the value proposition from sewage sludge is not comparable. We will need to make our own tests and market assessment since we have a much more qualitative product.

Late October early November 2012 SuSan Design expects that the NARO testing of the product varieties will give them a better picture of which product that has the most potential in the market place. The SuSan Design assumption is that long term soil improvement has relatively low market price while any immediate effect on yield or quality will have a strong market reception. Our goal is to break even on the faecal matter and make a profit on the urine sales. We will still need some support or levy some of the externalities that are generated by improved sanitation. The optimum solution would be a fee collection per ton shit taken out of the city and placed safely with agricultural production in combination with a service premium collected so the poor sections of the local slum can use the public units for free.

Financial aspects

The SuSan Design project has been characterized by a low funding and lack of support from investors. Due to this, the product development process is not fully complete. SuSan Design has not yet overcome the financial constraints, but this has not stopped the development. However, the lack of funding has slowed down SuSan Design's progress. Key personnel has had to work without pay to continue the development and keep outside sanitation partners informed about the work the partnership has been able to perform. One response to the financial challenge is to go towards private impact investment environments. This has not given the results yet but SuSan Design believes that it is the right direction since social investors/donors are looking for results that the sanitation sector can bring to people's lives if organized correctly. SuSan Design spends time on unconventional projects like an exhibition of innovations that takes place in Oslo, Norway in the fourth quarter of 2012. SuSan Design is expecting some publicity and interest from showing their developed uni-sex urinals that can lead to further funding of their strategy of developing sanitation value chains from home to farm delivering safe inputs to value creation in the agricultural sector. Over the past year, SuSan Design developed linkages into the conservation farming/low till farming sector that would suit the nutrient recovery strategy very well.

Based on the test unit in Uganda it looks like SuSan Design will be able to set up units that treat faecal sludge well within the Gates Foundation expectation of 5 US cents per user. In a rough calculation SuSan Design made earlier this year, it was estimated that per user cost of treatment was 1.4 US cents per user. If more sludge comes into the unit with high water content, the cost per user may increase and if bigger units are made and closer to the city they might be less. So a conservative estimate is that the treatment cost is 2 US cents per user and the interesting question to investigate further is how much of this cost can the farmer pay for the product and how much of it needs to be taken from other sides of the sanitation value chain. SuSan Design has never expected to make a profit of the shit side of this equation – it's the urine that will make money and that is why SuSan Design market research was done first with the urine side of the business. To improve this income potential Susan Design developed a uni-sex urinal. One of SuSan Design's next challenges is to develop market mechanisms for the soil improvement product so it can break even – that is SuSan Design's goal.

Technical approach, suitability and expected requirements

The SuSan Design secondary treatment unit is based on the treatment of excreta using ammonia as the disinfecting agent. For urine, the ammonia utilized in treating it is initially present in it as urea. Upon excretion, the urea transforms into ammonia in urine collection systems or storage containers in a reaction catalyzed by urease enzyme which is a component of ubiquitous microorganisms present in any environment. To conserve the ammonia for treatment, the urine

should be kept in sealed containers. For most applications, urine can be stored for a period ranging from 2 months (if used on crops to be cooked before eating) and for 6 months for unrestricted applications. The approach is based on studies at SLU and in Uganda, which found that under storage conditions in the tropics, the urea excreted in urine when stored in small containers e.g. 20 liter jerrycans produces uncharged ammonia in concentrations of 20-60 mM and at 24^{0}C, this ammonia content disinfects the urine to safe levels within a storage duration of 2 months. For the faeces, an external source of urea is needed. Based on the research done by SLU, SuSan Design has set up the treatment unit to assure that the faecal matter or faecal sludge is disinfected by it[4]. This quantity of urea produces a product with a stable pH of 9, which is sufficient to treat the faecal matter thereby producing a safe fertilizer. To keep a large proportion of the ammonia in the system and prevent it from loss via ammonia volatilization, the containers in which the mixture of urea and faeces is kept should be airtight. The mixing can be done by simply rolling the containers or mechanical stirring for larger volumes. The biological reaction which kick-starts in urine and faeces as a result of ammonia (naturally present for the urine or externally applied for the faeces) does not need additional energy and has been proven to be very robust. This gives fantastic potential for scale up. The methodology is doable on a local level so decentralized units can be set up with local entrepreneurs.

The main advantages of the methodology is low set up cost, flexibility in terms of size, robust treatment methodology with relatively simple quality assurance procedures that can be followed without on-site support from high level engineer or process engineer staff. The SuSan Design treatment Unit does not have to use outside energy so a smaller treatment unit can be in a village or section of town that is not served with 24/7 electricity. For tropical and hot climates, like most parts of Africa, the treatment will secure a pathogen free material with closed storage 30-50 days. From an environmental perspective the treatment system incentivizes to start up sanitation structures with as little water use as possible or UDDTs that are ideal for this methodology. Since it is low tech and robust in terms of pathogen kill off, it can work anywhere in Africa that has a large population and an agricultural community nearby that appreciates a reliable supply of natural fertilizer. When setting up the pilot unit in Uganda SuSan Design used all materials sourced locally. By investing in this type of treatment units, few components will be imported and no expensive service contracts will have to be made as it is with the sewage based treatment units that in Africa usually are dysfunctional.

