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ENDING THE MADNESS... OF THE FLUSH

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ABSTRACT

The toilet-wastewater-energy-pollution nexus is an emerging issue in the developed and developing world. The provision of safe, hygienic and appropriate sanitation solutions is a priority development in the world. Developed nations have followed a linear design approach to achieve to meet their sanitation needs with conventional waterborne systems implemented and continuously improved to meet more stringent control and pollution regulations in order to minimise the overloading of the natural environment.

Developing countries on the other hand continue to struggle to implement such systems, due to a myriad of factors associated with financing, affordability and revenue and thus resulted with a heavy reliance on on-site systems. On-site system poses a different set of technical challenges related to their management which is often overlooked in the developing world. Whereas, while technology strides increase in conventional sanitation processes towards zero effluent these all come at a significant cost and energy requirement. Further, climate variability and water security put on added pressure on resources available for flushing and transporting human wastes.

A new paradigm for sanitation which is proposed in this paper introduces and is based on technology disrupters which can safely treat human excreta and matches user preferences without the need for sewers, and reliance for external water and energy supply. Through innovation and smart chain supply, universal access can be achieved sustainably and linked to water security and business opportunities.

The opportunity opens up for leapfrogging these solutions in growing urban cities of the developing world, reducing water consumption and eliminating pollutant pathways.

Keywords

Faecal sludge management (FSM), off-grid sanitation, toilets, technology, disruption, IPAP

INTRODUCTION

With the conclusion of the Millennium Development Goals (MDGs), the United Nations (UN) reported that Goal 7, Target 10, which was to halve the world population which did not have basic sanitation by 2015, was achieved with 2. 1 billion gaining access to improved sanitation(http://www. un. org/millenniumgoals/environ. shtml). While this is a significant achievement, there is a growing concern in the sanitation sector with regards to the acceleration and the sustainability of the solutions provided. Conventional waterborne systems connected to centralised systems are usually the preferred treatment choice. These systems are associated with flushing toilets and are usually viewed as the gold standard among users. On the other side of the technological scale are on-site sanitation systems.

These less popular are among users but it remains the most prevalent technology choice in the developing world. Water is a critical design consideration of both these technological approaches and can influence the design approach used.

In the developing world, on-site sanitation approaches are often viewed as a stop-gap solution until conventional waterborne systems can be implemented. The challenge for developing countries is that they need to match the pace of increasing urbanisation and population growth under increasing water scarcity, and constrained financial and technical resources. Urbanisation is occurring at a rapid rate in developing countries and the dilemma that they are faced with is whether they will ever reach universal sanitation coverage via conventional systems, while also managing increasing water, energy and pollution demands. In this paper, a new paradigm in presented to current sanitation approaches; one which that moves away from the current linear design approaches - capturing, transporting, collecting, treating, and disposing human excreta – to a holistic model that shortens the management chain through innovative hardware which treats at point of generation and off the grid human wastes, as well in the processconsiders resource recovery. Through the introduction of innovative technology, it envisaged that new business opportunities will be created that could be aligned to management of the toilets to ensure that services are sustainable.

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On-site system pose a different set of technical challenges related to their management which is often overlooked in the developing world. Whereas, while technology strides increase in conventional sanitation processes towards zero effluent these all come at a significant cost and energy requirement. Further, climate variability and water security put on added pressure on resources available for flushing and transporting human wastes. A new paradigm for sanitation which is proposed in this paper introduces and is based on technology disrupters which can safely treat human excreta and matches user preferences without the need for sewers, and reliance for external water and energy supply.

Through innovation and smart chain supply, universal access can be achieved sustainably and linked to water security and business opportunities. The opportunity opens up for leapfrogging these solutions in growing urban cities of the developing world, reducing water consumption and eliminating pollutant pathways.

