# Challenges and Opportunities for Sanitation in Developing Countries

Kushal Seetharam
Duke University
Corresponding author: kushalseetharam@gmail.com
Keywords: sanitation, Africa, case studies, technology

**Executive Summary:** Sanitation is one the most serious problems facing humankind in today's world. Almost 40% of the world's population, 2.6 billion people, do not have access to adequate sanitation, meaning they must defecate openly ("Water, sanitation and hygiene statistics" 2013). This leads to increased transmission of intestinal parasites and diseases. On the current development trajectory, it is unlikely that the United Nations Millennium Development Goal, which is to halve the proportion of people without access to improved sanitation, will be met ("A snapshot of sanitation in Africa" 2008). There are countless different technologies that seek to ameliorate this situation, with more being developed every year. Urine Diversion Dehydration Toilets, the Fossa Alterna, and the Arborloo are three such technologies that are frequently used in sanitation efforts. There are significant challenges in sanitation projects beyond technology implementation, however, including the variety of regional actors involved, differences between rural and urban environments, as well as social and economic factors. This paper first provides a framework for assessing the technological aspects of the sanitation-development space. Then, it assesses the complexity of the sanitation landscape in the context of Sub-Saharan Africa. This is followed by a review and analysis of selected case studies from the literature. It is the goal of this discussion to more concretely illustrate the challenges prevalent in sanitation projects. Finally, recommendations are made that may make sanitation efforts more effective and sustainable: two shifts in mentality are suggested. First, sanitation should be viewed as an integrated value chain process. Second, the unique, environment-dependent nature of sanitation projects should be internalized by all actors. A network of NGOs, aid workers, local universities, and private sector participants could encourage local enterprises and share best practices in order to improve the success rate of decentralized initiatives

## I. Introduction

Sanitation is defined by the World Health Organization (WHO) as the provision of facilities or services that separate people from urine and feces. Even a pit that is covered when full can qualify as sanitation. Despite such a broad definition, 2.6 billion people around the world lack access to proper sanitation, with most living in developing countries ("Water, sanitation and hygiene statistics" 2013). When people do not have access to sanitation, their biological waste is left in the open, providing a means to transmit gastrointestinal disease ("UN-water global annual assessment" 2012). Cholera, gastroenteritis, dysentery, typhoid, hepatitis A, and intestinal parasites kill millions each year and infect hundreds of millions more (Songsore 2004). These conditions, overrepresented in developing countries, further hamper quality of life in populations that already lack sufficient food, clean water, and energy. In addition, about half of the 120 million children born in the developing world each year will live without access to improved sanitation ("Facts on children" 2007). The result is that over 5,000 children die each day from diarrheal diseases alone ("Facts on children" 2007).

The United Nations (UN) has recognized the problems caused by a lack of access to sanitation, and have included a target of halving the proportion of people without access to improved sanitation in the Millennium Development Goals (MDG's) ("A snapshot of sanitation in Africa" 2008). In effect, the goal is to have 75% of people around the world have access to improved sanitation by 2015. Improved sanitation facilities include systems that flush or pour-flush to a piped sewer system, septic tank, or pit latrine. Other options include ventilated improved pit latrines, pit latrines with a slab, and composting toilets. As of 2012, only 64% of people have access to improved sanitation ("Water, sanitation and hygiene statistics" 2013). The projected access in 2015 is 67%, thus falling 8% short of the goal. This 8% corresponds to more than half a billion people. Even if the Millennium Development Goal is met, there will still be 1.5 billion people in the world using hanging toilets, open pits, buckets, or engaging in open defecation. These lagging sanitation practices propagate severe health risks for people in developing countries.

The development community recognizes lack of sanitation as a serious issue, but has not been able to adequately address it. In 2010, $7.8 billion was spent on sanitation and water related aid, with an additional $4.4 billion provided in loans for development purposes ("UN-water global annual assessment" 2012). Despite the funding and attention to the issue, problems persist. There are several challenges to efficiently transforming aid money into tangible results in development projects, and sanitation is no exception. Social, political, cultural and economic factors must be taken into account, and there is no single technology that is best for all situations. The available actors such as local councils, Non-Governmental Organizations (NGO's), private companies, and the federal and municipal governments must all be considered. The local populace must also be willing and interested in adopting new practices. All of these factors have regional variance as well, thus making a general solution impractical. The purpose of this paper is to give a snapshot of the difficulties involved in increasing access to improved sanitation in developing countries. First, an overview of common technologies involved in sanitation is provided. Then, the challenges associated with technological implementation will be described through the context of sanitation in Sub-Saharan Africa. A review of several case studies of sanitation efforts will illustrate these complexities. Finally, an analysis of the sanitation landscape and recommendations will be presented.

