PAPER 4

NEXT GENERATION SANITATION TECHNOLOGIES, A SOLUTION FOR INFORMAL SETTLEMENTS

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ABSTRACT

The South African government has been focusing on eliminating service delivery backlogs since 1994, mostly through the employment of conventional solutions. However, indigent communities remain marginalized because most conventional solutions are not easy to implement due to the settlement topography and density. Furthermore, rapid urbanization means municipalities and water service agencies, who are responsible for service delivery are always playing catch-up.

Municipalities continually face challenges in meeting the costs and logistics of delivering free basic sanitation services, as informal settlements, which, by definition, are expected to be transient with no long-term CAPEX investment. As such only temporary or ad-hoc solutions such as chemical toilets and other container-based sanitation solutions are provided, which are expensive, unsustainable, potentially have adverse effect on the environment and have poor user acceptance. A shift in the current paradigm is long overdue if the SDG target for 2030 is to be achieved.

In South Africa, approximately 13% (7.27 million) of the population live in informal settlements (Danti, 2018). According to StatsSA, 68% of households living in informal dwellings are forced to share toilet facilities and approximately 6.8% rely on the 'bucket system', which speaks to the scale of the problem. The emergence of next generation sanitation (NGS) technologies such as non-sewered sanitation systems (NSSS) and other innovative sanitation offers a viable solution to meeting current sanitation challenges including in informal settlements.

This paper uses case studies where NSSS were successfully implemented in informal settlements in South Africa and provides lessons for governments and development agencies to prioritize the implementation of non-sewered sanitation systems in informal settlements to improve public health and hygiene in these communities.

Keywords: next generation, sanitation, informal settlement

INTRODUCTION

The South African government has made efforts to address service delivery backlogs and improve access to basic services since the advent of democracy in 1994. However, the implementation of conventional solutions has faced challenges in meeting the needs of marginalized communities, particularly those living in indigent areas. The topography and density of settlements in these communities often make it difficult to deploy traditional service delivery approaches. As a result, many indigent communities continue to face inadequate access to essential services.

According to a report by the United Nations Human Settlements Programme (UN-Habitat), rapid urbanization poses significant challenges for municipalities and water service agencies in delivering basic sanitation services. The report highlights that municipalities are often overwhelmed by the increasing demands resulting from rapid urbanization. The costs and logistical difficulties associated with providing free basic sanitation services become particularly pronounced in informal settlements, which are expected to be temporary and lack long-term capital expenditure (CAPEX) investments. Consequently, temporary, or ad-hoc solutions such as chemical toilets and container-based sanitation systems are commonly deployed. These solutions, while providing immediate relief, come with various drawbacks. They are expensive to maintain, lack sustainability in the long term, potentially harm the environment due to inadequate waste treatment, and often face poor acceptance by users due to limited functionality and hygiene concerns (UN-Habitat, 2020).

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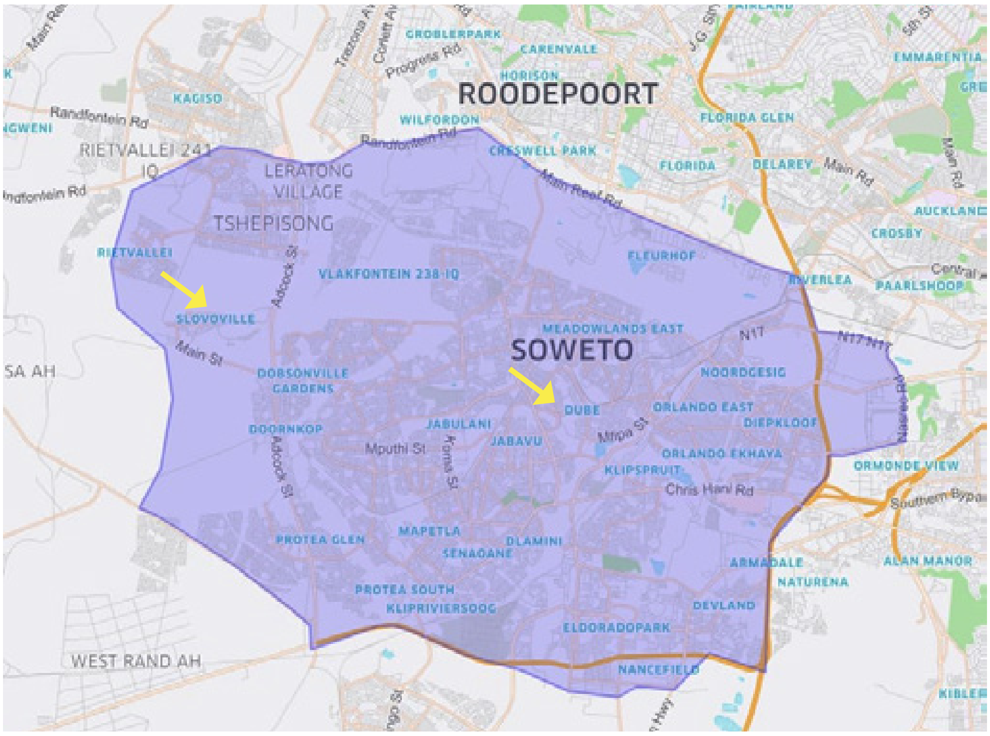

