Title of full paper: **Compost-based sanitation: a low-cost strategy for turning the toilet problem at Mekelle University (Ethiopia) into a solution.**

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Abstract

The main objective of this project was to implement a sustainable sanitation system based on composting from a case study at a university campus in Mekelle, Tigray, Ethiopia. Mekelle has not only shortage of water as well as poor water and soil quality, but also lacks sanitation systems adapted to users culture. A one-year pilot project started in July 2013 from a questionnaire survey and incursion around the seven districts of the city of Mekelle in order to investigate the condition and location of public water points, latrines and waste disposals. These primary data collected, combined to context analysis, resulted in a theoretical and practical intervention at the College of Health Sciences (CHS), Mekelle University. In addition to inform and discuss the sanitation gap in the city of Mekelle, a established work group formed by local staff, students and volunteers, designed, planned and constructed 8 compost based dry-toilets for male users at the student dormitories in CHS. Importance is placed in a low cost solution, making use of existing resources on campus and staff capacity while giving the added value of rich soil for campus horticulture. Toilets are designed around users behavior such as squatting and open defecation. The pilot is still running with high acceptance by its users and is ready for scale-up.

Key-words: **Sustainable Sanitation, Compost-based Dry Toilets, Thermophilic Composting, Technology Transferring and Environmental Education.**

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1. Introduction

The international community adopted the Millennium Development Goals in 2000. The seventh Millennium Development Goal (MDG 7) aims to ensure environmental stability. Target 10 of MDG 7 aims to halve the proportion of the population that lacks sustainable access to safe drinking water and basic sanitation.

While access has increased substantially owing to funding from external aid, there is much work that still remains in order to achieve this target, especially in Ethiopia, which fares amongst the least capacitated when considering safe access to water and sanitation resources, in Sub-Saharan Africa and the world at large.

Water supply in Mekelle, a city located in northern Ethiopia, does not meet demand, and sanitation coverage is low. Many households, schools and health institutions often lack water and basic sanitation facilities, which in turn, has had drastic implications on health outcomes (Castro and Maoulidi, 2009).

The Millennium Cities Initiative (MCI), a project of the Earth Institute at Columbia University in the City of New York, was established to help selected, under-resourced municipalities across Sub-Saharan Africa eradicate searing urban poverty and attain the Millennium Development Goals (MDGs). MCI brings together local staff and master's students to assist the designated "Millennium Cities" in identifying critical gaps that stand in the way of realizing the MDGs, as well as the financing, programs and partners capable of fulfilling them.

MCI works with regional and national governments to promote direct investment, create employment opportunities, stimulate domestic enterprise and ultimately, foster economic growth. In addition, MCI is working to generate a series of surveys that city officials and other stakeholders can use to help them determine their own development priorities and to articulate these priorities in the form of city development strategies.

As a part of this effort, a facility-based survey was administered in seven locations within Mekelle City, a process that influenced the author's observations and overall perception of the water and sanitation environment in Mekelle. Finally, this research and the lessons learned as a result of this research allowed the author to familiarize himself with the major constraints associated with water and sanitation in Mekelle and ultimately identify opportunities for innovative solutions. One of those solutions was a compost-toilet system pilot project at Mekelle University's College of Health Sciences (CHS).

1.1 Objectives

Initially, the main purpose of this assignment was to perform a needs assessment of water, sanitation and solid waste management to help identify the status of Mekelle City in meeting Millennium Development Goal 7, target 10, which seeks to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation.

Inspired by local demand and the presence of a great opportunity to promote low-cost and community-based water and sanitation practices, an additional objective was established to pilot a sustainable sanitation project at the Ayder Referral hospital in Mekelle City.

Information on the location of skips, waste dumps, as well as MDG indicators was collected.

1.2 Methodology

The research practicum occurred over a three-month period between June and August of 2013 in Mekelle, Tigray, Ethiopia. The first two months were dedicated exclusively to approaching local authorities and stakeholders with the goal of establishing a partnership for both data-collection and prototype construction. The prototype consists of 8 dry-toilets built from a composting model. The actual prototype construction was executed during the third month.

The second portion of the research practicum, which involved data-collection on public water points, latrines and solid waste management systems, occurred with the strong support of local MCI staff and was accomplished with the use of android phones that contained pre-prepared digital forms that were generated by the MCI New York office. ODK forms version 1.1.7 was the software used for harvesting information.

To build capacity and to contribute to the transfer of technology, a logical framework was designed. Specific objectives, outputs, activities, inputs, 'SMART' (specific, measurable, achievable, relevant and time-bound) indicators, risks and assumptions, as well as a Gantt chart were included in the design. A presentation and a training session were given to inform students and managers of the appropriate use, maintenance and replication procedures of the technical alternative.

Finally, the construction of the composting toilets themselves was an initiative of the author without liability or support from MCI and represents a partnership within the community using local financial and labor resources as well as reused 'scraps' (old materials).

1.3 Study Area

Mekelle City is located at the coordinates, longitude of 130 30' N and latitude of 390 29' E. The city is spread out over a plain and partly encircled by a chain of mountains.