## II. Technology Overview

Sanitation is a multi-step process from waste generation to end use or disposal and must therefore be viewed in a value chain framework (van Dijk 2012). Each section of the value chain has inputs, outputs, and associated technologies. There are waterborne systems and dry systems, each with their own benefits and challenges (Brikke and Bredero 2003). In addition, technologies can range from a simple covered pit with a hole at ground level (pit latrine) to aqua privies with water-tight settling tanks and anaerobic digesters (Steinberg 2009). Tilley et al. give one systematic approach to classification of these technologies (Tilley et al. 2008). Different sections of the value chain are termed functional groups. The inputs and outputs to these groups are called products. Products that are input into one stage come out as different products at the output end, and are fed into subsequent stages. The five given functional groups are user interface, collection and storage/treatment, conveyance, (semi-) centralized treatment, and use and/or disposal. A description of each one these groups and a set of example technologies is given in Figure 1. There are several products that are associated with the sanitation process including urine, feces, anal cleansing water, stormwater, greywater, flushwater, organics, dry cleansing materials, blackwater, fecal sludge, treated sludge, excreta, brownwater, dried feces, stored urine, effluent, compost/EcoHumus, biogas, and forage. An exhaustive description and evaluation of different technologies is beyond the scope of this paper and can be found in the literature (Brikke and Bredero 2003; Tilley et al. 2008). To provide context to the technology landscape, however, an example sanitation value chain will be described and three technologies will be examined in detail.

One possible sanitation value chain can begin with feces, urine, and flushwater. A pour flush toilet can be chosen as the user interface. The output of the toilet is blackwater (a combination of feces, urine, and flushwater), which can be collected and stored using twin pits. After sufficient incubation and the right conditions, the collected blackwater will turn into compost, which is then removed by people using buckets and shovels, or manually operated pumps in the conveyance phase. Finally, the compost is mixed into soil as fertilizer before crops are planted to increase agricultural productivity. According to the sanitation framework, the technologies used are pour flush toilets, twin pits, human-powered emptying and transport, and application of compost. The products involved in the system are feces, urine, flushwater, blackwater, and compost. It is instructive to note that there was no (semi-) centralized treatment phase in this example. Every functional group need not be included in a particular sanitation value chain. In fact, inappropriately forcing this structure upon a project without full consideration of the local situation will often lead to failure. Further examples of sanitation value chains can be found in Tilley et al (Tilley et al. 2008).

**Figure 1: Sanitation Value Chain and Associated Technologies**
*Source: Tilley et al. 2014*

| **Functional Group** | **Description** | **Example Technologies** |
|---|---|---|
| User Interface | What the user comes in contact with and how they access the sanitation system. Often depends on the availability of water. | • dry toilet<br>• urine diverting dry toilet<br>• urinal<br>• pour flush toilet<br>• urine diverting flush toilet |
| Collection and Storage/Treatment | The way the outputs from the user interface are collected, stored, and occasionally treated. Further treatment at a later phase is usually required. | • single pit<br>• ventilated improved pit<br>• Fossa Alterna<br>• twin pits for pour flush<br>• dehydration vaults<br>• composting chamber<br>• septic tank<br>• anaerobic biogas reactor |
| Conveyance | The method by which products are transferred from stage to stage, especially between collection/storage and (semi-) centralized treatment. | • human emptying and transport<br>• motorized emptying and transport<br>• simplified sewers<br>• transfer station<br>• sewer discharge station |
| (Semi-) Centralized Treatment | The method used to treat outputs from large user groups. Generally has higher operation, maintenance, and energy costs. | • aerated pond<br>• constructed wetland<br>• trickling filter<br>• activated sludge<br>• planted drying beds |

| | | |
|---|---|---|
| Use and/or Disposal | Method by which outputs from previous stages are turned into a useful final product, or, at least, into a reduced-risk form. | • Arborloo<br>• application of compost/Eco-Humus<br>• irrigation<br>• soak pit<br>• aquaculture ponds<br>• floating plant pond<br>• groundwater recharge |

Three technologies that are interesting to examine due to their frequent use in sanitation efforts are the Urine Diverting Dry Toilet (UDDT), the Fossa Alterna, and the Arborloo. These technologies are also used in the case studies analyzed later in this paper. The UDDT is a user interface technology with the inputs of feces, urine, and anal cleansing water (Tilley et al. 2008). The same products are output for collection and storage. The UDDT is a toilet that consists of a front area and a hole in the back. The front area collects urine while feces falls through the hole down a chute. While the toilet is simple to design and build using concrete, wire mesh, plastic, and other materials, it is not intuitive to certain users. In addition, the need to keep the solid feces and liquid urine separate can complicate cleaning and maintenance. Feces may fall into the urine area and users that anally cleanse with water may get liquid into the feces pit. Demonstrations and education efforts are therefore necessary to ensure correct operation of the toilet. The benefits of this technology is that it does not require a constant water source, can usually be built and repaired with local materials at low capital and operation costs, and, with proper maintenance, does not have odor or insect issues.