FIGURE 1: *Location of the informal settlements*

TABLE 1: *Key demographics within the selected sites*

Name	WSA/WSP	Population (households)	Average hh size
Slovoville	Johannesburg water	25	4
Mofolo North	Johannesburg water	75	4

and approximately 6.8% rely on the 'bucket system', which speaks to the scale of the problem. The emergence of next generation sanitation (NGS) technologies such as non-sewered sanitation systems (NSSS) and other innovative sanitation offers a viable solution to meeting current sanitation challenges including in informal settlements.

A study conducted by Smit and Pieterse (2019) explored the complexities of service delivery in South Africa, highlighting the limitations of conventional approaches in effectively reaching marginalized communities.

The research highlights the importance of context-specific interventions that account for the unique settlement characteristics and challenges faced by indigent communities. Additionally, a report by the Development Bank of Southern Africa (DBSA) (2020) acknowledges the need for innovative and adaptive approaches in overcoming service delivery challenges, particularly in areas with complex settlement patterns and limited resources.

Site Selection

This study is part of the Water Research Commission's South African Sanitation Technology Enterprise Programme (SASTEP), whose aim is to fast track the adoption of NGS technologies capable of addressing sanitation challenges. The programme prioritizes the demonstration of appropriate technologies to ensure their appropriateness within local context and works with capable local commercial partners to early adopters such as municipalities and water service providers to ensure uptake and adoption of these innovative solutions.

SASTEP is funded by the Bill and Melinda Gates Foundation (BMGF) and the Department of Science and Innovation (DSI) and, has partnered with Johannesburg Water to demonstrate two (2) NSSS technologies at informal settlement sites that are not currently serviced by the city's sewer reticulation system. Two informal settlements (Mofolo North and Timehouse in Slovoville) were selected by Johannesburg water.

The location of the sites is indicated on figure 1. Both sites were depending on the chemical toilets for their sanitation needs.

Summary of site demographics

The sites are characterized by high rates of unemployment and poverty. Table 1 summarizes key demographics of each site.

RESEARCH OBJECTIVES

The primary aim of the demonstration projects is to evaluate the technical performance and the community acceptance of the innovative sanitation technologies, NEWgenerator technology and Clear recirculating toilet in South African informal settlements which are currently not serviced by formal sanitation reticulation systems.

Objectives of the demonstration projects are:

- To evaluate the technology performance
- To assess social/user acceptability of the systems
- To use the experience gained from the demonstration projects to assess the technologies for local manufacturing.

APPROACH AND METHODOLOGY

Stakeholder Engagements

Widespread consultations were conducted with the active role players ranging from community leadership (political), community representatives, water service provider (JW), local NGOs and forums. The municipality served as an entry point to the community due to its role of a Water Service Provider (WSP) and the project sites fall within its jurisdiction.

