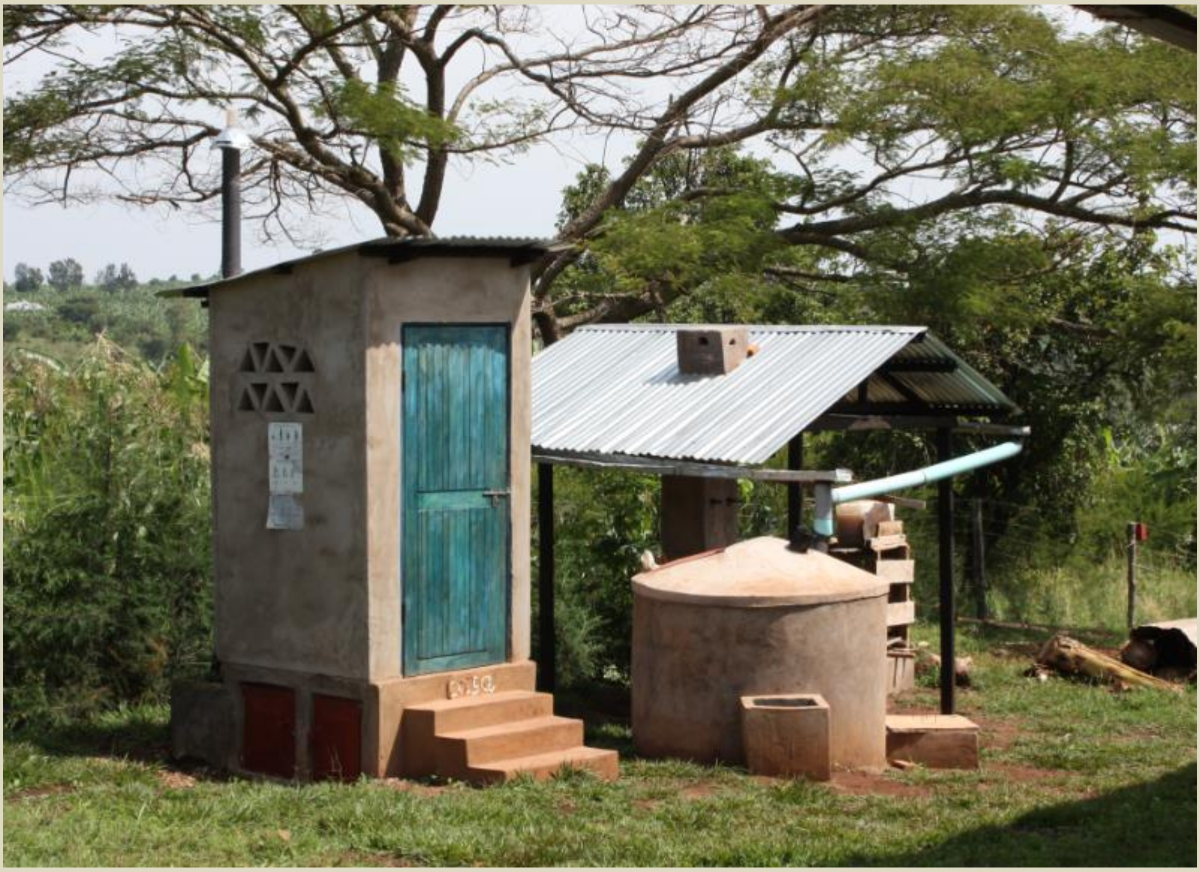
Conference on Sustainable Manufacturing

Blue Responsibility Award: Manufacturing for a Sustainable

Terra Preta Sanitation System



Carbonization and Sanitation

“CaSa”

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Table of abbreviations

CaSa	"Carbonization and Sanitation"
EWBG	Engineers without Borders Germany
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics
IRR	Internal Rate of Return
K	Potassium
MDG	Millennium Development Goals
N	Nitrogen
NPV	Net Present Value
NGO	Non-Governmental Organization
P	Phosphorus
RCA	Replacement Cost Approach
SME	Small and Medium-sized Enterprise
TPS	Terra Preta Sanitation
TZS	Tanzanian Shilling
UDDT	Urine Diverting Dry Toilette
WHO	World Health Organization

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Abstract

The Carbonization and Sanitation project “CaSa” is taking a decentralized and resource oriented sanitary approach that aims to address two leading challenges:
It responds to declining soil fertility, water-holding capacity and interrelated malnutrition through an efficient recovery of valuable nutrients - Nitrogen, Phosphorus and Potassium - and organic matter from human excrements. Afterwards, the nutrients can be safely reused in cultivation by means of two fertilizing end-products: *Terra Preta* and liquid urine fertilizer. Its application results in the production of nutritient-rich food and consequently contributes to better food security as well as soil quality.
Simultaneously, the waterless sanitation system deals with the lack of an adequate sanitation infrastructure and/or to inefficient water-based sanitation systems. The reduction of wastewater and faecal pollution of water bodies play a key role in preserving scarce water resources and in fighting the high incidence of diarrheal and infectious diseases. Worldwide unsafe water, sanitation or hygiene cause around 88 percent of diarrheal death and 99 percent of that occur in developing countries[1].
The basic idea of the novel CaSa concept houses three major components which are particularly adapted to the Tanzanian context but include the possibility to incorporate differing culture specific or technical adaptations: (i) the Urine Diverting Dry Toilet (UDDT) for the separate collection of excreta and its pretreatment, (ii) an energy efficient oven combined with the on-site generation of bioenergy and production of biochar by means of a micro-gasifier. The energy is required for the safe hygenization of faeces while biochar represents a valuable input for the subsequent (iii) *Terra Preta* composting, where carbon and nutrient-rich soil represents the end-product of natural formation processes without requiring external inputs like energy, water or ventilation.
This serves, in combination with stored and thus sanitized urine, as marketable fertilizer for agriculture and forestation in areas of unfavorable soil structures and health hazards.
This recovery and acknowledging excreta as valuable raw material helps to activate regional potential along the entire sanitation chain, to create jobs and to improve the local standards of living.
Summarizing, the CaSa construction closes the nutrient cycle and promotes an eco-efficient collection and recycling of human excreta through safe sanitation technologies and integrated biological processes.
Technical expertise and research, needed for the system´s development and implementation, has been provided by Engineers without Borders Germany (EWBG) in conjunction with Technische Universität (TU) Berlin and the local NGO, MAVUNO project. The applicability of the system, which can be installed independently from central sewage and water infrastructure or electricity grids, has been investigated: At first by means of a feasibility study, followed by a pilot scale (UDDT and treatment plant) in Berlin in 2010 and a small scale pilot set-up in northern Tanzania, which was initiated in 2012 and lasts until today and is accompanied with ongoing ecological research.
Following a participatory approach, high involvement of the local community at every stage determined the project cycle. The integration of regional-specific possibilities and limitations into the development of adaptive technologies resulted in steady refinements and a user friendly format of the sanitary solution. Local value creation, adaptation to cultural needs, use of locally available resources, application of skill-appropriate technology and provision of educational material and training for easy replication as well as maintenance represent the leading principles in the course of development and research. Propelled by promising results, the implementation of the sanitary service is now scheduled at institutional level at Chonyonyo Secondary School.
Overall, this paper will suggest that the CaSa approach has the potential to increase hygiene awareness, to foster close relationships between local stakeholders and thereby to contribute to affordable demand-driven manufacturing and sanitation services at local, district or national level.

[1] WHO (2009). Global health risks. Mortality and burden of disease attributable to selected major risks.

1 Technical Description

1.1 CaSa System

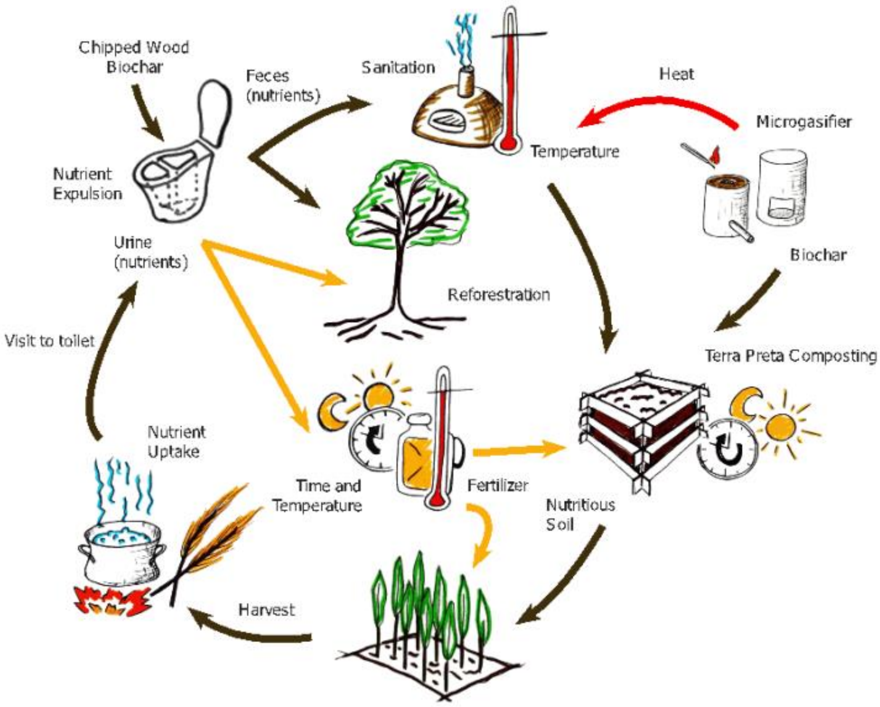
The innovative CaSa system recognizes the need for sustainable and efficient sanitation systems. That is, it promotes human health and food security without environmental degradation of resources. Instead, the system is based on a closed nutrient cycle by following the idea of Terra Preta Sanitation (TPS) and focuses on technical appropriateness, economic viability as well as social acceptance.