The Fossa Alterna is a collection and storage/treatment technology that can be used in conjunction with a UDDT. It takes in excreta, organics, and anal cleansing water, while producing compost/Eco-Humus (Tilley et al. 2008). The system consists of two waterless pits that are each about 1.5 meters deep. The first pit typically takes one to two years to fill. Afterwards, it is covered and the other pit is used. As the time it takes for the material in a full pit to turn into compost typically equals the time it takes to fill the second pit, people can alternate between the two and generate useful compost every year. Figure 2 shows a Fossa Alterna in Ethiopia with one pit in use inside a covered latrine structure while the second pit is awaiting use. There are some maintenance challenges, however. To ensure that the waste properly composts, organic material such as soil, ash, and leaves must be added after defecation. In addition, while urine and small amounts of anal cleansing water can be tolerated in the pit, additional water must not be added. The Fossa Alterna is therefore especially suited to environments where water is scarce. While the constant need of organic materials to ensure aerobic composting and the risk garbage poses to the process can pose adoption issues, this technology has attractive benefits. It can be made with local materials at low cost, has an unlimited life if the pits are sequentially used, significantly reduces pathogens in the waste, and produces compost/Eco-Humus that can increase agricultural productivity.

The Arborloo is another composting technology that belongs to the use and/or disposal functional group. The system consists of shallow pit latrine covered by a concrete slab meant for one family ("Lessons" 2007). After each use, a mixture of soil and ash is added to the pit. When the pit is full (about 4-9 months), the concrete slab is moved, a layer of soil is added, and a fruit tree is planted in the compost pit (Figure 3). The fruit tree provides economic value, the soil and ash reduce the odor from the pit, and the compost is never directly handled. The Arborloo is a simpler technology than the Fossa Alterna and is easier to use when it is not possible to empty the compost pit. Banana, papaya, and guava trees have all successfully been planted in Arborloo systems (Tilley et al. 2008). In addition, as people do not come in direct contact with the waste products, there is a low risk of pathogen transmission. Appropriate composting conditions have to be preserved; however, the Arborloo has the same maintenance and adoption issues as the Fossa Alterna. While there are additional labor costs associated with fencing and watering the tree, the compost does not have to be dug out of the pit.

**Figure 2: Fossa Alterna**

*Source:* [*http://commons.wikimedia.org/wiki/File:Fossa_alterna_in_Arba_Minch,_Ethiopia_(6626714367).jpg*](http://commons.wikimedia.org/wiki/File:Fossa_alterna_in_Arba_Minch,_Ethiopia_(6626714367).jpg)

The three example technologies given above can all be built and repaired from locally available materials. In addition, they typically have low capital and operating costs. This characteristic makes them especially suited for rural and peri-urban areas. Urban areas also have serious sanitation difficulties, though there are often similarities between the problems they face and those in rural areas. These regional challenges can be illuminated by examining sanitation in the context of Sub-Saharan Africa.

## III. Sanitation in Sub-Saharan Africa

Sub-Saharan Africa has the least developed sanitation infrastructure when compared to other developing regions. Compared to the world average of 36% without access to improved sanitation, 70% of people in Sub-Saharan Africa still use shared or unimproved facilities ("Water, sanitation and hygiene statistics" 2013). There are, however, significant regional and sub-regional differences with access to improved sanitation fluctuating based on country. For instance, Burkina Faso has 17% access compared to South Africa, which has 79% access ("A snapshot of drinking water and sanitation in Africa" 2012). There is also a significant disparity between urban and rural settings. Urban settings have about 43% sanitation coverage compared to the 23% in rural areas ("A snapshot of drinking water and sanitation in Africa" 2012). Rapid urbanization is causing this gap to shrink, but only by bringing the urban number down, as there is an increase in overcrowding, slums, and squatter settlements in cities (Songsore 2004).