Field testing

The technologies were field tested from November 2021 to date to obtain data on functionality and performance of the technologies. Field testing is a research method that entails carrying out tests or collecting data in real-world settings, outside of laboratory circumstances. It enables researchers to observe and study occurrences in natural or applied settings, providing insights into the practicability and efficacy of interventions or hypotheses (Yin,2017).

System design and configuration

Both systems consist of a community toilet block, the treatment systems, ancillary water and sewage storage tanks, a mechanical screen in the case of new generator, and interconnecting pipework.

User Surveys

User surveys was conducted to measure the satisfaction of the users with the technologies and get insights about the technologies. According to Sheffield & McClanahan (2017) user surveys are critical for getting important feedback and insights from people who interact directly with products, services, or experiences. These surveys enable researchers and businesses to better understand user preferences, needs, and levels of satisfaction. User surveys provide numerous important advantages in terms of informing decision-making and encouraging improvements.

Sample collection and analysis

Monthly samples of the raw water and product water from the clear system and new generator system are taken and submitted to an accredited laboratory for analyses.

RESULTS AND DISCUSSION

Two informal settlements were provided with NGS technologies to demonstrate and evaluate their technical performance and the user acceptance of the innovative sanitation technologies.

Mofolo North – Clear Recirculating Toilet System

The Clear Recirculating Toilet System, installed at the Mofolo North informal settlement, The Clear toilet uses a full water recycling process for treatment of the sewage. An advanced unique "Biofilm MBR" treatment process is employed as the core technology for treatment, producing a stable and clean effluent that is further disinfected through ozone to ensure safety of the effluent for reuse. The system is modular and can be moved should the need arise.

The installation at Mofolo North informal settlement service 75 households. The community was trained on the safe use of system as well as the benefits.

User acceptance in Mofolo North

A total of 26 respondents were interviewed (10 males, 13 females and 3 janitors). The survey was conducted in December 2021. The users have indicated their satisfaction with the system and have agreed that the Clear system is an upgrade from the chemical toilets that they were using.

There is also community ownership of the system, where cleaners and security are from the area, and they all assist each other to look after the system.

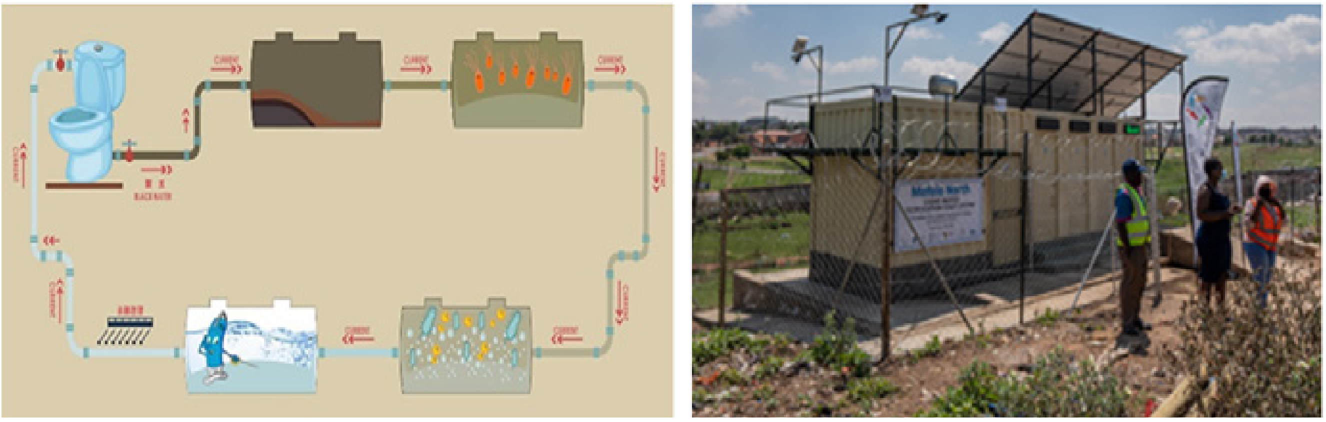

FIGURE 2: *Clear recirculating system process (Left) and demonstration (Right)*

Operation and maintenance of the Clear system

The system does not require constant water supply. Only the first fill water needs to be secured for the startup of the system, thereafter it continues to treat and recycle with no need for top up. This water can be secured from a potable water supply line, rainwater harvesting tanks or nearby springs or rivers or even stormwater drains. The water for handwashing needs to be provided via municipal supply line, borehole, or rainwater tanks. To run optimally, the system needs minor maintenance, which entails cleaning the membrane every 6 to 8 months and desludging (major service) is required every 18 months. Effluent quality results for the Clear Recirculating Toilets are presented in Table 2.