This holistic approach does so by comprising three basic modules in the hygienic recycling and reuse of nutrients and organic matter from human excreta: The Urine Diverting Dry Toilets (UDDTs), the thermal treatment using an oven that is powered by a micro-gasifier and thirdly, the composting process to create the fertile Terra Preta.

At the beginning of the sanitation chain, human excrements are collected and stored by means of urine diverting dry toilets (UDDTs). Their use prevents large amounts of wastewater and faecal pollution while rainwater collection from the roof provides water for hand-washing. The resulting greywater is directed to a nearly located bed of plants where it is soil-filtrated and trickles away into the ground afterwards. Waterless toilet-designs incorporate a divider allowing for solid and comfortable separation of urine and faeces. Vessels for separate collection of the excreta are installed in different storage chambers underneath the toilet. This helps to facilitate its subsequent handling in terms of processing and fertilizer use since both components of human excreta require different procedures of sanitation treatment.

Urine is mostly sterile with an adequate crop assimilation ratio of the nutrients Nitrogen (N), Phosphorus (P) and Potassium (K). It can be used as fertilizer, neat or diluted, depending on the desired nitrogen rate right after a retention period - one month at 20 °C according to WHO[2]. The safe re-

Figure 1: Illustration of the Casa concept



[2] WHO (2006). WHO guidelines for the safe use of wastewater, excreta and greywater. Vol IV: Excreta and greywater use in agriculture.

turn of faeces into the natural cycle requires a more complex proceeding.

First, a carbonic mixture is added to the faeces after each defecation. It contains sawdust for good absorption of water, ash which is high in pH, charcoal comprising both properties from above and terra. This helps to decrease undesirable odour, the number of pathogens and to reduce moisture. Furthermore, the low moisture level and high pH level keep losses of organic matter and N low. After the vessel is filled, dehydration is enhanced by solar heating and an integrated ventilation system regulates the oxygen supply and simultaneously favors rapid pathogen destruction. This process is located in the solar chamber where the temperature rises up to approximately 40 – 50 °C.

These pretreated faeces are then transported in closed vessels to the sanitation area, where full sanitation is effected by means of thermal treatment in loam ovens. The temperature profile of this so-called "pasteurization process" – which is a thermal treatment at an average of 70 °C during 30 minutes up to several four hours - encompasses nutrient conserving processing and the deactivation of all dangerous pathogens. Corresponding results for the feasibility assessment of this sanitation process conducted by the Leibniz-Institut für Gemüse- und Zierpflanzenbau Großbeeren/Erfurt e.V. in combination with a security screening executed by the Landeslabor Berlin-Brandenburg will be published soon.[3] The energy supply for the oven is provided by an on-site micro-gasifier while the structural design and choice of construction material ensures an efficient exploitation of the produced energy (Figure A.1). The oven is based on the principle of the "masonry stove". The exhausted hot air from the micro-gasifier passes through an outer and inner circle of clay bricks. The high heat storage capacity and an insulation of 10 cm thickness reduce heat losses and retain the heat as long as possible, even after the micro-gasifier ceases to burn.

Controlled combustion of wooden scrap or other plant debris like coffee husks, which are local waste-products, serves as primary energy carrier. This procedure is significantly more efficient than e.g. open fire. Simultaneously, biochar is obtained as a result of the reaction in the micro-gasifier and serves as essential input - carrier and binder of organic matter - for the subsequent composting process. Furthermore, the energy demand is low due to prior reduction of the water content in the faeces. Hence, using this CO_2 sequestration as a part of the gasification process with incomplete combustion represents an efficient, thanks to lower CO_2 emissions environmentally friendly and also economically viable solution. On larger scale, a more complex process of pyrolysis that allows additionally for manifold usage of bioenergy beside the energy provision and biochar production for the hygienization process only, could represent an alternative solution[4] while simultaneously discouraging deforestation and consequent soil erosion. Conventional firewood would be substituted by efficient alternative fuel sources as kitchen and agricultural waste.

During the final composting process, the material is combined with organic residues from the kitchen, harvest residues from agricultural activities, biochar from the micro-gasification process, microorganisms and some of the pure liquid urine fertilizer to supplement the C/N ratio. Hence the actual composting process does not require external inputs like water, energy or ventilation. Only two till three months of time and also the work of many different microbes in the soil are needed until the black soil can be finally used in agriculture or in forestation[5] matters.

The application of such carbonized material as well as urine as liquid fertilizer to agriculture closes the nutrient cycle and, on the ecological front, is expected to discourage degradation.

The ecological evaluation of the field trials on distinct parameters of the soil "quality" and structure (e.g. carbon and nutrient contents, pH-values, salt content) using urine fertilizer and Terra Preta did not yet yield significant results, but the values of the substrate analysis indicate that the product of

[3] This involved the working group „Urban Cycles" and the corresponding dissertation will be published by Felix Letow.

[4] Research on such a pyrolysis system is conducted for example by Dr. Rajabu in Dar es Salam.

[5] The use of Terra Preta for fertilization of forests does not necessarily require previous thermal treatment and would therefore facilitate even more the treatment phase.

the TP-composting corresponds to a good soil.[6] Fostering the awareness of potential environmental, hygienic and monetary gains as well as acceptance for such fertilizers among the local population renders the possibility to produce and sale Terra Preta and urine fertilizer respectively. This provides a key incentive for the establishment of private sector interaction and consequently, this system is not restricted to small scale implementation of self-sufficient households, but can together with local entrepreneurs be implemented in more densely populated regions where the demand for sanitary solutions is most urgent.

In order to provide a working sanitary solution that is applicable to urban regions and can be installed independently from sewage and electricity grids, the CaSa concept follows the approach of public sanitation systems. The sanitation facilities shall be located in external buildings in order to keep costs of construction low and circumvent difficulties regarding the implementation of solar chambers or limited storage capacities that arise especially in multi-storey houses. Nevertheless, such common sanitary blocks are applicable to densely populated peri-urban and informal areas as well as to non-residental buildings as schools or public places.

Sanitary services as storage, transport and treatment must be integrated into the sanitation chain. Regarding the urine management, two large tanks for each sanitary complex, alternatively used for central collection and storage, need to be implemented. The size should be chosen so that each tank has the capacity to absorb the volume of urine of at least one month. In peri-urban settlements as Dar es Salaam´s[7] northern and western fringe where farming is central to many households, the urine may be transported to another bigger tank in order to overcome time periods until the application season and may later be directly used as fertilizer on the field via an integrated drip irrigation system. In more densely populated urban areas, the urine has to be transported in smaller tanks, rather than using one big tank truck, to the area of use or to the distributor. Numerous smaller tanks facilitate loading and allow for alternative transportation activities. Regarding the containers that hold the faeces, the volumetric capacity and/or the frequency of emptying have to be adjusted to the amount produced in each sanitary complex in a specific time period. Community-based treatment areas (thermal treatment and compost) or decentralized treatment plants avoid expensive central wastewater treatment plants and are necessary to handle such volumes. Further, authorized persons who monitor the urine level, faeces load and move the containers to the solar chambers have to be appointed.

1.2 CaSa Toilet

The CaSa toilet represents one of the tree essential components of the entire system. The existing prototype is an exemplary design for a simple UDDT unit with adjustments to environmental conditions and cultural habits. The focus during the course of development was on hygiene, user comfort, cost-efficiency and the ease of deployment without the need for heavy infrastructural implementations such as central sewage or water supply. The final draft of the self-sufficient toilet has constantly been optimized through experiences from constructing, operating and maintaining it in the pilot set-up.