Regional disparities in sanitation access are further complicated by the decentralization of political power that has occurred in most African countries (Banerjee et al. 2008). In rural areas, the local community, private companies, and municipalities are in charge of water supply and sanitation. In urban areas, there are usually corporatized utilities that are responsible for water supply and sanitation. Depending on the country, there may be a single national utility that covers all urban areas, or several utilities that each operate in local jurisdictions. Benin, for example, has a single national utility called SONEB while Kenya has several utilities such as KIWASCO, MWSC, and NWASCO (Banerjee et al. 2008).

Rural and urban areas face different challenges ("Meeting the MDG drinking water and sanitation target" 2006). Rural areas on a whole have significantly less access to improved sanitation and often have no utility or central government that is actively seeking to improve the situation. The growing rate of poverty in cities leads to increased waste in regions where there is no sanitation infrastructure. Moreover, urbanization in African countries is due to demographic, rather than economic, factors (Songsore 2004). Rural-urban migration and ethnic conflicts, wars, droughts, and famine are rapidly increasing the city population without a corresponding increase in agricultural productivity and industrialization, resulting in a large lower-class population without access to adequate infrastructure. While people living in cities generally have better sanitation access than rural dwellers, the urban poor end up having similar rates of disease and death as people living in rural areas.

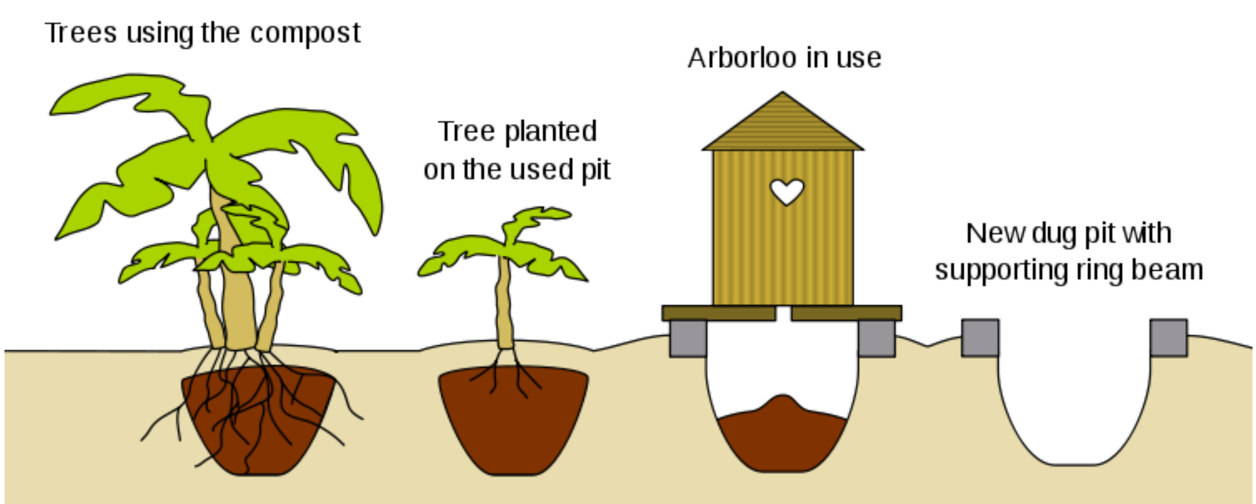
Open defecation is common in both rural and poor urban areas that do not have access to improved sanitation. This practice is particularly troublesome as it pollutes ground waters, contaminates agricultural produce, and spreads diarrheal diseases ("Abandoning open defecation" n.d.). Previous efforts have shown that simply providing toilets and latrines is often insufficient to stop this practice (Dittmer 2009). Ignorance of the health risks, ingrained cultural norms, and a lack of incentives (open defecation costs nothing) causes people to continue to defecate in the open. Outreach regarding cultural attitudes towards sanitation and communication about the desirable benefits of new practices is therefore required to make a lasting impact. This outreach can often be done by the organization in charge of the sanitation project, but must eventually be internalized and spread by local partners and leaders as these organizations seldom have a sustained, long-term presence in the community.

There are multifarious factors that must be taken into account when implementing any sanitation project. Countries differ from each other, urban and rural areas face different challenges, and social and economic factors must be understood (Keene 2007). It is instructive to look at several case studies of sanitation projects to further explore this complex landscape.

## IV. Review of Case Studies

The following case studies were selected from the literature to more concretely represent the complexity of sanitation projects in sub-Saharan Africa and illustrate the challenges that must be given due consideration. The example case studies were chosen to represent several geographic regions, environments with different levels of development (rural, per-urban, urban), and projects that faced varied technical, social, and economic challenges.

