Sao Tome and Principe Innovative Resource Recovery Approach to Sanitation: Lessons Learned and the Way Forward

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Abstract
A sanitation project with societal demonstration purposes and rooted on a resource recovery concept was carried out in Sao Tome and Principe within an integrated water resources management initiative. Therefore, a set of five full-scale bathrooms equipped with composting toilets and urine diversion dehydration toilets were designed and built in the peri-urban area of Neves. The first assessment regarding toilet design, construction costs, technical performance and social acceptance is positive and denoted affordability and effectiveness. Monitoring and proper operation is the next challenge in a learning process and social innovation towards a wider application of ecological sanitation in Sao Tome and Principe.

Keywords
Ecological sanitation; UDDT; dry toilet composting; resource recovery; Sao Tome and Principe.

INTRODUCTION AND OBJECTIVES

Among 2015 United Nations sustainable development goals is the need to ensure clean water and sanitation for all, which is a major challenge for the Democratic Republic of São Tomé and Principe. Indeed, the current situation is clearly unsatisfactory in this African Sub-Saharan island state. The country has 186,300 inhabitants and 41% of family members have individual household sanitation facilities (INE-UNICEF, 2015). The population that has improved sanitation facilities is 35% and open defecation attained a very high value, 54%, being the remaining values sanitation/unimproved sanitation (WHO/UNICEF, 2015). Furthermore, the 2014 Human Development Index (HDI) of São Tome and Príncipe was low, attaining the rank 143/187 (UNDP, 2014). Those figures are a direct consequence of current social and economical constraints. Sao Tome and Principe has 1,001 sq. km only and consists of two islands of volcanic origin, distant 300 km from African west coast. Despite the health conditions progress that was observed in recent years, the country suffers from a narrow GDP at purchaser's price of $337,4 million and $1,470 GNI/per capita (World Bank, 2014). In addition, Sao Tome and Principe faces significant climate change challenges with food production affected by rising temperatures, asymmetric rainfall and coastal erosion threats (UNEP, 2013).

A widespread access to safe and healthy sanitation is a Sao Tome and Principe governmental goal and the water administration is carrying out a strong effort to move forward. In this regard a main problem is Neves, a town with 7,400 inhabitants without any sanitation infrastructure. Neves is the second largest São Tome urban area and the main one of Lembá administrative district, being the focal point of Provaz river basin. Neves has a large peri-urban structure out of a few main streets and in the peri-urban area there is no energy grid or wastewater disposal facilities. A water supply

system is under construction and a collective waste collection system is available, although rather informal. The governmental decided to apply for multilateral organizations in order to gather financial support for an integrated water protection programme for Provaz river basin. The Global Environmental Facility (GEF) and World Bank (WB) decided to support a comprehensive project envisaging an integrated water resources management, whereas the elimination of uncontrolled domestic wastewater discharges is one of the objectives. Although the financial contribution from GEF/WB was just for a demonstration project in Neves urban area and only five individual toilets were targeted, this initiative was an opportunity for a paradigm shift towards ecological and sustainable sanitation processes.

The Ecological sanitation (EcoSan) strategy is a resources-oriented sanitation rooted on a simple, effective, affordable and modern sanitation concept that entails a resource recovery perspective (Langergraber et al, 2004; Werner et al, 2009). Besides the ecological rational, EcoSan decentralised approach is also moved by cost savings when comparing to centralised options (Libralato et al, 2012). In the present case, the topography of Neves territory is flat and trencher excavation for gravity sewers would be very costly. In addition, since energy would not be unavailable for pumping, sewerage system and a centralized wastewater treatment plant would be inappropriate. It should be mentioned that the same reason would concern sea outfall, even if this type of system is considered a pitfall since contaminant dilution is no longer a sustainable option in pollution control policies. Therefore, smart decentralized wastewater systems are the only option that could be envisaged. The urine diversion dehydration toilet (UDDT) was chosen as the basic EcoSan design. UDDT is based on urine diversion from faeces with the purpose of enhancing dry organic matter composting for agriculture purposes, while urine application may be used in local fertigation practices (Chirjiv et al, 2014; Hu et al, 2016). Therefore, natural resources would be recovered and reused (phosphorus, nitrogen and soil amendment material) and energy consumption would be avoided.

After a local assessment and interaction with local community during late 2015, five full-scale bathrooms based on a ecological sanitation model were built in Neves, Sao Tome and Principe, with the support of Directorate of Natural Resources and Energy from the Ministry of Public Works and Natural Resources. Therefore, this communication aimed at presenting the natural context in which involved the dry toilet composting and UDDT concepts, design specifications, costs and the societal perspectives derived from the construction of these new on-site resources recovery facilities.

MATERIAL AND METHODS

Process design and specifications

The EcoSan composting toilet was completely fit-to-purpose designed, based on quality and eco-design principles and aimed at a straightforward use and easy cleaning. Good design plays a critical role in facilitating social learning and is to influence shifts towards sustainable outcomes (Lopes et al, 2012). The bathroom comprises a UDDT toilet, shower, a lavatory, a male urinal. The composting chamber has one cubic meter of nominal volume. Air intake and distribution along the composting bin base is assured by PVC pipes. A ventilation pipe with a fan was installed in order to increase convection flux. Urine is collected in 150 L reservoir, with a dedicated design in order to prevent ammonia emission. Grey waters from shower and hand washing are discharged into an adjacent constructed wetland and infiltrated.