The technical solution renders local entrepreneurial possibilities as it is adjusted to low-tech skills and simple materials – a system that recognizes the needs and conditions of low income households (Table B.1 List of Materials). Nevertheless, the design can flexibly meet a variety of different conditions (building materials) and needs (sitting vs. squatting pedestals; dry vs. water cleansing). In the context of the targeted Tanzanian population there is high acceptance and user experience towards the squatting technique. That is why squatting pedestals do not require challenging behavioral changes regarding the handling compared to already existing solutions (e.g. pit latrines). The “two-hole-system” of the squatting slabs facilitates the comfortable separation and collection of human excreta. Moreover, the risk of infection is minimized due to the avoidance of direct contact compared to sitting pedestals. In order to prevent the necessity to install an additional discharge piping for blackwater and minimize the water input, toilet

[6] CaSa (2013). Summary of the ecological evaluation.

[7] Dar es Salaam is the largest city in Tanzania and is very important for business and government and is located on the cost of the Indian Ocean.

paper can be chosen instead of water cleansing, or both be implemented[8].

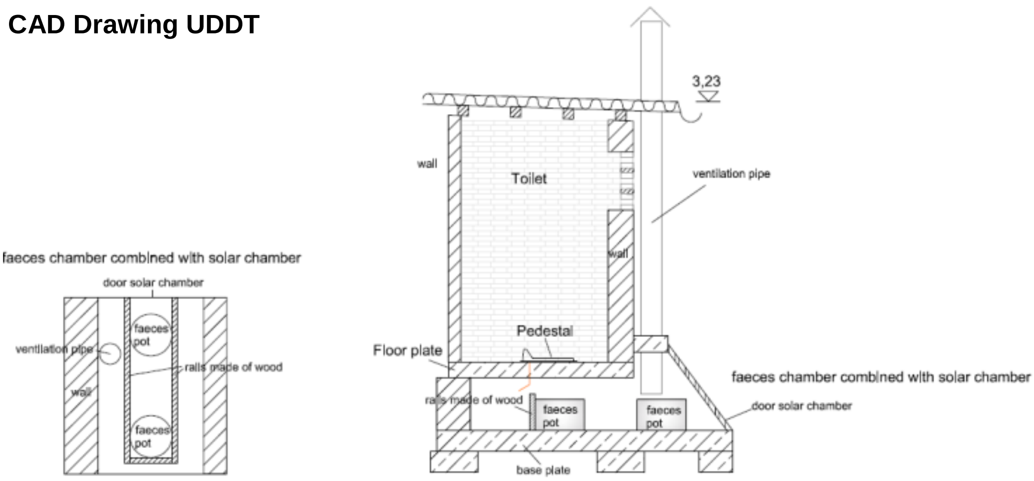
According to Figure C rather than underground pits, the sanitation building is designed at ground level to facilitate the operation and exchange of containers and tanks. The substructure consists of three chambers and is built on a septic foundation. This “basement” is covered with an intermediate plate – the above floor, which users access via steps or alternatively, disabled people via a ramp. For this barrier-free access the whole house could be build closer to the ground or exploit the natural slope in order to cut the required length of the ramp.

The first chamber in the basement is equipped with two tanks for alternate collection and storage of urine. If the required storage capacity and thus the tanks are too large to fit the basement, they can optionally be placed outside the building at lowered level. In order to minimize losses from ammonia, a lid that closes airtight is important for storage. The urine is directly guided from the UDDT into the collection tank. Since the urine cannot be filled in at the bottom of the tank due to hydrostatic pressure, the pipe enters from the top. Typically, consequences of such an filling from the top are ammonia losses and bad odour, but by using a perforated pipe which enables a steady increase of urine such unfavorable consequences are reduced.

Faeces are collected inside exchangeable containers. They are located in the second chamber beneath the faeces hole. Hence, the faeces drop directly into the pot and the dry cleansing material as well as the carbonic mixture is supposed to cover the fresh faecal surface. Thereby the additive keeps biological degradation low. As soon as it is filled, it manually has to be replaced by the second empty pot and moved to the third chamber – the solar chamber. An integrated passive ventilation system supports air circulation while the design of the chamber and the mosquito mesh at the top of the ventilation pipe prevent flies that had contact to the faeces from escaping and spread diseases. The ventilation pipe is blackened on the top such that the upper part of the pipe is heated and develops low pressure. As a consequence, the air is sucked out of the chamber and fresh air enters. Thereby humidity and as a consequence the volume of the faeces is reduced, odour is minimized and oxygen supply improved. The high pH and the rise of the air temperature in the solar chamber, both contribute to further elimination of bacteria and pathogens. The solar chamber is oriented to the south, painted black from the inside and covered with iron. This helps to efficiently absorb the heat but omits the use of transparent material for reasons of social acceptance. This protects users and service personal since it reduces the risk of infection in case of undesirable contact during handling the chambers. Furthermore, both the ventilation system and the solar chamber represent technical adaptations to the local climate, i.e. to frequent sun exposure.

The robustness and technical problems of the pilot toilet (Figure B.2) have been revised during construction and use. This phase has contributed to

Figure 2: CAD Drawing UDDT



[8] Generally, adjustments to the culturally accepted cleaning technique can be easily realized, e.g. by installing a double discharge piping system.

identify potential vulnerabilities and resulted in several revisions. E.g. refinements have been realized concerning the height of the blackened part of the ventilation pipe by which it exceeds the roof in order to guarantee an effective air circulation and prevent high prevalence of flies through an optimized chimney effect.

An up-scaling of the sanitary solution can be achieved by adjusting the number of separate squatting slabs, which are installed in each sanitary block, optionally urinals for men (Figure C.2 and C.3).

For a reference population of 20.000 inhabitants under the assumptions that 25% of the excreted amount is left at public places, residential buildings etc., the tanks for central collection and storage of urine require the capacity to absorb 10.000 l, which corresponds to the average volume excreted per month plus a security buffer in each of the 18 necessary sanitary complexes (Table C.1). Each sanitary block encompasses six toilet units for men and women respectively. Furthermore, the faeces pots need to hold 40 l if they are moved into the solar chamber after 7 days and after another 7 days transported to the treatment plant, while assuming a volume loss around 50% during drying in the solar chambers. Hence, 4081,4 l of dried faeces must be transported from each sanitary complex on a weekly basis to the sanitation area.

1.3 Manufacturing Process

The manufacturing process of the UDDT in the regional context of Tanzania is adapted to the use of locally available construction materials. Further selection criteria as weather resistance, durability and costs were considered. Following an affordable processing by local people or small and medium-sized enterprises (SMEs), the technical requirements of the system are suited to low-tech know-how in order to facilitate construction and maintenance. Complementing, the program aims to transfer knowledge through accompanying workshops on functioning, mutual construction and maintenance throughout all parts of the system.

The manufacturing starts with the foundation, which is designed as a continuous footing with a base plate made of reinforced concrete. The three base chambers are separated by locally manufactured clay bricks. The covering intermediate plate, including cut-offs for the faeces drophole, urine hole and ventilation pipe, completes the substructure.

Concerning the squatting pan, a negative with the following measures serves as template:

- slab: 80 x 60 cm
- poo hole: diameter 20 cm
- pee hole: 45 x 30 cm
- footsteps: 35 x 12 cm

This handmade template is built of loam due to its local availability. Then, a frame of 55 cm x 80 cm for the formwork of the squatting slab is constructed and filled with concrete and water proof additive. Since the lifetime of the negative is restricted to one use only, future and large-scale production should use more persistent material such as rubber. Nevertheless, most molding processes require the application of separating agent to prevent the material from bonding and the use of technical amendments, which may be regionally limited and therefore play a critical role. Smashed tiles or leftovers of alternative materials cover the footsteps, therefore facilitate accurate positioning and decorate the floor with individual mosaic designs while simultaneously contributing to a sterile finish. A splash protection reduces urinary dirtying and a molded lid closes the faeces hole to prevent accidental contact during urination only. The walls of the cabin are constructed by bricklaying and integrated windows and a wooden door frame. The main door is made from strong wood. The cabin is completed with a flat roof of corrugated iron on top of wood planks.

The sanitation complex can be accessed via a short staircase. The solar chamber is attached to the faeces chamber and covered with an iron sheet since the initially planned glass window is fragile, hence difficult to transport, more expensive and presumably less comfortable for the users since it does not hide the faeces. All doors for the chambers are constructed and plastered in by local metalworkers. Summarizing, the manufacturing of the UDDT emphasizes the use of abundant resources, involves different local manufacturing sectors and circumvents the expensive import of materials.