**Figure 3: Arborloo**




*Source: http://commons.wikimedia.org/wiki/Category:Arborloo#/media/File:Arborloo-en.svg*

### A. Northern Pretoria, South Africa

Over 60% of South Africa lacks basic services and shelter (Ishani and Lambda 2012). The goal of the government and local civic leaders was to install a cost effective sanitation system in the northern part of Pretoria in areas with communal water use. As there were insufficient resources to create sewerage reticulation and treatment infrastructure, an Aqua Privy system was implemented. The user interface is a toilet where clean water is poured into the toilet bowl after every use. The effluent then flows into a soakway with the sludge emptied periodically. The system does not tolerate plastic and other foreign objects that are thrown into the toilet.

Local civic organizations were consulted when deciding what type of sanitation system to install. The leaders of these organizations were all male with no technical expertise regarding sanitation. No NGOs or local women were consulted or involved in the design or planning of the system. The project was funded by the South African government's Independent Development Trust (Ishani and Lambda 2012).

While the system did utilize less water in a resource-constrained area, the project was ultimately a failure. Primarily, the problems were unfriendliness to women and inadequate financial planning. The local residents wanted a system that preserved privacy and human dignity. However, the toilets faced the street and thus offered insufficient privacy and security for women who faced the threat of potential rapists. In addition, there was no place to dispose sanitary pads. The size of the toilet also prevented pregnant women from properly utilizing it. On the financial side, operational costs were not accounted for during the planning phase. Labor to dig holes, maintain the toilets, and toilet paper were not included in financial estimates. Therefore, the cost of the project was also over-budget. Due to a combination of these problems, some of the systems had to be abandoned.

### B. Malawi

WaterAid sought to improve sanitation conditions in a variety of rural and peri-urban districts in Malawi through its Ecological Sanitation (EcoSan) program ("Lessons" 2007). It popularized two types of composting toilets; the Arborloo and the Fossa Alterna. These systems have economic value as they produce fruit trees and compost respectively. These systems were readily adopted by the people as they are similar to traditional pit latrines, cost very little, use local materials, and are easy to construct.

Promotion of these latrines through workshops and demonstrations was insufficient to substantially increase usage. WaterAid had to encourage local cement providers to become involved with cement slab manufacture and ecological latrine promotion. A network of promoters and manufacturers was developed to create entrepreneurial and economic incentives to spread the project. Local champions, sanitation clubs, and communication by word of mouth and radio was used to encourage adoption of the EcoSans systems. Ultimately, people started using the systems due to the fertilizer value of the manure and increased prestige, comfort, and convenience. Between 2001 and 2006, WaterAid was able to construct over 12,000 EcoSan composting latrines that were regularly used ("Lessons" 2007).

### C. Nairobi, Kenya

Sanitation in Nairobi is the responsibility of the Nairobi City Council (NCC). Lack of decision-making authority, lack of accountability, corruption, and a lack of equipment make the Council inadequate at this task. Only 50% of garbage is collected most of which is from sparsely populated areas (Ishani and Lambda 2012). The garbage build up results in blocked drains, overflowing sewage, and inaccessibility to open spaces. In addition, rapid urbanization has led to a large lower class in Kenya. About 46% of the urban population live below the poverty line. Incentivizing the populace to collect waste as a method of subsistence in order to earn money is therefore kills two birds with one stone.

Instead of installing a specific technology, this project looked at sanitation collection programs in Nairobi. Specifically, several women's groups involved in composting organic waste were studied. Women in these groups collect waste from settlements, sort it into organic and inorganic waste, remove foreign objects, and then store the waste for composting. After the waste finishes composting, it is put in bags and sold. NGOs help train the composting groups and, depending on resource constraints, aid in packaging and marketing the compost.

The composting program enabled women to exchange information, integrate the community members, lesson environmental problems, and earn an income. Income potential, however, was strongly dependent on market access. The women's groups without easy access to markets made significantly less money. As urban-rural linkages are not developed, compost could not be sold to rural areas either. Storage of the compost was also logistically challenging; the cost was high and the compost had to be transported within one month of production to remain useful.

While these logistical problems are not negligible, there were significant positive environmental results. Drainage channels and nearby rivers were clear of garbage, access to roads and footpaths increased, and there was a lower incidence of environmental illnesses such as diarrhea and malaria.