According to the results some parameters tested are within specification and comply with the DWS general discharge limits. Nitrate has a high reduction removal rate (>90%), and total phosphate has a reduction removal rate between 0% and 69%. Pathogen removal is in accordance with SANS limits and observed to be above the required limits. COD, TSS, pH and *E coli* complied with the performance requirements of SANS 30500. The salinity of the water and electrical conductivity are elevated due to accumulation of salts.

Slovoville – NewGenerator

The NEWgenerator, installed at Time-house Informal Settlement, Soweto is a compact, portable, and modular resource recovery machine that eliminates waste while recovering fertilizer nutrients, renewable energy, and clean water. The system uses an anaerobic baffled reactor design followed by a nanomembrane filter operated at subcritical water flux to extend the longevity of the membrane. Permeate from the filter is treated by electrochemical chlorine production from table salt for toilet flushing. The unit is equipped with solar panels to generate sustainable energy for the operation of the NEWgenerator system. The system services 25 households.

User acceptance in Slovoville

The first survey was conducted after commissioning in November 2021 and the second survey was conducted in August 2022, the surveys were conducted to assess the community's satisfaction with the use of the toilet block. The first survey had 40 participants and the second survey had 39 participants. The surveys were conducted to identify any areas where improvements could be made and to assess the satisfaction of the users with the new toilets. The survey's results showed that the community is pleased with the NEWgenerator system and that the toilets are still preferred to the previous chemical toilets. The NEWgenerator system is a significant improvement over the previous chemical toilets and is providing a much-needed service to the community.

Operation and maintenance of the NEWgenerator

The NEWgenerator also require water for startup and then it recycles the water for flushing. The system is Off Grid and Modular Design which can be moved easily. There is also remote monitoring & operation. The screen must be cleaned twice daily and major maintenance (desludging) is required every 12-18 months. Effluent quality results for the NEWgenerator Toilets are presented in Table 3.

According to the results all parameters examined are within specification and comply with the DWS general discharge limits. Total nitrogen has a high reduction rate (>95%), but total phosphate has a reduction removal rate ranging between 0% and 69%. This is because the NEWgenerator system was not designed for phosphorus removal, which can be linked to the system's

TABLE 2: *Effluent quality result raw vs product vs DWS limits*

Parameters	DWS Limits General	Special	Units of measure	Raw	Product
pH				4,3	6,8
Electrical conductivity	70 - 150mS/m	50 - 100 mS/m	mS/m	285	208
Salinity			mg/l	1909,5	1313
Total dissolved solids			mg/l	1270	830
TSS [Total Suspended solids]	25	10	mg/l	99	4,7
Colour			Pt-Co	19	10
Turbidity			NTU	14	2,8
COD [Chemical Oxygen Demand]	75*	30*	mg/l	88	60
Dissolved oxygen			mg/l	8,5	8,4
Nitrates as NO3	15	1,5	mg/l	73	6,9
Phosphate as P Ortho			mg/l	0,3	<0.1
Saline Ammonia as N free	3	2	mg/l	78	191
E. coli	1000	0	MPN per100ml	820	<1