THE CENTRALISED APPROACH

Since the last century, the centralised approach has been the conventional wastewater management strategy applied. Itis typified by a network of sewers linked to communities and which transport large volumes of wastewater to a collection, treatment and disposal point. Historically, the roots of this approach can be traced back to the outbreak of waterborne diseases, especially Cholera, on the European

continent. Once scientific evidence linking the outbreak of waterborne diseases to poor sanitation became clearer, there was an increased motivation to transport household human excreta away from ever-expanding urban populations. Water is an essential component of this approach in order to transport human excreta from point to the next. While this strategy led to the significant reduction of the outbreak of waterborne disease outbreak in Europe (evidence cited in Lofrano and Brown, 2010), is it wasteful as considerable amounts of limited and potentially potable water is contaminated with human excreta and other pollutants for the sole purpose of transporting pollutants from one catchment to the next.

In developed world, the centralised approach underwent continuously improvement from basic treatment and dilution strategies to protect public health towards more efficient systems to meet ever-increasing environmental protection and control standards (Lofrano and Brown, 2010). Today, the centralised approach can be considered as the *de facto* sanitation approach, especially for urban areas, worldwide.

While developed countries have continuously improved conventional wastewater based strategies to become more reliable and efficient as time progressed, developed countries have struggled to be implement this technology successfully. There are number of reasons for this.

There is a significant unserved population in developing countries and the infrastructure provision has to address these backlogs and in urban areas, also keep pace with the rapid population growth and urbanisation. Developing countries need significant investment for centralised sewerage infrastructure (Lettinga et al., 2001). Several technical requirements need to be met: excavations are needed for laying pipes, there has to be reliable water infrastructure and supply to complement the conveyance system, and energy-intensive pumps and treatment systemsare needed to move and treat wastewater. Hauf and Lens (2001) indicated that the financial investment required for such systems may beyond the reach for most developing countries. Even in developed countries, these systems are directly cross-subsidised to enable them being financially sustainable (Hauff and Lens, 2001).

Connection to a sewer system can be costly; a generalised estimate put forward by the WHO/UNICEF (2000) indicated that cost per personconnecting to the sewer network is 5 to 50% higher than on-site alternatives. Further, the capital cost of treatment option can be nearly double to that of a septic tank (based on community of 10,000 people and in comparison with activated sludge process - http://water.worldbank. org/shw-resource-guide/infrastructure/costing-sanitation-technologies/estimate-capital-costs). Cost can be major driver for the technical approach used. Von Sperling (1996) hypothesised that the four main aspects considered by developing countries in the selection of a wastewater treatment were infrastructure costs, sustainability, operational costs and simplicity. Conversely, the developed countries perceived efficiency, reliability, sludge disposal and land requirement as the major drivers for technology selection.

Besides the infrastructure investment, a suite of other resources, such as water, energy, and high-level designers, technicians and operators, are required to properly manage wastewater plants and their auxiliary equipment. The lack of these resources can result in infrastructure deterioration and / or unreliable services (evidence cited in: Eales, 2008; Hawkins et al. , 2013; UN-Water, 2015). Eales (2008) noted that in South Africa, only a small percentage of plants were operated and maintained adequately with there being a critical shortage of skilled staff to operate and maintain the treatment works. Josiane et al. (2013) reported similar themes with the expected treatment performance rarely achieved in the African countries analysed. In that study, a common challenge reported was that inability of the treatment works to deal with increasing pollution loads. Other issues included unstable energy supply, poor operation and maintenance and the lack of investment in current infrastructure. The technical requirements needed for conventional waterborne systems is challenging, not only in the developing (Hawkins et al. , 2013) but also the developed one (Tsagarikis et al. , 2001; European Commission, 2004).

Conventional systems continue to put pressure on scarce water resources, require high energy inputs and continuously pose a threat to the environment. It is clear that the application of the centralised waterborne approach in the developing world has not reached the desired impact as it has done in the developed one. As a consequence, the developing world still has a heavy reliance on on-site sanitation approaches.