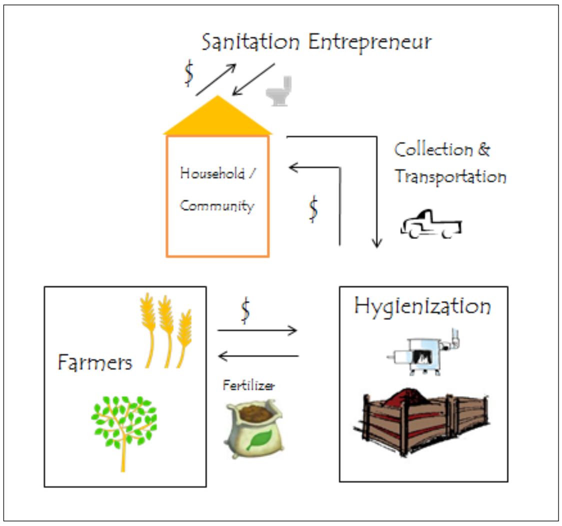
2 Business Model

2.1 Business Model Canvas

The premise for any successful business model is an unsatisfied demand. This demand can be met by private businesses that will play a fundamental role in providing sustained access. While it is generally true that there is demand for appropriate sanitary solutions as global commitments like the Millennium Development Goals (MDGs) demonstrate, the individual demand depends heavily on behavioral patterns, environmental sensibility, hygienic education and economic factors. Especially in densely populated areas appropriate sanitation solutions are most urgently needed but in particular the less affluent society with its latent demand does not always provide sufficient incentives for private sector participation. As a consequence, conventional sanitation systems are likely to continuously depend financially on donors or subsidies. The CaSa concept aims to circumvent this and supports a decentralized solution that is self-sufficient in terms of energy- and water input, closes the nutrient circulation and is financially sustainable. The key for “making business out of shit” lies in the acknowledgement of the value of human excreta – a renewable and vastly abundant raw material.

The opportunities for business development that are included in the entire sanitary chain will be outlined in the following by means of eight building blocks listed below while the direction of the basic financial flows may be organized as illustrated in Figure 3.

Figure 3: Illustration of the Cash Flow



2.1.1 Key Partners

Among the public authorities, mainly municipal authorities, but also a multitude of relevant small-scale operators may act as key partners and should be brought together to collaboratively scale-up the implementation of the CaSa design.

At municipality level, objectives usually contain economic and environmental protection. Excessive wastewater production and the lack of adequate sanitation entail health risks and hamper the attractiveness of the city. Elections, financial restrictions and penalties from higher hierarchical levels of government may make municipalities responsive to the sanitation solution.

Further support may originate from governmental support since the CaSa concept may affect the wider society with respect to important health matters and in targeting the MDGs.

Relevant stakeholders and service providers on the market side include:

- Local manufacturers and suppliers (brick manufacturers, metalworkers, cement factories, sand suppliers, etc.)
- Treatment plants, fertilizer manufacturer, retailer
- Logistic providers (collection and transportation service, regular distribution of additive)
- Local microfinance institutions that offer financial products to different groups of clients as SMEs (thereby helping them to provide good sanitation services) and to users (thereby allowing e.g. landlords to realize investments in sanitation facilities).

2.1.2 Key Activities

Essential business activities are:

1) Maintenance and operation, including storage if on-site capacity and reuse is limited, monthly/weekly collection and emptying of the containers, transportation, treatment (thermal and composting) as well as marketing of the end-product
2) Manufacturing (e.g. slab fabrication) and marketing of sanitation facilities

2.1.3 Key Resources

The following assets allow an enterprise to offer a value proposition:

- Raw material for construction of sanitary facilities (slab molds, mansonry tools, etc.)
- Raw material for fertilizer and soil conditioner production (human excreta)
- Human resource requirements for processing (low-tech know-how, knowledge on Terra Preta composting)

2.1.4 Value Proposition

A variety of aggregated benefits is offered to the costumers and society:

- Access to comfortable and hygienic toilets
- Conservation of the environment (reforestation, water preservation, drought and flood resistance)
- Eradication of hunger and improvement of health
- Increased access to locally manufactured fertilizer as substitute for chemical fertilizer
- Local value creation through job creation along the chain of sanitary businesses.
- Spread of the sanitary and fertilizer sector is expected to result in increasing costumer orientation, lower customer price and improved agricultural efficiency

2.1.5 Costumer Relation

The customer relationship needs to be long-term transactional and embody reliance in order to drive customer acquisition:

- The collection and transportation service needs to guarantee regular and hygienic services
- The fertilizer manufacturer must guarantee hygienic and fully sanitized fertilizer
- The facility design must assure privacy, comfort, no smell and no contact to the other peoples waste

2.1.6 Channels

In order to establish broad product acceptance, the following channels are of utmost importance:

- Enhancement of acceptance for excreta based fertilizers in agriculture through information dissemination, workshops and demonstration plots
- Public campaigns that encourage desirable views as toilets being a status symbol
- Social marketing by governments or community-based promoters for awareness creation of health advantages, environmental and eventually income-based benefits
- Pilot implementations, especially in schools are suited to convey hygiene and favorable behavioral patterns as well as to spread knowledge and acceptance

2.1.7 Customer Segments

Potential customer segments can be identified on household, but especially on community and institutional level. They can be further differentiated according to the degree of urbanization.

1) Especially peri-urban regions are well suited due to favorable conditions with regard to storage capacity and agricultural activities. The local reuse of urine fertilizer and Terra Preta, possibly via a directly linked irrigation system or moderate transportation distances, contributes to the efficiency of the system. Implementations of sanitary concepts in those regions represent very effective moves since these areas may convert into urban areas in the future and therefore possibly support the effective spread of technologies and acceptance
2) Highly populated areas combined with low income, the so-called informal areas where the implementation of community-run common sanitary blocks can have a huge beneficial impact and where the problem of partly inexistent sanitary facilities is dominant. The collection of fees may serve as motivation.
3) Public places and residential buildings, not necessarily restricted to lower income areas represent further target groups.

On the other hand, farmers and gardeners represent the customers for the end-products, local farmers from Kagera[9] already inspected the fields treated with CaSa compost. They have shown great interest in buying such compost. In addition, already existing distribution channels of industrial fertilizers could be used for marketing and are very important since the upcoming sensitivity analysis emphasizes the relevance of the demand side (Table F.4).

2.1.8 Cost Structure and Revenue Stream

Fertilizer application is a crucial input to increase agricultural productivity. Accordingly, powerful quantities of nutrient-rich fertilizer are traded. Thus, the physical end-products of our closed loop system entail potential income generation through the commercialization of excreta-based fertilizer and soil conditioner:

- High quality carbonized soil "Terra Preta" as conditioner and fertilizer.
- Liquid urine fertilizer

In Tanzania, fertilizer is mainly imported with a market size of 302.000 mt in 2010[10], but application is still below the targeted 50 kg/ha of arable land by the Abuja Declaration, and could have substantial benefits for subsistence farmers. Local production as substitute for the expensive import of chemical fertilizers may therefore improve affordability, access, dealer participation and strengthen the local demand.
In order to assess the economic value of the nutrients contained in human urine and faeces, the Replacement Cost Approach (RCA) is used to assign monetary values to such soil nutrients based on the market value of chemical fertilizer. The market value of nutrients in human urine and faeces is approximately 0,016 USD/l for urine and 0,68 USD/kg for wet faeces which corresponds to 1,51 USD/l of dried faeces[11] (Appendix D). The nutrients contained in a certain amount of excreta can only demonstrate a rough approximation since consumption patterns are mainly decisive for the nutrient content and overall amount excreted. Furthermore, the nutrient content refers to faeces neglecting changes in the content during drying and processing for reasons of simplification. Nevertheless, this conveys an idea of a monetary value that can be attached to the main nutrients (N, P and K).
For a reference population of 20.000 inhabitants, the monthly volume of urine that can be realized under the given assumptions[12] corresponds to 180.000 l of urine and 35.100 l of faeces (17.550 l of dried faeces). The corresponding market value of the nutrients is 2.800 USD for urine and 26.520 USD for the faeces before compostation (Table C.1).
One can expect that after the thermal treatment and composting the value of the material will significantly increase as hygienic concerns do not limit the area of application anymore. With 17.550 l of dried faeces approx. 46.800 l of compost will be generated[13].

On the cost side, investment and O&M cots for the scenario of 20.000 inhabitants originate from the sanitary blocks, transportation and treatment (Appendix E):

The distance per round trip (directly to the consumers or places of distribution) is restricted by the value of nutrients contained in 10.000 l of urine, which corresponds to the monthly amount of urine collected in one public building block (all other costs excluded). The maximum distance for which the monthly transportation costs of one sanitary complex do not exceed the value of nutrients is 175 km (Table E.1.1). The low value-to-volume ratio of urine may limit an effective and economic management if transportation distances are high and storing capacities insufficient. In this context, the idea of producing fertilizer powder of urine is worth further investigation.

[9] The region Kagera is located in the northwestern corner of Tanzania.

[10] http://africafertilizer.org/Platform-Administration/Countries/Tanzania.aspx [July 7, 2014].

[11] The price s to the nutrient value of faeces without considering prior or subsequent treatment/drying losses.

[12] The underlying assumptions are listed in Table C.1.

[13] Under the assumption that at the beginning of composting, faeces make up 15 Vol-% and during the process the total volume reduces down to 40%.