### D. Koulikoro, Mali

The town of Koulikoro, Mali had a population of around 26,000 people when the sanitation project was undertaken in 2001 ("Compilation of 25 case studies" 2012). Initially, about 3% of households had flush water toilets and septic tanks, 25% had soak pits, and almost all of the houses had traditional pit latrines. A German organization called GTZ began a project to improve the sanitation situation in Koulikoro. They piloted several different technologies including urine and feces separation at the source, double-vault dehydration toilets, separate collection, storage, and utilization of urine, greywater treatment using planted soil filters, and a greywater garden. After conducting a feasibility study dependent on environmental factors and existing infrastructure, GZT decided to install urine diversion dehydration toilets (UDDT) combined with a greywater garden. This closed loop system would ideally provide improved sanitation and reuse of human waste in agriculture and gardening. Project personnel had intensive discussions with local stakeholders to ensure that there was high interest in recovering fertilizers and food production and a high degree of awareness and motivation regarding the need for external support, experienced manpower, and initial financial support. Even though these social factors were seemingly addressed, the project ran into several problems that led to its eventual abandonment.

First, follow-up field visits during 2002-2004 made clear that there was a lack of interest and demand from the town population ("Compilation of 25 case studies" 2012). There was low user awareness or commitment towards maintenance of the system. Secondly, there was poor cooperation with the Koulikoro municipality. Scaling, operation, and participatory planning failures also made it very difficult for long term maintenance and management of the system. For example, the reuse of dried feces and collected urine which was a major benefit of the system lost its utility when the local university stopped using these materials. An evaluation of the project in 2009 found that only one family was still operating and using a UDDT system and the greywater garden was in disuse. While the choice of technology was still appropriate, lack of attention to social, cultural, and educational aspects of the system doomed the project. The only lasting beneficial impact achieved was increased awareness of ecological sanitation in the area.

## V. Discussion

There are a number of lessons to be learned from the above case studies. From the South Africa Aqua Privy project, it is clear that participatory development is key to success. Those leading the project did not involve women in the design process, and therefore overlooked many user issues. Consideration of gender is often a key factor in successful sanitation projects (Mbugua et al. 2006). In addition, NGOs with technical expertise and sanitation experience were not consulted. Thorough planning is also required; overlooking the operational cost of the system was a grave mistake for this project.

The Malawi EcoSans project teaches us that introduced technology must consider social and economic factors to be successful. The fact that the composting toilets were very similar to pit latrines that locals were used to lowered the adoption barrier, while the economic value of the fruit tree and the compost fertilizer gave them a reason to cross the barrier. This project also showcased the role that communication, education, and local promotion plays in scaling up a development project.

The study of composting groups in Kenya shows that even a win-win situation can have trouble from logistical issues. Women collecting waste and composting it helped improve the environment while providing them a much needed income source from the produced fertilizer. However, limited access to buyers in markets and rural areas bottlenecked the potential of this approach for several of the groups.

The GZT sanitation project in Mali makes it very clear what happens when only technological considerations are taken into account. Even though pilots and feasibility studies were conducted to choose an environmentally and economically sound technologies, there was insufficient due diligence towards social, cultural, and educational factors. While GZT nominally knew of these issues and engaged in some participatory dialogue with the community, they pushed ahead with the project too fast and did not let the community adjust to and adequately shape the project.

These case studies collectively show how unforgiving the sanitation landscape is in Sub-Saharan Africa. For any particular project, the appropriate technologies must be chosen after careful evaluation of the environment, existing infrastructure, and local norms. Economic feasibility must be considered when structuring incentives and accounting for operation and maintenance costs. Social elements such as gender, religion, and culture practices must be factored in through participatory engagement with the community and local authorities. Finally, education regarding improved hygiene practices must be encouraged to create lasting behavior changes in the populace. Inadequate consideration of any of these factors will often doom an endeavor to failure.

Even if project planning is thorough, the conflicting interests of landlords, tenets, ministries, NGOs, donors, and international lending agencies hinders the organization of actors necessary to scale solutions (van Dijk 2012). Challenges such as inadequate regulatory frameworks, a lack of clarity on institutional roles and responsibilities, and problematic financial systems make it difficult to create sustainable improvements in sanitation. There is no silver bullet for these issues and every situation must be treated uniquely. Many people believe that increasing private sector participation is the key to creating lasting progress in sanitation as profit-seeking companies and individuals are more able and better incentivized to navigate this complex landscape.

Any non-governmental actor who provides some part of the sanitation value chain for profit is a part of Private Sector Participation (PSP). Actors can range from an individual running a singular latrine, to large companies that provide water and sanitation services. There are a variety of different forms of PSP that vary based on the degree to which commercial risk and the responsibility for capital investment is shifted from the public to the private sector (Davis 2005). These arrangements include service or management contracts, leases, concessions, build-operate-transfer agreements, divestitures, and independent service providers.