EXPLAINING THE MADNESS

Based on the more than 200 years old concept of sanitation, in the form of flush and forget, raises this quagmire of the MADNESS. Let us look at the numbers of this madness:

- A human being produces on average between 150g to 250g of faecal matter per day. (Strande et al, 2017)
- He/she uses between 6 to 13 litres to move this away from his toilet to the sewer.
- In addition we need another 200 – 300l of grey and brown water (water from baths, dishwashing, etc.), to now transport this 150g to 200g, many kilometres to a treatment plant. (Neil Macloed communication)
- We then use large quantities of electricity and chemical to treat this faecal matter, with the end point producing an effluent of compliance (but yet a pollutant).

The above is the madness, so much energy, water and pollution just to treat and manage 150 g to 200 g of human waste. This is the face of several emerging constraints such as climate change, water scarcity, rising energy costs, rising chemical costs, emerging contaminants and a paradigm which is financially become prohibitive in developing countries, as well as developed countries.

It's time to end this madness, if we wish to secure a water future for generations to come. Going off the grid (OTG) or Non-sewered sanitation (NSS) offers several benefits, in the immediate form that it can result in a direct benefit of some 40% of fresh or treated water available to the system. Further, it can also eliminate the pollution threat and consequences which wastewater poses, as well as the need to all the infrastructure requirements (pipes, pumps and plants).

NSS offers this hope and opportunity, and can become one of the biggest contributors to water security into the future. This has to come on the back of new, radical and innovative sanitation technology which disrupts the current norms and standards.

And there is 2. 4 billion people and more who are off the grid waiting for such solutions, rather than be dependent on a future designed with the same problems.

SANITATION GRAND CHALLENGE

In his response to world challenges, Bill Gates recognised the need to shift the sanitation technology agenda. In 2011, the Bill and Melinda Gates Foundation's Water, Sanitation & Hygiene programme initiated the *Reinvent the Toilet Challenge* (RTTC) to address the limitations of current sanitation approaches highlighted earlier.

The Foundation set itself the ambitious goal to develop the next generation of toilet system in a 5year period. To achieve this target, grants were initially awarded to sixteen research teamsfrom around the world to develop innovative toilet technologies - based on fundamental engineering processes - for the safe and sustainable management of human excreta. The technical requirements set by the Foundation was that the sanitation system had to fulfil the following: 1) protect public and environmental health, 2) recover valuable resources such as energy, water and nutrients, 3) operates *off the grid* without connections to water, sewer, or electrical lines, 4) cost less than US$0. 05 cents per user per day, 5) promotes economic sustainability, and 6) is an aspirational product that will attract both developing and developed country contexts.