The transportation costs of the dried faces (four trips per month and per sanitary complex) are less restrictive. The volume of the faeces is subject to reductions during the drying process and yields a higher value-to-volume ratio. Each round trip, the truck can load the weekly volume of dried faces of all 18 complexes with a relatively high profit margin such that the less profitable urine transportation may be subsidized by this branch. Assuming that the average distance per entire round trip to all complexes and the sanitary area is approximately 100 km the estimated transportation costs are 80 USD per week and 340 USD monthly[14] (Table E.1.III).

Altogether, the profitability analysis for a five-year-scenario with costs listed in Appendix E yields a positive net present value (NPV) of 475.509,00 USD for the less conservative calculation (Table F.2), after considering a 15% loss in the value of the end-products a NPV of 237.248,35 USD (Table F.3) is obtained and for changing parameters in the sensitivity (Table F.4) analysis the NPV is also positive. This NPV indicates the amount of surplus that the project is expected to generate and suggests that the project is likely to be profitable. A second indicator is the internal rate of return (IRR). The IRR can be directly compared to the prevailing cost of capital and indicates the rate of profitability. The IRR exceeds the nominal interest rate and thus, is expected to be profitable. This relatively high margin between cost of capital and IRR is especially important in the context of SMEs who cannot take substantial risks. This reveals that each business involved in the sanitation sector may generate profits, which in turn encourages private sector participation. Summarizing, if the human waste were to be treated and used as a valued fertilizer, decentralized eco-sanitation may be realized in a very cost-effective way.

2.2 Sustainability and local Value Creation

To achieve local sustainability in all of its three dimensions - environmental, social and financial – especially for the latter it is of utmost importance to overcome the bottleneck of financing. The ability to provide benefits from collecting human excreta – better health, higher crop yields, environmental preservation – contributes to sustainable demand-driven entrepreneur-customer relationships and stakeholder networks. Small enterprises are confronted with possibilities to start businesses. This activation of entrepreneurial drive along the sanitation chain is particularly important in urban settings to guarantee safe and reliable handling of human excreta and contributes further to local job creation. The regionally suited low-tech sanitation system and integration of local materials enable more than one supplier to provide the required products. Supporting such competitive structures benefits the customer value creation e.g. through lower prices, wider access, higher standards and better system efficiency or service product superiority. As a consequence, this diminishes the dependency on external donors or subsidies.

Hence, the economic sustainability is not conflicting with the targeted ecological sustainability of the nutrient loop system. The waterless toilets and rain water collection for hand-washing induce water preservation and reduced water pollution. The efficient and nutrient-protective reintroduction of the essential elements of human excreta into the natural cycle simultaneously discourages the import of energy-intensively produced artificial fertilizer or phosphate mining while making use of solar energy and low input requirements during the natural formation processes or during storage. As a consequence, water holding capacity of the soil and the nutrition content of plants increases and contributes to social sustainability due to better food security and water supply. Besides the rich nutrient value, access to clean water is likely to entail major impacts on water quality-related diseases and their transmission through better hygiene conditions. The provision of hand-washing facilities and squatting pans prevent direct contact, reduce health risks and aim at improving the quality of life. Furthermore, health risks in case of undesirable contact during transportation to the sanitation area are minimized via previous solar radiation and the entire treatment process - pre-treatment, thermal treatment and post-composting

[14] Based on 368 days, 52 weeks a year and 4,3 weeks per month.

– entails high pathogen removal efficiency. In terms of cultural acceptance, the UDDT will probably rank lower among countries where flushing toilets are already considered as status quo and the acceptance of excreta based fertilizer application has still to be promoted in order to guarantee sustainable acceptance. Nevertheless, regarding the institutional sustainability, the system is designed in accordance with the WHO guidelines on safe use of wastewater, excreta and greywater. From a socio-economic point of view, local materials and personnel create job opportunities in construction, maintenance, transport and treatment sectors while the participatory development of the low-tech solution ensures the availability of skill appropriate human and physical resources.

3 Additional Questions

3.1 Implementation Status

The CaSa sanitation system has been already implemented as a pilot set-up in Tanzania, Kagera, after a previously conducted on-site feasibility study (completed 2010) and a phase of prototypical testing of the technical components in Germany (completed 2011). This set-up included the construction and use of the UDDT, loam oven, micro-gasifier and composting in Tanzania, Kagera (2012 - 2013). The subsequent phase (2013 - 2014) comprised refinements concerning the ease of use, cost-optimization of a second toilet and the comfortable handling of the loam oven, supplemented with ongoing ecological research by TU Berlin on soil quality, plant nutrients as well as substrate analyses to screen epidemic and phytochemical safety. Additionally, the local population has access to open-source instructions for construction of the sanitation facilities as well as the possibility to attend workshops on the following topics: hygiene, closed cycles, Terra Preta, use and maintenance of the UDDT. Some regional farmers did already express their interest in buying the end-product. These achievements originated from the collaboration of the local partner organization MAVUNO, TU Berlin and EWBG and build the foundation for the scheduled large-scale implementation of the entire system at institutional level - at Chonyonyo Secondary School.

3.2 Applied Technologies

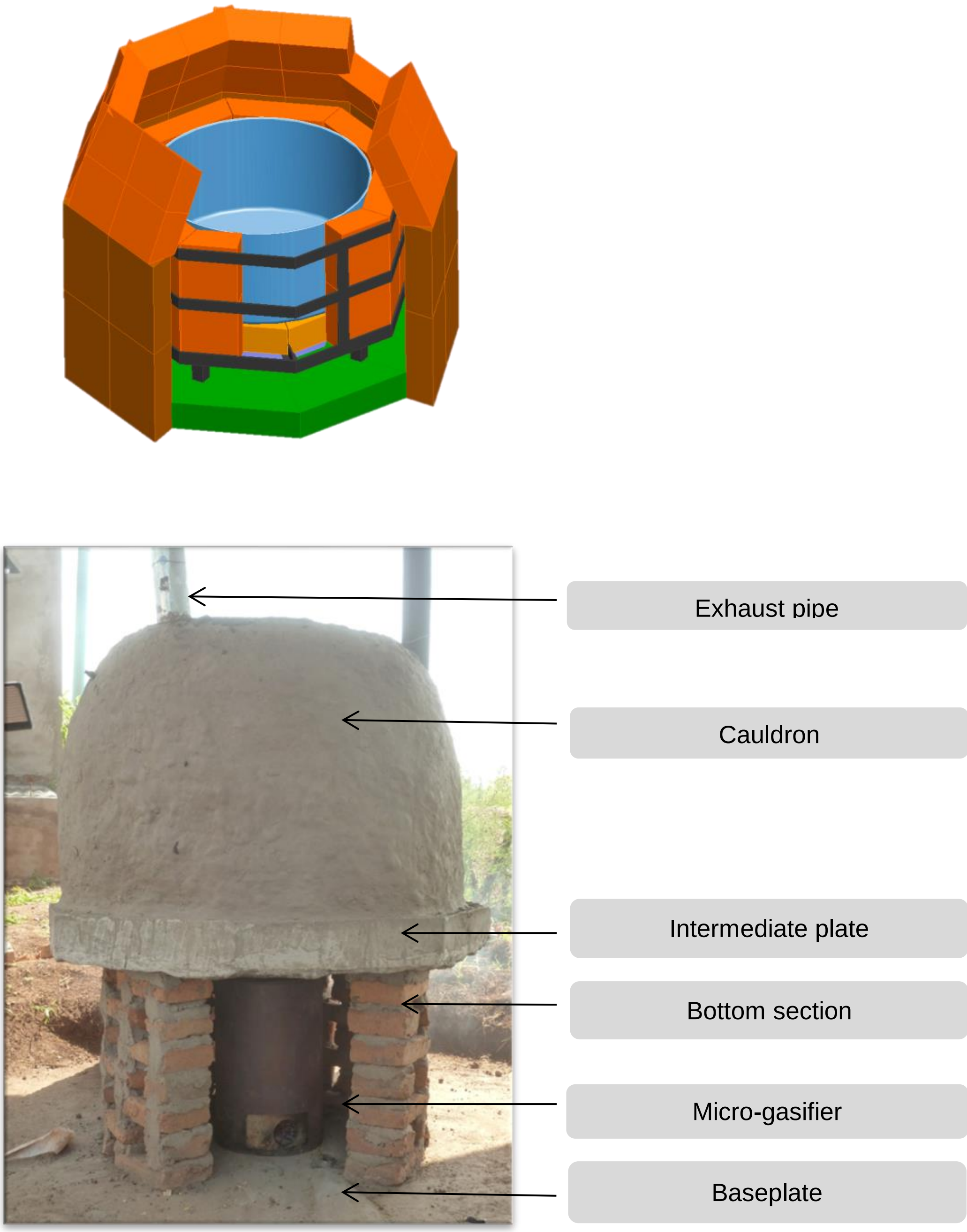
The CaSa sanitation approach houses a multitude of different technologies ranging from ancient methods to partly already individually market-ready components. One key element is the concept of Terra Preta that has been rediscovered for adequate treatment of human excrements, known as TPS. To facilitate this process, the CaSa concept draws on the classic example of double-vault toilets and applies a combination of dehydration and decomposition for primary treatment, which is adapted to climate and cultural conditions of Tanzania as well as to low-income and low-tech, e.g. the solar chamber as already existing solution.