The debate whether to increase PSP in the sanitation space is very polarized (Davis 2005). Proponents argue that PSP can increase investment, expand access to services, and improve sanitation infrastructure more efficiently. Critics are concerned that PSP will result in substantial price increases for the poor, environmental damage, and the government's abdication of its responsibility to provide what many see as a public service. Unfortunately, there are few unbiased studies of the role of PSP in sanitation. Davis has done a review of the existing empirical literature and found that PSP probably improves efficiency in the sanitation value chain, accelerates capital investment (though less than expected), and increases scrutiny of environmental performance among regulators, civic organizations, and the public even if there is insufficient evidence to determine actual environmental impact (Davis 2005). Increased PSP does, however, increase fees and tariffs affecting users due to the need for financial self-sufficiency and responsibility towards shareholders. Sanitation access may therefore become biased towards middle and high-income families.

Another problem is that a large portion of the private water and sanitation services market is dominated by a small number of large European firms; the two largest companies are responsible for 70% of the market (Davis 2005). Not only does this have negative sovereignty implications for individual states, it also crowds out the involvement of small-scale independent providers (SSIP). SSIP often deliver reliable service and have flexible financial arrangements that benefit low-income households. The downside is that their per-unit charges are higher as they cannot exploit economies of scale. Private sector participation clearly has its own set of challenges and cannot solve the sanitation crisis in developing countries on its own. It can, however, play an important role in improving access to services.

## VI. Recommendations

There is no silver bullet that will drastically improve the sanitation challenge in developing countries. As evidenced by the case stories, each situation is unique and needs a different approach. Even if the best technology is chosen, implementation challenges persist. Social, cultural, economic, and political factors complicate the successful implementation of a sanitation project. Once a project is successful on a small scale, there are additional difficulties in scaling the solution. Two seemingly contradictory shifts in thinking can help in untangling the knot that sanitation efforts often find themselves in.

First, governments, NGOs, and other actors seeking to improve sanitation must understand the integrative nature of the sanitation process. They must start viewing sanitation in a value chain framework where focusing myopically on one part of the chain will significantly limit the potential for sustainable progress. Overemphasis of technology at the user interface (toilet) stage at the expense of downstream technologies is one example of this issue (Tilley et al. 2014). It is most important for state and municipal governments to take the lead in internalizing this viewpoint. As they control the institutional framework under which other actors operate, they can set policies to make the regulatory, economic, and political environment more amenable to the flow of sanitation products along the value chain. For example, taxes and subsidies can be structured to help small scale independent providers compete with large multinational firms.

Secondly, the different actors in the sanitation sphere must internalize the fact that there is no one-size fits all solution to any particular project. This shift in mentality is most important for NGOs and private sector participants. As they have a more hands-on role than the government, the multifarious nature of sanitation projects affects their work more directly. A network of NGOs, aid workers, local universities, and private sector participants could encourage local enterprises and share best practices. By supporting and improving the success rate of decentralized solutions to sanitation, the unique challenges in each locale will be better addressed. A similar network sponsored by the European Commission was in operation between 2006 and 2008 (Zurbrugg and Tilley 2009). Called the Network for the development of Sustainable Approaches for large-scale implantation of Sanitation in Africa (NETSSAF), the program sought to, “bring together the most relevant stakeholders in the field of sustainable sanitation in Sub-Saharan Africa and Europe, and to promote international cooperation between research organizations, associations, universities, and social and governmental stakeholders...(“NETSSAF final report” 2011).” In practice, however, the project focused on researching different technologies and their feasibility in situations with different social, economic, and governmental constraints. The main results of this effort was a participative sanitation management support tool that helped users and project managers decide which technology to implement. While the outputs of the short-lived NETSSAF experiment lay important groundwork for future sanitation projects, a permanent network that focuses on supporting the process of sanitation endeavors along the full value chain instead of on individual technologies would have a more sustainable impact. The creation of such a network can be encouraged by NGOs and other international partners involved in the sanitation space.

## VII. Conclusion

Sanitation is a pressing health problem that adversely impacts billions of people around the world. There are several challenges, however, to successfully making an impact. Regional variance, rural and urban differences, and social and economic factors complicate any project. There are numerous technological options available that are suited for different environments with more appearing every year. Excessive focus on a particular technology or even technology in general, however, is insufficient to effect sustainable change. This paper has only given a snapshot of the complexity involved in the sanitation sphere. The connection between water resources, sanitation, and hygiene, the tension between large centralized and small decentralized private sector participants, political instability, and entrenched international policies further muddle the landscape. However, some progress can be made in spite of these difficulties. The various actors at play must understand the integrative value chain nature of sanitation and realize that projects must be tailored to each situation. These shifts in mentality are two sides of the same coin. Taken together, they may be able to pay the toll for improved sanitation in developing countries.