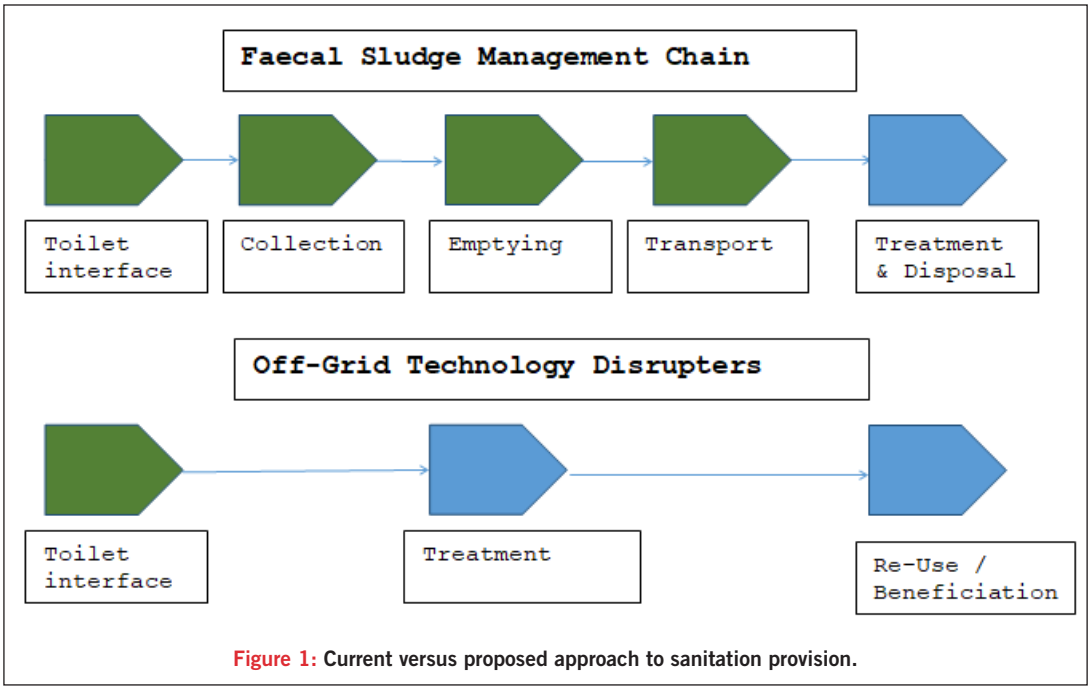

Figure 1: Current versus proposed approach to sanitation provision.

The number of research teams involved in this initiative has expanded since 2011 with a number of technological advancement made with respect to sanitation treatment process. The innovative, off-grid sanitation prototypes developed through the Foundation's initiative focussed primarily on mechanical, physical, heating, and chemical treatment processes, such as liquid/solid separation, hydrothermal carbonisation, combustion and electrochemical treatment, in order to treat human excreta almost immediately.

In the first phase of the RTTC, grantees provided the scientific testing and validation of the processes withthe first prototypes showcased at the 2012 RTTC Fair in, Seattle, USA. The first prototypes underwent rigorous testing and evaluation, optimisation and improvement with demonstration-ready units showcased at the next RTTC Fair in 2014 Delhi, India. Demonstration-ready models are being evaluated in India, China and South Africa, to establish market readiness, ensure durability and reliability, develop specifications and manufacturability, and understand soft-issues relating to usage, including user acceptance and the re-use of beneficiated waste streams. The Foundation aims to establish a provision and servicing model similar to commercial household appliances to deal with the constraints of current approaches.

Through innovative design and treatment processes, the technologies developed under this initiative have the potential to address the limitations of current sanitation interventions by eliminating pathogens on-site, recycling/re-using limited resources, meeting user experience and acceptance, minimising environmental pollution, and the potential to link sanitation infrastructure to innovative management approaches. By treating human excreta at the source,it eliminates the need for sewers or in the case of on-site sanitation technologies, having to find ways to manage faecal sludges (Fig. 1). Water is not wasted – the technologies significantly reduce requirements for water or re-use/recycle it. Further, human excrement is transformed into by-products of potential economic value allowing for linkages to new business and service delivery models that has the potential to reduce the financial burden to municipalities. Such innovative approaches not only challenge the way in which we approach unserved areas but also the way in which we manage water security and sanitation in formalised areas operating on conventional technologies. In the developed world, water supply and sanitation have followed a linear design trajectory - from achieving water supply, to sewered settlements, then drainage – to integrated urban water cycle management (Brown et al. , 2009). Developing worlds appear to following the same route. The off-grid solutions developed by the Foundation have the ability to leapfrog this trajectory enabling developing countries to mitigate water security, achieve sanitation provision with no additional water and / or energy, and create opportunities for employment through new service and operation and maintenance models.

In the traditional, linear FSM approach, any weakness in the management chain would result in disruption of the service. In the proposed option, the collection, emptying and transport cycle is reduced or eliminated by treating human excreta off-grid into safe, potentially value by-products. Quality assurance is achieved through specification and manufacturing standards which the Foundation has started.

DEVELOPING A NEW SANITATION INDUSTRY

In South Africa, the Water Research Commission (WRC) has been pioneering new sanitation thinking and solutions. In partnership with the Gates Foundation, UKZN, DST, DWS and eThekwini Municipality they have been driving an in-depth science and research programme to feed into the solutions of the future. The early indications are that greatest opportunities exist in non-biological processes with regards to this disruptive sanitation agenda, which also offer elements of valorisation and beneficiation. Recognising this progress and development, in 2017 the Department of Trade and Industry launched the ever water and sanitation industrial platform as part of its Industrial Pathway Action Plan (IPAP).