The challenge SuSan Design envisages is to divert attention from water-based toilets to decentralized systems that assure recycling of plant nutrients. There will have to be a company responsible for the units that bring in entrepreneurs that have the right mindset to do this job correctly. In the startup phase SuSan Design intends to be very selective of from where to receive faeces/faecal sludge since there is a bad habit of putting anything into a pit latrine or in the water that leads out to the septic tank. So the challenge might be that SuSan Design starts with only Urine Diversion Dry Toilets (UDDTs) and have too little to process.

Institutional and legal settings and public support

The government institutions that may be involved in such projects include the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), via their lead agencies the National Agricultural Research Organization (NARO), and Uganda National Bureau of Standards (UNBS). There is no legislation against the use of fertilizers from excreta. What is important is that the fertilizers to be used should be safe. SuSan Design is already working with NARO. Therefore, it is possible to apply for the certification of the fertilizer product by the UNBS. However, SuSan Design has not yet done this, as the project is still at the testing/piloting phase. Prior to the phase of

[4] Vinnerås, B., 2007. Comparison of composting, storage and urea treatment for sanitising of faecal matter and manure. Bioresource Technology 98(17), 3317-3321, Vinnerås, B., Hedenkvist, M., Nordin, A., Wilhelmson, A., 2009. Peepoo bag: Self-sanitising single use biodegradable toilet. Water Science and Technology 59(9), 1743-1749, Vinnerås, B., Holmqvist, A., Bagge, E., Albihn, A., Jönsson, H., 2003. The potential for disinfection of separated faecal matter by urea and by peracetic acid for hygienic nutrient recycling. Bioresource Technology 89(2), 155-161.

scaling up, SuSan Design will have to apply for certification of the fertilizer product by specifying the quantity of NPK present in it as well as guidance on application.

Productive and safe resource use
The productivity of the fertilizer produced by SuSan Design is still being tested at the NARO farm. Results are expected late October or early November 2012. While working with the excreta both in the field and in the laboratory, the workers should make use of protective gear in order to be safe. Those who do not use protective gear usually just do not like. However, they have hand disinfectants which they wash hands with after working. The final product is safe and therefore does not necessarily have to be handled while wearing protective equipment.

Valuation of economic benefits and assessment of other (possible/actual) externalities
SuSan Design has not been able to evaluate the externalities that are relevant to the safe fertilizer produced. Farmers rely on the natural soil fertility which is still high in parts of Uganda, especially in the central region where Kampala is located. Therefore, some farmers will not see the need to purchase fertilizers as they obtain relatively good yields without applying any fertilizers. Also, some farmers who already use animal dung/manure may not purchase the fertilizer produced by SuSan Design. There is of course also competition from the commercial fertilizers and this competition will be challenging when farmers have to shift from purchasing what they have been used to, in replacement of a fertilizer from an unusual raw material such as excreta. Therefore, a lot of work has to be done, to demonstrate that the fertilizer from human excreta is safe and it can produce high crop yields. This will call for marketing and behavior change strategies.

Key performance indicators:	
Land requirements:	2 acres
Capital requirements:	Estimate 50-100.000 USD – small unit treating FS from 20-30.000 people
Output in Phase I unit:	26m3 of quality pathogen free soil improvement product produced during the pilot phase
Gains if scaled:	Expects to generate 1000's of jobs when full value chain from home to farm is at scale in cities across Africa, reduced decease burden, economic growth, wasteful spending of medications will be transferred to quality of life purchases, and improved soil quality is expected outcomes.
Labor requirements:	2 persons at the level of casual laborer at pilot level, One support staff at the SuSan Design regional office based in Nairobi, from time-to-time two experts from Oslo, Norway, two students for the studies, and two local staff from SSWARS.
Water requirements:	For hand washing, washing of working tools, and adding moisture to the compost but the amount was not quantified in the pilot phase.

Conclusions
The Sustainable Sanitation Design (SuSan Design) model of a secondary treatment unit for faeces from pits, septic tanks and UDDTs has shown that when controlled by trained staff it can transform them into a safe and standardized agricultural input. Urban populations should not and do not want to handle their excreta and the SuSan Design treatment unit does propose a low cost logistical structure that can provide a quality service to large segments of people. The approach by SuSan Design to develop scalable implementation strategies of sanitation services based on local entrepreneurship, management incentives and value creation from excreta is important for sustainable economic development and the achievement of "Sanitation for All".

The SuSan Design treatment unit stands to become a platform for assuring safe reuse. Based on its low investment, off grid capacity, robust treatment process, all size container flexibility and safe end product that is useful to land based value creation massive dissemination can become a solution that bring sanitation to all across Africa in a sustainable way.