But instead of exclusively relying on composting, an additional process of pasteurization is integrated into the system. This decreases the warranted composting time and improves pathogenic removal. To be able to sanitize large amounts of excreta the already mentioned pyrolysis system by Dr. Rajabu may be worthwhile further investigation.

3.3 Creative Common License

Appendix A

Figure A.1: Structural design of the loam oven



Appendix B

Table B.1: Bill of materials for prototype UDDT without labor costs					
Requirements	**Quantity**	**Unit**	**Unit Costs [TZS]**	**Total Costs [TZS]**	**Total Costs [USD]**
UDDT					
Chamber doors and frames (metal)	3	Number	35.000,00	105.000,00	
Main door and frame (wood)	1	Number	80.000,00	80.000,00	
Claybricks (20x12x5cm)	1.000	pcs	40,00	40.000,00	
Sand	43	tins	433,00	18.619,00	
Cement (density 2000 kg/m^3)	4	bags	14.000,00	56.000,00	
Waterproof additive	3	kg	1.500,00	4.500,00	
Urine Tank (collection and storage)	2	20 l	5.000,00	10.000,00	
Nails	2,5	kg	4.000,00	10.000,00	
PVC Pipe (ventilation)	1	Number	18.000,00	18.000,00	
LPS Pipe 1" (urine) [6m]	1	Number	20.000,00	20.000,00	
Corrugated iron sheet 28 gauge (roof)	2	pcs	25.000,00	50.000,00	
Hinges	1	pair	5.000,00	5.000,00	
Round bar (10mm)	3	m	3.333,00	9.999,00	
Beams	3	pcs	3.500,00	10.500,00	
Reinforced steel	4	m^2	7.200,00	28.800,00	
Urinal Plate	1	pcs	2.000,00	2.000,00	
Poly tank (central storage)	1	Number	25.000,00	25.000,00	
Locks for doors, Elbow and T-Connectors, Putty, Wood laquer, Bending wire			34.000,00	34.000,00	
				527.418,00	332,71
Infrastructure					
Microgasifier	1		570.000,00		
Tank for Rainwater	1		325.000,00		
Shredding mashine	1		798.200,00		
				1.693.200,00	1.068,11
Oven	1			1.820.500,00	1.148,41
Grand Total of Materials				**4.041.118,00**	**2549,23**

* Average Official Exchange Rate (May 2013 - May 2014) = 1/1585,23 (USD/TZS) (http://www.oanda.com/lang/de/currency/converter)

**The above prices are either founded on an experiential basis of the Tanzanian markets from on-site implementation and construction or on estimates. Due to the lack of detailed information about some of the items, it has to be emphasized, that those correspond to approximate values.

Figure B.2: UDDT of the pilot set-up in Tanzania

Appendix C

Table C.1: Mass and Revenue Calculation	
Underlying assumptions	
Reference population	20.000 inhabitants
Level of collection	common sanitary facilities shared facilities residental buildings
Type of sanitation system	decentralized collaborative private entrepreneurs incentive-driven
Volume of urine produced per day and person [l/day]*	1,2
Weight of faeces produced per day and person [kg/day]**	0,26
assumed density [kg/l]	0,9
Volume of faeces produced per day and person [l/day]	0,234
Percentage of feaces and urine collected [%] in each block	25%
# of sanitary blocks	18
# of UDDTs/urinals per sanitary block	12
# of people using each block assuming same population density	1.111
Mass and Revenues	
Total volume of urine per month [l/month]	180.000,00
Total weight of faeces per month [kg/month]	39.000,00
Total volume of faeces per month [l/month]	35.100,00
Volume of dried faeces [l/month] ***	17.550,00
Total volume of compost [l/month]+	46.800,00
Market value of nutrients in human urine per month [USD] ++	2.880,00
Market value of nutrients in human feaces per month [USD] +++	26.520,00
Market value of nutrients in human urine per month [TZS]	4.565.462,40
Market value of nutrients in human faeces per month [TZS]	42.040.299,60

* the amount of urine depends on the fluid intake, due to the relatively low intake based on experience reports from the Tanzanian population, we assume 1,2 l per person per day instead of the average amount 1,4 l per day Berger (2008). *Kompost-Toiletten : Sanitärsysteme ohne Wasser.* 1. Aufl. Staufen bei Freiburg : Ökobuch-Verl.
**due to the relatively high-fibre diet in Tanzania we assume the amount excreted to be at the upper end of the typical amount ranging between 50 g and 250 g per person per day.
*** assuming a volume loss of 50 % after one week in the solar chamber plus max. one week/min. few hours during collection
+assuming that at the beginning of composting, faeces make up 15 Vol-% and during the process the total reduces down to 40 %.
++according to price calculations from Appendix D: 0,016 [USD/l] and 25,27 [TZS/l] and 0, 68 [USD/kg] and 1.078,43 [TZS/kg] for urine and faeces respectively.
+++assuming the same nutrient content and accordingly the same monetary market value for dried 1,51 [USD/l] and wet mass of faeces respectively 0,76 [USD/l].

Figure C.2: Layout and side view of the sanitary block

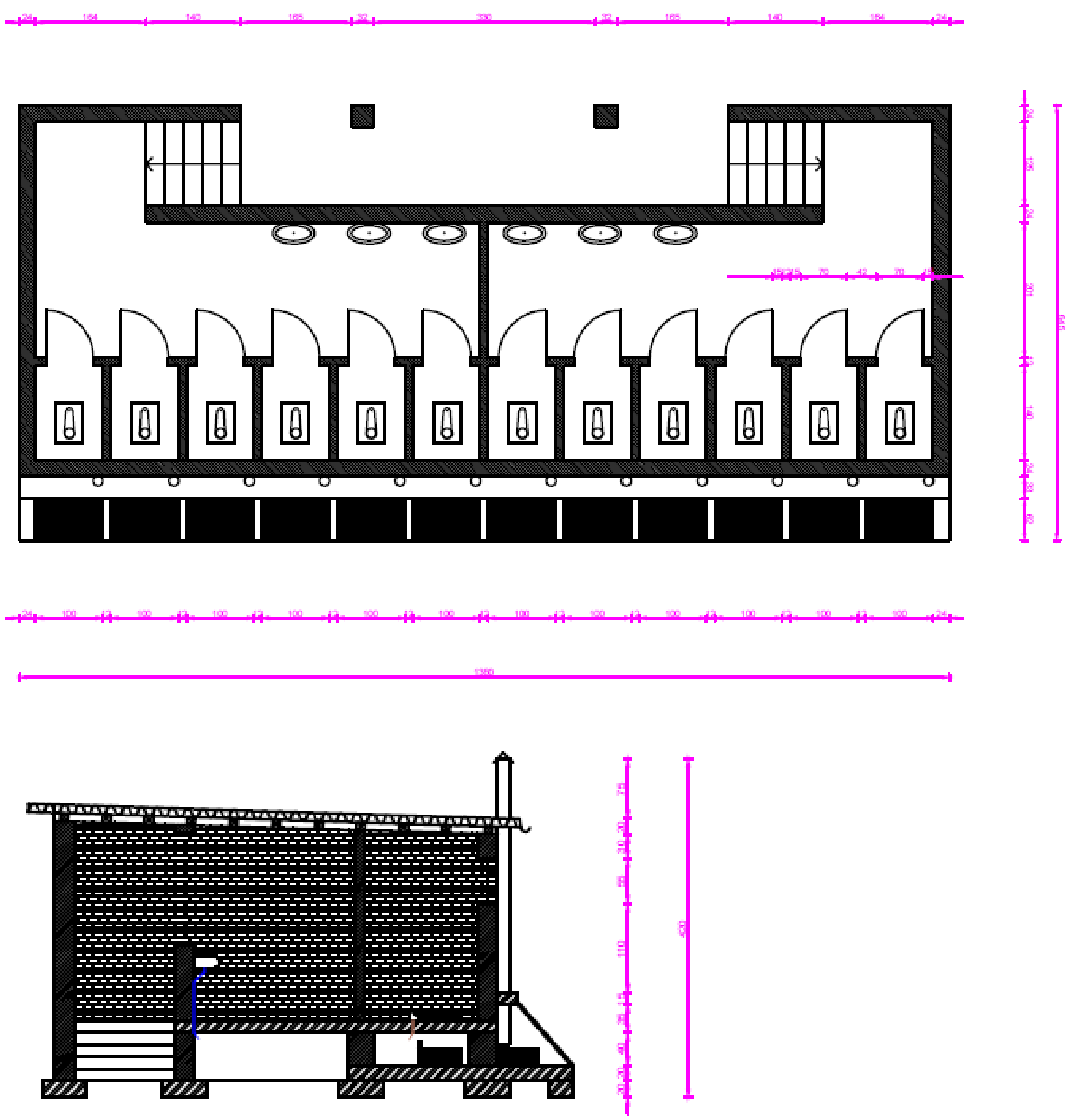


Figure C.3: 3-dimensional view of the sanitary buiding block

Appendix D

Data on the world market prices of fertilizer raw materials and the average nutrient content serve as point of departure for the calculation of prices of the three main nutrients N, P and K as well as the standardized price ratios.