The water and sanitation chapter of IPAP (2017), recognises that water is a critical input factor to industrial sectors like agriculture,

agro-processing, forestry, manufacturing, energy production and mining. Citing reports, it cautioned that some regions of the world, including Africa, could experience a decline in growth rates of as much as 6% as a result of water-related losses. It identifies that not only does water underpins economic growth; leaders of the World Economic Forum (WEF) consider it a strategic sector in its own right. The WEF Global Risk Report has ranked water availability in the top three global risks for three consecutive years - 2015 to 2017 - highlighting the need to identify and implement intensive mitigation strategies. The report recognises that Sub-Saharan Africa is one of the regions with the lowest sanitation coverage in the world with only 70%.

Almost 66% of the African continent is arid to semi-arid, with poor water infrastructure. The challenge of providing "traditional" centralised water infrastructure for most African countries is made more difficult and complex by the vast distances required to transport water, social inequalities, high unemployment, and fledgling water institutions without the capabilities to meet increasing demand. On the other hand, Africa contains many of the fastest growing economies in the world – if, in many cases, off a comparatively low base and marked by highly uneven distribution - resulting in rapid urbanisation and a growing tendency for internal migrant populations to agglomerate in mega-cities.

In this context, recognition of the importance of investment in water and sanitation - and the need to improve access and quality of drinking water and provide new sanitation solutions – is the necessary first step towards identifying and grasping the opportunities that a regionally shared industrial approach to water can provide. Specifically, on sanitation the IPAP present the action plan described in Table 1.

Next Generation Sanitation Cluster Development Programme
Nature and Purpose of the intervention Development of off-grid sanitation technologies will lower water requirements for sanitation, enabling reallocation to alternative needs and economic sectors and more effective service delivery in rural, peri-urban and water-scarce areas. An off-grid sanitation market presents an expansion opportunity for manufacturing, service and supply sectors. • Expand sanitation industry to service the unserved 40% households and diversify the market with new products. • Increase water availability for social and economic needs using efficient technologies. • Unlock new private sector delivery mechanism for sanitation services. **Targeted Outcomes** • The establishment of the next generation sanitation CDP. • Development of emerging industry capable to develop new technology, within the framework of localisation. • Procurement and policy incentives for improved uptake. • Development of high-end skills for advanced thermal sanitation technologies and artisanal skills for operation and maintenance. • 20 SMMEs per annum post-implementation. • Potential 15,000 jobs at 20% market penetration for the currently unserved.

Table 1: Next generation Sanitation Cluster Development programme *(Source: IPAP 2017)*

CONCLUSION

The sustainability of sanitation services relates to finance, people, institutions and technologies. Our current linear design approaches to sanitation delivery, either in the form of full waterborne or on-site systems, are not sustainable especially in the future against the growing challenges. Numerous case studies have shown that the failure of sanitation infrastructure investment due to poor consultation, understanding of needs, poor management and operation and maintenance, and lack of technological alternatives.

Through innovation, we can shift the paradigm in which we serve our towns and cities towards more responsible use of our water, energy and nutrients while achieving the main aim of sanitation: protecting public health and the environment.

The IPAP programme of the South African Government offers us this platform, in shifting this paradigm whilst serving our needs in terms of backlogs, but also creating opportunity for new jobs. This is an opportunity to grow a new service industry and operation and maintenance industry through the use of innovative products which result in smart supply chain management.

Through the appliance-based model, there could be opportunities to grow business that manufacture toilets and their parts, have the operation and maintenance component included as part of sanitation management model. This will enable the rendering quality facilities and sanitation services which municipalities struggle to fulfil.

In addition, the approach seeks to recover potentially valuable by-products which open up other servicing models to ensure the sustainability of the approach. Developing countries should take advantage of this opportunity to leapfrog developed countries who have followed a linear design approach to their water and sanitation supply.

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SLUDGES FROM ON-SITE SANITATION SYSTEMS –LOW-COST TREATMENT ALTERNATIVES

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