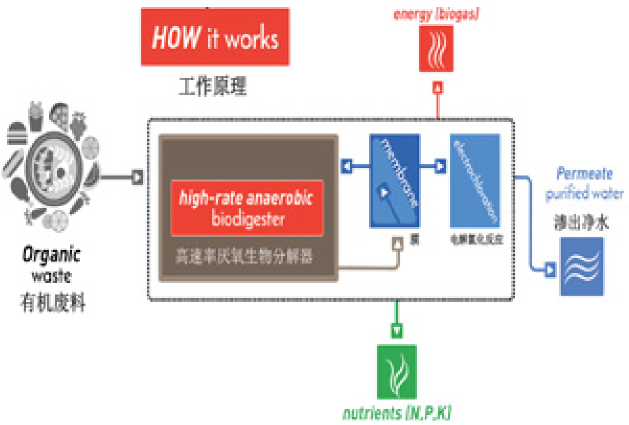

FIGURE 3: *NEWgenerator system process (Left) and Slovoville demonstration (Right)*

low phosphorus reduction. The phosphorus removal performance was improved by treating the zeolite bed with calcium chloride. Pathogen removal in accordance with SANS limits is observed to be above the required limits. COD, TSS, TN, pH and *E coli* complied with the performance requirements of SANS 30500.

LESSONS LEARNT FROM THE DEMONSTRATIONS

1. Stakeholder engagements are key to ensure understanding and ownership.

2. Access to electricity

- The next generation sanitation technologies are being designed to try and reduce energy needs and these systems can be installed with solar panels but there are more sustainable options explored.
- Risk of vandalism or theft and hence, for the demo itself security is provided but this remains a massive collective burden for South Africa. Thorough community engagements is required for the community to be

3. Access to water

- Only the first fill water needs to be secured for the startup of the system, thereafter it continues to treat and recycle with no need for top up. This water can be secured from a potable water supply line, rainwater harvesting tanks or nearby springs or rivers or even stormwater drains.
- Water for handwashing will need to be provided via municipal supply line, borehole, or rainwater tanks.

4. Cleaning and Upkeep of toilets

- Janitorial services are a requirement for the upkeep of the systems, training on hygiene and use of the toilets was done but there is no guarantee of ownership and proper use.
- Hence, constant engagement has shown some benefits but it's challenging as it is linked to practice, behaviours, and values.

5. Operations and Maintenance

- Ideally a contract /SLA needs to be put in place to operate and maintain the whole system (inclusive of any energy supply system).
- The current suppliers of these NSSS technologies are being asked to look at innovative models to ensure O&M can be done correctly.
- At a sector level we are trying to encourage certification of O&M companies to ensure quality of service.

6. Social Engagement

- Expectations need to be understood at start of project demo.
- During a testing and O&M phase it is useful to continue to collect social data on use, smell, cleanliness, and acceptance of the technology.

CONCLUSION

It is concluded that the water treated by the NEWgenerator system meets the DWS general discharge standard limits and is safe for re-use in the multi-use toilet block and for irrigation purposes. The nutrient rich liquid fertiliser will be used to water the new community garden, The results indicate that the NEWgenerator system is performing as anticipated. The *E coli* and faecal coliforms also indicate that the water is free from any disease-causing bacteria. The effluent treated with Clear recirculating toilet is also free from disease causing bacteria, therefore safe to re-use, however, the water has elevated salinity.

From the user acceptance surveys conducted, both communities are pleased with the next generation sanitation technologies and that the new toilets are still preferred to the previous chemical toilets they used.

TABLE 3: *Effluent quality results for the NEWgenerator*

Parameters	DWS Limits		Units of measure	NewGen Slovoville	
	General	*Special*		***Raw***	***Product***
Faecal coliforms	1000	0	MPN per100ml	>100000	<1
COD	75*	30*	mg/l	418	44
Free and saline Ammonia as N	3	2	mg/l	10	<0.1
Nitrate as N	15	1,5	mg/l	<0.1	14
Free chlorine	0,25	0	mg/l	0	<0.1
TSS	25	10	mg/l	154	1,3
Electrical conductivity	70 - 150mS/m	50 - 100 mS/m	mS/m	45,3	52
Total phosphorus	10	1 (Median) and 2.5(maximum)	mg/l	4,8	3,4
E-coli	1000	0	MPN/100ml	>100000	<1
Turbidity			NTU	100	0,6
Colour			Pt-Co	180	60
BOD			mg/l	<10	<10
TKN			mg/l	36	2,8

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