Table D.1: World market prices of fertilizer raw materials

Selected Fertilizer Raw material	USD/mt	(USD/kg) *	Nutrient	Nutrient in %	Price of Nutrient (USD/kg)	Price ratio/N
UREA	333,63	0,33	N	0,46	0,73	1
DAP	434,63	0,43	P2O5	0,46	0,94	1,3027
MOP	316,75	0,32	K2O	0,6	0,53	0,7279

* international average price from Sep 2013 - Apr 2014 (http://www.africafertilizer.org/Data-Centre/Monthly-International-Prices-for-Fertilizers.aspx)

Based on the above price ratios average nutrient costs on the Tanzanian market were determined in Nitrogen equivalents.

Table D.2: Unit cost of nutrients in Nitrogen price equivalents in Tanzania

Chemical fertilizer (N:P:K)	N in %	P in % *	K in % **	Sum of nutrients	Price (USD/kg) ***	Costs in terms of nitrogen equivalents
NPK (17:17:17)	0,17	0,0974	0,0906	0,3581	0,85	2,3611
Urea (46:0:0)	0,46	0	0	0,46	0,77	1,6761
DAP (18:46:0)	0,18	0,2637	0	0,4437	0,92	2,0789
Average cost per N unit						**2,0387**

* P is in NPK available as P2O5 which contains P to 44%

** K is in NPK available as K2O which contains K to 83%

*** local average price from Jun 2013 - Jan 2014 Tanzania (http://www.africafertilizer.org/Platform-Administration/Countries/Tanzania.aspx)

Multiplying the average cost per N unit by the price ratio of raw material for P and K, the nutrient costs were determined.

Table D.3: Average nutrient costs based on the Tanzanian market			
Nutrient	**N**	**P**	**K**
Price (USD/kg)	2,03	2,66	1,48
Price (TZS/kg)*	3.231,82	4.210,21	2.352,41

* Average Official Exchange Rate (May 2013 - May 2014) = 1/1585,23 (USD/TZS) (http://www.oanda.com/lang/de/currency/converter)

The amount of excreted nutrients can be approximated by the nutrient intake since the retention of the proportion of nutrients by the human body is negligible. The amount of nutrients excreted on the other hand depends on the food intake hence any calculation needs to take regional consumption patterns into account. Partitioning the total nutrient excretion between urine and faeces (Table D.4) and making relatively restrictive assumptions about the nutrient composition and daily amount excreted (Table D.5) and linking this with the above information, the value of the fertilizer content in urine and faeces were calculated for Tanzania.

Table D.4: Estimated daily excretion of nutrients per capita in Tanzania, partitioned between urine and faeces			
	N (g/capita/day)	**P (g/capita/day)**	**K (g/capita/day)**
Total *	7,098	1,0912	3,8356
Urine	6,2462	0,7311	3,2603
Feaces	0,8517	0,3601	0,5753
Considering the nutrient loss **			
Urine	0,6059	0,7311	3,2603
Faeces	0,7666	0,3601	0,5753

*formula for estimation of nutrient content of N and P according to Jöhnsson 2004 and data from http://faostat3.fao.org/faostat-gateway/go/to/download/C/CC/E :

N = 0,13 * (total food protein)

P = 0,011 * (total food protein +vegetal food protein)

K is approximated by the Ugandan content due to a lack of suggested formulas found in the literature (1,4 kg/capita/yr)

Total food Protein: 54,6

Vegetal food protein: 44,6

Assuming 12% of N, 1/3 of P (Jönsson, 2004) and 15 % of K (Berger, 2008) of total for faeces and the respective remaining share urine.

** Considers the loss of N through treatment and storage. For simplification, the loss of urine is assumed to be 3 % and of faeces 10 %, P and K are approximated to be zero.

Table D.5: Nutrient content in excreta			
Excreta type	N	P	K
Urine (g/l)*	5,0490	0,6092	2,7169
Faeces (g/kg)**	2,9484	1,3849	2,2129

* assuming 1,2 l/capita/day
** assuming 260 g/capita/day faeces excreted

Table D.6: Assigned market value of nutrients in urine and faeces					
Excreta type	**N**	**P**	**K**	**Total [TZS]**	**Total [USD**]**
Urine (TZS/l)	16,3176	2,5651	6,3912	25,27	0,016
Faeces (TZS/kg)	9,5287	5,8311	1.063,0653	1.078,43	0,68

*The market value of nutrients in human urine adds up to 0,016 USD/l and of human faeces to 0,68 USD/kg.
** Average Official Exchange Rate (May 2013 - May 2014) = 1/1585,23 (USD/TZS) (http://www.oanda.com/lang/de/currency/converter)

Appendix E

Table E.1: Cost Overview					
I Pubic toilet complex					
Investment Costs					
Category /Item	**Unit**	**Quantity**	**Unit Costs [TZS]**	**Total [TZS]**	**Total [USD*]**
Urine Storage / Collection Tank [10.000 l]	number	2	1.852.374,33	3.704.748,66	
Main door and frame (wood)	number	2	80.000,00	160.000,00	
Door of each cabin	number	12	5.000,00	60.000,00	
Chamber doors and frames (metal)	qty	12	35.000,00	420.000,00	
Cement [50 kg]	bags	113	14.000,00	1.582.000,00	
Sand	m^3	11,256	290.697,00	3.272.085,43	
Waterproof additive	kg	54	1.500,00	81.000,00	
Reinforced steel	m^2	140	7.200,00	1.008.000,00	
Clay bricks (20x12x5 cm)	qty	26650	40,00	1.066.000,00	
Infrastructure for toilets (watertank for rainwater collection, connections, tabs for hand-washing)				4.000.000,00	
Faeces pots aluminium with airtight lit [40 l]	pcs	36	16.000,00	576.000,00	
PVC pipes (ventilation)	number	12	20.000,00	240.000,00	
PVC/LPS Pipes 3" (urine)	number [6m]	4	20.000,00	80.000,00	
Corrugated iron sheets 28gauge	qty	21	8.000,00	168.000,00	
Nails [kg]	kg	7,5	4.000,00	30.000,00	
Hinges	pair	2	5.000,00	10.000,00	
Locks for doors, Elbow and T-Connectors, Putty, Wood laquer, Bending wire, PVC Ellbows 3"				52.000,00	
Workers for construction	8 hours/day	7	14.576,00	102.032,00	

Costs per public toilet block				16.611.866,09	10.479,15
Total for 18 public toilet blocks	18			299.013.589,70	188.624,74
Operation and Maintenance Costs					
Category /Item	**Unit**	**Quantity**	**Unit Costs [TZS]**	**Total [TZS]**	**Total [USD*]**
Caretaker's salary (monitoring level urine & load faece, moving loaded faeces pots into solar chamber)	monthly salary	18	600.000,00	10.800.000,00	
Facilities (cleanliness, soap, sawdust)	pcs	18	78.920,00	1.420.560,00	
Toilet paper	pcs	1296	1.000,00	1.296.000,00	
Maintenance and repair				1.495.067,95	
Total				**15.011.627,95**	**9.469,68**

II Treatment plant / Sanitation Area					
Investment Costs					
Category /Item	**Unit**	**Quantity**	**Unit Costs [TZS]**	**Total [TZS]**	**Total [USD*]**
Microgasifier	number	15	700.000,00	10.500.000,00	
Oven (capacity 300 l)	number	15	1.043.461,27	15.651.919,04	
Bricks per oven	number	2613	40,00	104.520,00	
Cement (density: 2000kg/m3)	bags (50kg)	42	14.000,00	588.000,00	
Sand	m^3	0,88	290.697,00	254.941,27	
Aluminium pot [100l]	pcs	3	32.000,00	96.000,00	
Compost Area		1	3.000.000,00	3.000.000,00	
Shredding mashine	number	8	798.000,00	6.384.000,00	
Experts for Construction	8 hours/day	14	24.133,00	337.862,00	
Workers for Construction	8 hours/day	14	20.000,00	280.000,00	
Total				**36.153.781,04**	**22.806,64**

O & M					
Category /Item	**Unit**	**Quantity**	**Unit Costs [TZS]**	**Total [TZS]**	**Total [USD*]**
Caretaker	monthly salary	8	600.000,00	4.800.000,00	
Compost input (46800 l Kitchenwaste+ harvest waste, 1462 l urine , earthworms, 4387l l biochar (600-850 TZS/35kgor105l), 14625 l wooden material)				1.038.691,00	
Microgasifier input (wooden scrap)	Kg (=2,5l)	1.000,00	6,10	6.100,00	
Maintenance and repair				1.807.689,05	
Total				**7.652.480,05**	**4.827,36**