## References

*A snapshot of drinking water and sanitation in Africa - 2012 update.* 2012. Cairo, Egypt: Africa Ministers' Council on Water.

*A snapshot of sanitation in Africa: A special tabulation for AfricaSan based on preliminary data from the WHO/UNICEF joint monitoring programme for water supply and sanitation.* 2008. World Health Organization/United Nations Children's Fund.

*Abandoning open defecation: Comparison and adaptation of social change dynamics.* WaterAid.

Banerjee, S., Skilling, H., Foster, V., Briceno-Garmendia, C., Morella, E., & Chfadi, T. 2008. *Africa infrastructure country diagnostic - ebbing water, surging deficits: Urban water supply in sub-saharan africa.* World Bank.

Brikke, F., & Bredero, M. 2003. *Linking technology choice with operation and maintenance in the context of community water supply and sanitation*. Geneva, Switzerland: World Health Organization.

*Compilation of 25 case studies on sustainable sanitation projects from Africa.* 2012, ed. Elisabeth von Muench. Eschborn, Germany: Sustainable Sanitation Alliance.

Davis, Jennifer. 2005. Private-sector participation in the water and sanitation sector. *Annual Review of Environment and Resources* 30 (145-183).

Dittmer, Alison. 2009. *Towards total sanitation: Socio-cultural barriers and triggers to total sanitation in West Africa.* WaterAid.

Facts on children: Water and sanitation. in UNICEF [database online]. 2007 Available from http://www.unicef.org/media/media_36238.html (accessed June 10, 2015).

Ishani, Z., & Lambda, D. 2012. *Urban community waste management: A sub-Saharan region study.* Habitat International Coalition.

Keene, Courtney. 2007. *Development projects that didn't work: The perils of narrow approaches to complex situations.* Globalhood.

*Lessons from a low-cost ecological approach to sanitation in Malawi.* 2007. Water and Sanitation Program.

Mbugua, W., Peebles, D., & Jubb, N. 2006. *Gender, water and sanitation case studies on best practices.* United Nations.

*Meeting the MDG drinking water and sanitation target: The urban and rural challenge of the decade.* 2006. Geneva, Switzerland: World Health Organization.

*NETSSAF final report.* 2011. Germany: European Commission.

Songsore, Jacob. 2004. Urbanization and health in Africa: Exploring the interconnections between poverty, inequality, and the burden of disease. Paper presented at 20th African Health Science Congress, Accra, Ghana.

Steinberg, Lisa Marie. 2009. Improved anaerobic digester stability to organic loading rate shocks with the use of an environmentally derived inoculum. Doctor of Philosophy., Pennsylvania State University.

Tilley, E., Luthi, C., Morel, A., Zurbrugg, C., & Schertlenleib. R. 2008. *Compendium of sanitation systems and technologies*. Dubendorg, Switzerland: Eawag: Swiss Federal Institute of Aquatic Science and Technology.

Tilley, E., Strande, L., Luthi, C., Mosler, H., Udert, K., Gebauer, H., & Hering, J. 2014. Looking beyond technology: An integrated approach to water, sanitation and hygiene in low income countries. *Environmental Science and Technology* 48 (17).

*UN-water global annual assessment of sanitation and drinking-water (GLAAS) 2012 report: The challenge of extending and sustaining services.* 2012. Geneva, Switzerland: World Health Organization.

van Dijk, Meine Pieter. 2012. Sanitation in developing countries: Innovative solutions in a value chain framework. In *Management of technological innovation in developing and developed countries.*, ed. Hongyi SunIntech, http://www.intechopen.com/books/management-of-technological-innovation-in-developing-and-developed-countries/sanitation-in-developing-countries-innovative-solutions-in-a-value-chain-framework (accessed March 7, 2015).

Water, sanitation and hygiene statistics. in UNICEF [database online]. 2013 [cited March 7 2015]. Available from http://www.unicef.org/wash/index_statistics.html (accessed March 7, 2015).

Zurbrugg, C., & Tilley, E. 2009. A system perspective in sanitation - human waste from cradle to grave and reincarnation. *Desalination* 248 (410-417).

Kushal Seetharam is a recent graduate of Duke University where he completed degrees in Electrical and Computer Engineering and Physics. He has worked on projects in electromagnetic metamaterials, computer architecture, sanitation, and biochemistry. Kushal has also interned at Intellectual Ventures and the White House Office of Science and Technology Policy. In the fall, he will start his PhD in Applied Physics at MIT.