House´s architecture in Neves are based on elevated wood constructions supported by trellises and wood stakes. Therefore, all bathrooms were constructed outside the houses and above ground, with an independent access. The bathrooms have a base level with the composting chamber and in the

second level, the same of the family residence, the bathroom in itself. Two types of bathroom designs were prepared in accordance with the social context. The first scheme was intended to be multi-familiar, meaning that the same family group occupies several near-by houses and all members will use the same bathroom. The second scheme was dedicated to just one family.

Ceramic toilet and composting equipment

Arch-Valadares (Portugal) provided the advanced designed ceramic toilets with an intersect barrier set to separate toilet into front and back drains. After some pilot trials, full-scale pieces were manufactured in a dedicated pottery and curing process. A 3-layered toilet seat wood manufactured was also designed in order to facilitate children use and to minimize faecal cross-contamination. The bathroom has convenient urine ceramic bowl for adults and young man use. Plastidom (Portugal), Domplex^{TM}, tailored PET reservoirs for organic matter composting and separate urine collection, including drainage and ventilation pipes, as well as valves.

RESULTS AND DISCUSSION

Edafo-climatic factors and agriculture production

São Tomé and Principe has a typical wet climate and ferralitic and paraferralitic soils of volcanic origin (MNREE, 2004). Precipitation pattern is very uneven with two distinct seasons, the rainy between September and May and the dry one from June to October. An unbalanced rainfall along the territory intensifies this pattern, with only 1000 mm/year in Neves, an eastern seashore town located in a flat zone with alluvial soils adjacent to basalt steep slopes. In fact, the average monthly rainfall in Neves oscillates between 81 mm in November, down to practically zero during the June-July period and less than 9 mm in August-September. The agricultural sector of São Tomé and Principe is very relevant, 60% of the active population is involved in agriculture practices with a GNP contribution of 23% (2014). In this framework, important products are cacao (92% of exports), coffee, pepper or bananas. Increasing food productivity will demand nutrients and organic matter, but fertilizers are not imported. Thus, nutrients and organic matter are scarce resources in agriculture zones and peri-urban areas of Neves.

Site selection, awareness rising and capacitation

As stated in Ramani et al (2012), toilets are a pro-poor innovation because they empower through imparting ‘social dignity’ which is as important, or even more important, than augmentation of income-generation capabilities and help to change social values at the core. An assessment matrix for site selection was developed and fieldwork was carried out during October 2015 aiming at to select 5 locations out of 10. Technical, social and environmental aspects were briefly identified and prioritised, including a personal interview with all potential end-users. In addition, public workshops and debates with the national and local authorities were held since the project very beginning. The aim was twofold, first to involve local entrepreneurs and sanitation professionals from Neves and second to promote the new system among the population that was chosen to receive the toilets. In order to foster societal acceptance, communication involved religious leaders also. Accepting the fact that this bottom-up approach is mandatory for public acceptance of composting toilets, the time period was rather short for involvement and empowerment (Luthi et al, 2011). However, during the construction phase (45 days) the interaction with the local community was reinforced.

Concept, design specifications, construction aspects and costs

Sustainable sanitation concept is rooted on the concept of decentralised and small low energy systems with favourable life cycle analysis (Vera *et al*., 2009; Machado *et al*., 2007). Several low energy options were pre-assessed, among them constructed wetlands, ponds, septic tanks or pit

latrines. However, because the ambition was to design useful resource recovery facilities for Neves population, UDDT systems were preferred. **Figure 1** presents some pictures of main UDDT components and **Figure 2** shows selected photos of demonstration EcoSan bathrooms and toilets that are now in full operation in Neves.

Figure 1. Main features of UDDT systems: (from left to right) air admission into composting chamber; ceramic toilet and layered toilet seat; urine reservoir and composting box

Figure 2. ECOSAN bathrooms installed in Neves

Toilet construction costs

Bathroom construction costs included foundations and retaining structures, walls and roofs, composting bins and ceramic toilets, among other materials and ancillary equipment. The final costing data indicate that EcoSan bathrooms built end-to-end to the existing houses had a cost, in average, of 3,091 €/unit. In the case of an adjacent/isolated EcoSan that serve more than one family, the average cost was 3,477 €/unit. The ceramic material (UDDT toilet, male urinal and lavatory) represented less than 10% of total costs. These values are very favorable comparing with commercial composting toilets (Chirjiv et al, 2014; Hu et al., 2016). This achievement was the result of an appropriate design, although supplier companies provided affordable budgets for their deliveries. In average, the sum of all construction material required to build one bathroom amounted to 2,792 € and the working labor cost was 685 €/unit.