III Transportation Management										
Investment Costs & Operation and Maintenance Costs										
Category /Item	**Unit**	**Qty**	**Unit Costs [TZS]**	**Costs/month [TZS]**	**Cost/trip [TZS]**	**Total [TZS]**	**Total [USD*]**	**Costs/month [USD*]**	**Cost/trip [USD*]**	**Costs/yr [USD*]**
Truck costs (payload 10 tons, 10 yr lifespan, 20 km/h , 4 km/l)		1	14.472.91	120.607,60	120.607,60	1.447.291,20	9.129,85	76,08	76,08	912,98
Truck costs (payload 10 tons, 10 yr lifespan, 20 km/h , 4 km/l)		1	14.472.91	120.607,60	30.151,90	1.447.291,20	9.129,85	76,08	19,02	912,98
Truck Maintenance [10 % of monthly cots]			1.447.291,20	12.060,76	3.015,19	144.729,12	912,98	7,61	1,90	91,30
Fuel consumption [l/km]										
Average Tansanian Diesel prices [TZS/l]*			1.997,39				1,26			

Driver's salary [TZS/hour]			1.82				1,15			
Jerrycans [25l]	Number	400	5.000	16.666,67	16.666,67	200.000	1.261,64657	10,51	10,51	126,16
Urine Transportation Costs at average distance 35 km and 5,75 workhours for all blocks				**3.191.196,37**				**2.013,08**		
Faeces transportation Costs at average distance 100 km and 23 workhours for all blocks				**537.533,69**	**125.007,83**	**537.533,69**		**339,09**	**78,85**	

* Average Official Exchange Rate (May 2013 - May 2014) = 1/1585,23 (USD/TZS) (http://www.oanda.com/lang/de/currency/converter)

**Average from 03-Mar-2014 to 09-Jun-2014 (http://www.globalpetrolprices.com/Tanzania/diesel_prices/)

Table E.1.1:Transportation Costs broken down by Distance				
(a) URINE	TZS	USD	TZS/month	USD*/ month
Value of 10000 l urine [monthly amount per block]	253636,8	160		
Frequency of Trips [1 / month] per block [18 /month] for all 8 block				
Transportation Costs / km				
Distance [km]	Hour			
5	4,25		159.575,26	100,66
10	4,5		162.527,50	102,53
15	4,75		165.479,73	104,39
20	5		168.431,98	106,25
35	5,75		177.288,69	111,83
50	6,5		186.145,40	117,42
100	9		215.667,77	136,05
150	11,5		228.523,48	144,16
175	12,75		259.951,33	163,98

(b) FAECES		TZS/kg	USD* / kg
Value of 250 l dried faeces = nutrient content of wet mass		583.893,05	368,33
Frequnecy of Trips [4 /month] covering all 18 blocks Transport of 250 l of dried faeces per complex on a weekly basis to the treatment and compost area			
Total value [volume of 18 complexes] per trip		10510074,9	6630
Transportation Costs /km			
Distance [km]	Hours		
10	18,5	71.867,56	45,34
20	19	77.772,04	49,06
50	20,5	95.485,46	60,24
100	23	125.007,84	78,86
150	25,5	154.530,21	97,48
200	28	184.052,58	116,10
250	30,5	213.574,95	134,73
500	43	361.186,82	227,85
1000	68	656.410,54	414,08
1500	93	951634,265	600,31

*Average Official Exchange Rate (May 2013 - May 2014) = 1/1.585,23 (USD/TZS)
(http://www.oanda.com/lang/de/currency/converter)

Appendix F

Table F.1: Yearly Investment Costs		
	Total [TZS]	**Total [USD**]**
Investment Costs		
Public Toilet block	299.013.589,70	188.624,74
Transportation / (Equipped Truck)	3.094.582,40	19.521,35
Treatment/Sanitation	36.153.781,04	22.806,65
	338.061.953,10	230.952,73
	Total [TZS]/yr	**Total [USD**]/ yr**
O&M Costs		
Public Toilet block	180.139.535,40	81.754,70
Transportation	44.744.760,77	28.226,04
Treatment/Sanitation	91.829.760,62	44.244,36
	316.714.056,77	154.225,10
Revenue		
from Urine	54.785.548,80	34.560,00
from Compost*	504.483.595,20	318.24,00
	559.269.144,00	352.800,00

*for simplification the value of the feaces only is used to approximate the revenues of compost.
** Average Official Exchange Rate (May 2013 - May 2014) = 1/1.585,23 (USD/TZS) (http://www.oanda.com/lang/de/currency/converter)

Under the assumption of a five years scenario and with steady development, the net present value (NPV) corresponds to the sum of the discounted annual net cash flows and is calculated as follows:

$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+i)^t}$, where n corresponds to the lifetime of the project, i to the discount rate and CF_t to the net cash flow in year t.

The internal rate of return (IRR) corresponds to the discount rate that would yield an NPV of zero. This IRR should then be compared to the to the market interest rate. The nominal interest rate in this case is 11,78 % and reflects the costs at which the project can be financed. Hence, as Table F.1 suggests, the IRR being larger indicates that the future profit is expected to be higher than the costs of financing it and the NPV being larger than zero implies the same conclusion in favor of implementation of the project.

Table F.2: Cash Flow Analysis

Year (t)	Inflation factor*	Investment	Recurrent Costs	Rev / yr	Net CF	Discount factor **	Discounted CF
0	1,00	-338.261.953,09			-338.261.953,09	1,00	-338.261.953,09
1	1,08		-341.734.467,25	603.451.406,38	261.716.939,12	0,89	234.126.532,08
2	1,16		-368.731.490,17	651.124.067,48	282.392.577,31	0,80	225.990.861,08
3	1,26		-397.861.277,89	702.562.868,81	304.701.590,92	0,72	218.137.896,79
4	1,36		-429.292.318,84	758.065.335,45	328.773.016,60	0,64	210.557.815,44
5	1,46		-463.206.412,03	817.952.496,95	354.746.084,92	0,57	203.241.134,59
						NVP	753.792.286,89 TZS (475.509,71 USD***)
						IRR	79%

*(1+infl)^t with infl. = 7,9 % for 2013 (http://www.worldbank.org/en/country/tanzania)
**1/(1+δ)^t with δ being approx. by the nominal interest rate, which is calculated by (1+i) = 1,036*1,079 with 3,6% - the real interest rate for 2012 (http://api.worldbank.org/countries/TZA/indicators/FR.INR.RINR?per_page=1000). →i = 0,117844
*** Average Official Exchange Rate (May 2013 - May 2014) = 1/1.585,23 (USD/TZS) (http://www.oanda.com/lang/de/currency/converter)

The above inferences do also hold for a profitability analysis where a loss of 15 % is included in the value of the end-product, which may occur during the processing.

Table F.3: Cash Flow Analysis incl. 15 % loss in monetary value

Year (t)	Inflation factor*	Investment	Recurrent Costs	Rev / yr	Net CF	Discount factor **	Discounted CF
0,00	1,00	-338.261.953,09			-338.261.953,09	1,00	-338.261.953,09
1,00	1,08		-341.734.467,25	512.933.695,42	171.199.228,17	0,89	153.151.269,91
2,00	1,16		-368.731.490,17	553.455.457,36	184.723.967,19	0,80	147.829.411,11
3,00	1,26		-397.861.277,89	597.178.438,49	199.317.160,60	0,72	142.692.481,77

4,00	1,36		-429.292.318,84	644.355.535,13	215.063.216,29	0,64	137.734.055,76
5,00	1,46		-463.206.412,03	695.259.622,40	232.053.210,37	0,57	132.947.930,27
						NVP	376.093.195,75TZS (237.248,35 USD***)
						IRR	48%

*(1+infl)^t with infl. = 7,9 % for 2013 (http://www.worldbank.org/en/country/tanzania)

**1/(1+ð)ᵗ with ð being approx. by the nominal interest rate, which is calculated by (1+i) = 1,036*1,079 with 3,6% - the real interest rate for 2012 (http://api.worldbank.org/countries/TZA/indicators/FR.INR.RINR?per_page=1000). →i = 0,117844

*** Average Official Exchange Rate (May 2013 - May 2014) = 1/1.585,23 (USD/TZS) (http://www.oanda.com/lang/de/currency/converter)

Referring to the F.2 scenario as starting point, the sensitivity analysis one can examine that a drop in the revenue will generate significant financial effects and hinder profitability, therefore, more emphasize should be put on the demand side through marketing and promotion.

Table F.4: Sensitivity Analysis			
Parameter	**Change**	**Impact on NPV**	**Impact on nominal IRR**
Revenues	10 % decrease	decrease of 57 %	decrease of 41 %
Start up Investments	10 % increase	decrease of 9 %	decrease of 12 %
Transportation Costs	100 % increase	decrease of 54 %	decrease of 39 %