Considering per capita costs, an end-to-end bathrooms was 515 €/user (considering they serve a single family with less than 7 persons) and the ones designed for more than one family amounted to 316 €/user (considering more than 10 persons). External trade-offs related to resource recovery could add value to composting toilets and UDDT systems, namely considering the fertilizer value of urine, which was estimated in a research study carried out in Burkina Faso as 0.01 €/L (Richerd et al, 2010; Nogueira *et al.*, 2007).

Guidelines for process operation and maintenance

The government have a crucial key role in the EcoSan project success. Therefore, guidelines for toilet routine maintenance and inspection were prepared and delivered to project authorities. Instructions were also given to end-users. Regarding the composting unit, a digital thermometer and

a mechanical instrument for mixing was comprised in the delivery because these are the most important process parameters. In addition, it was recommended that all composting bins should be replaced when they are full (probably every six-months or similar) and a confined open space should be prepared in order to receive the organic material for further processing, thus allowing one year composting before soil application, as prescribed by WHO. Regarding fertigation process and just because this is the starting phase, it was advised that urine should be incorporated into the soil and applied in non-food crops. Local farmers could be involved in these projects in order to provide knowledge on nutrient crop requirements but an application of approximately 1.5 litres of urine/m^2 (corresponding to 40-110 kg N/ha) 3-4 times a year was suggested. In spite of such rule of thumb, official agriculture services or an ONG should provide consultancy and training (Richert et al, 2010). Finally, the toilet cleaning process was explained to all families and to use as less water as possible in order to prevent the compost of becoming too wet was suggested. In case of water spills into the composting bin, shredded wood wastes should be added (they are easily accessible in Neves region).

Moving from composting technology to social innovation

Composting toilets and UDDT systems are much more than a technology. In Sao Tome and Principe, as in many other countries, the public investment in sanitation coverage is low (as mentioned before, 52% of the population practice open defecation), mostly because local population does not perceive this as a social problem or health hazard. Therefore, an integrated strategic perspective on sanitation involving all stakeholders is required if the aim is to move forward. A SWOT analysis based on Neves experience is presented in **Table 1**.

Table 1. The EcoSan project in Neves: a SWOT analysis

Strengths	**Weaknesses**
• The project address a societal need and population directly involved welcome it; • Public administration and end users involved in site selection and toilet construction; • Users were proud of having a toilet and to end open defecation; • Health hazards mitigation;	• Isolated action without a comprehensive sanitation project in Neves already available; • New bathroom construction and service expansion needs funding that is not available locally; • Some construction materials were not of the best quality; • No skilled experience in civil construction or plumbing works.
Opportunities	**Threats**
• Job creation and small private companies may provide services to new users; • The demonstration project may foster the design and implementation of an integrated sanitation plan with social and economical outputs in Neves, as well as in Sao Tome and Principe.	• No political or social encouragement to adopt new sanitation practices; • Ex-post analysis, training and monitoring was not included in Neves composting toilet project (and users have no previous experience); • There is no integrated management programme foreseen for the compost collection and fertigation practices in Neves.

Therefore, if the governmental aim is to cover Neves with an appropriate sanitation infrastructure and to take the process off the ground, dedicated resources and time are mandatory. Probably, the first step is about creating a shared understanding of the health problem and to inspire a need for

change. However, as shown in Benin and the Philippines, the most desired qualities of a sanitation facility (in comparison to no sanitation at all) is related to the status issue, which appears to be a important component, as well as the issue of social relations. Avoiding contact and smell and ensuring safety also were high priorities (Cairncross, 2004, cited in Rosenquist, 2005). Indeed, population perceives a toilet building as a home improvement, not as a health intervention. This is exactly the critical issue if Neves experience is to succeed. Therefore, the importance of local leadership should not be neglected: from local municipality, religious leaders, school professors and medicine services, all will be important to empower man and woman adults and youngsters to the new sanitation approach.

International records always show that a monitoring programme after construction is necessary in new sanitation models and a psychological or social change is necessary (Ramani et al, 2012; Rosenquist, 2015). Going beyond the standard model of delivery and to move to a sustained use in the post-construction period is needed. In the case of Neves, the reason is far more evident, because there is any local experience available. If there are maintenance problems and if the users cannot approach anyone to correct them, the toilets will fall into disuse. In addition, the monitoring will avoid that bathrooms could be diverted to other uses, as this tendency is common in many situations. Unfortunately, these contexts are not guaranteed in Neves yet, but efforts to gather additional international support are believed to occur. Furthermore, a management model for a full-scale operation of composting and urine collection and application should be in place in order to guarantee a safe and regular operation and control. These would be key points for the success and enlargement of this innovative initiative to other peri-urban and rural areas in São Tome and Principe.

CONCLUSIONS

Ecological and sustainable sanitation is a modern and viable approach, which is paving the way towards a more rational and holistic sanitation. The first full-scale sustainable sanitation based on a resource recovery concept was designed and is now in operation in Sao Tome and Principe. Affordable bathrooms based on composting and urine diversion dehydration toilets were successfully designed and serve a peri-urban area of Neves. The project displayed the environmental value, the economical asset and the social acceptance of this innovative sanitation approach. Monitoring and proper operation is the next challenge in order to guarantee success, not failure.

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