Mekelle's territory covers 28 square kilometers and is 2200 meters above sea level. It has a rapidly growing estimated population of 298,000.

Mekelle City is the capital of the state of Tigray and the largest city in northern Ethiopia, located around 680 kilometers north of the nation's capital Addis Ababa. Mekelle is also one of Ethiopia's principal economic, health and educational centers (Figure 1).

The average annual rainfall amount in Mekelle is around 600 millimeters. The pattern of rainfall is unimodal and about 60 to 84 percent of the total rainfall falls within a four-month period (June-September). The spatial distribution is influenced by topography (Tesfaye & Walker, 2004).

Figure 1: Map of Ethiopia, outlining the City of Mekelle. Source: Nations Online Project.

1.4 Limitations

There were many limitations that complicated data collection and analysis efforts. The lack of proper training for interns and local staff on how to conduct the survey and treat the data, inconsistent cooperation, refusals or disinterest on the part of authorities tasked with the provision of important information, malfunctioning phones and phone theft, incomplete digital forms, the delayed release of the Ethiopian annual reports, communication barriers, and long distances without adequate transportation were among the many challenges faced by the project implementers.

With regards to the construction of the toilet prototype, some of the limitations included difficulties achieving financial support, attaining the proper materials and tools, as well as a shortage of time, limited practical experience on the part of the author and cultural barriers such as fecophobia and a mistrust of the technique.

2. Solid Waste Management

Figure 2: Waste dump nearby the City of Mekelle.

2.1 Background

In the rapidly growing cities of the developing world, issues of municipal solid waste management are of major importance. Inadequate solid waste management is the most serious environmental and health problem in many cities within the developing world.

Urbanization and population growth have led to an increase in waste quantities in urban areas. Since the mostly inefficient waste collection schemes generally serve only a limited section of the urban population, waste is often dumped on streets and in uncontrolled dumpsites (Zurbrügg et al., 2007).

2.2 Solid Waste Management in Mekelle

Waste collection in Mekelle is performed regularly by cooperatives organized by the Municipal authority. Waste is collected every other day from house to house and later transferred to four transshipment stations: Adishumduhun, Ayder, Hadnet and Hayelom. When each station gathers a significant amount of material, it is collected and directly carried in containers to a central dump area.

There are no systems of waste segregation or recycling in place. In the central dump area (Figure 2), recognizable plastics are collected by hand and later incinerated with the intention of reducing the volume of waste and extending the dump's lifespan. Workers contracted for this task are submitted to subhuman conditions and compete for space with vultures, pigs, dogs and flies amidst an unbearably hot and malodorous environment.

2.3 Policy Recommendations

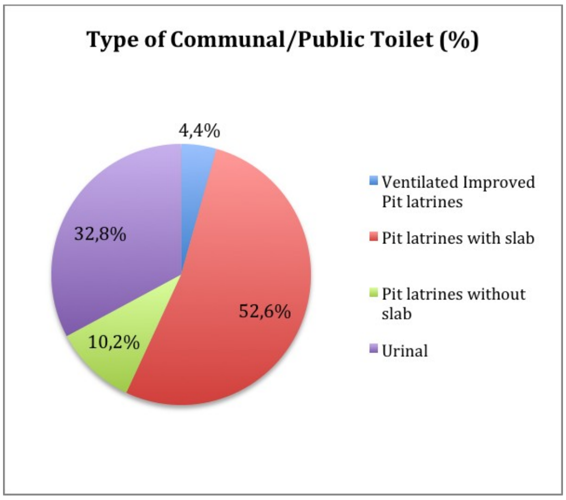
Specific measures must be taken to make the process of waste disposal less costly and ensure the proper functioning of institutional waste management in order to improve upon the current waste disposal technique (TADESSE et al., 2008).

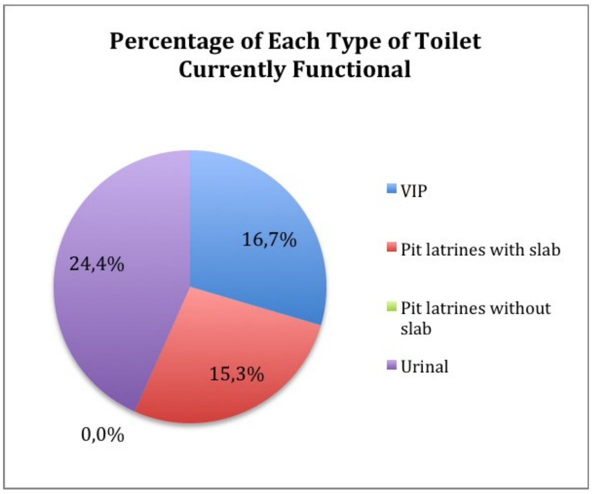
Mekelle City needs a structured and consistent plan on integrated waste management, which should incorporate different areas of public administration and civil society in the effort to clean, harvest, process and dispose of rural and municipal solid waste. A well-structured plan should consider who the main producers are, the total amount and type of waste, social, cultural and economic characteristics of the community as well as demographic, climatic and urban local peculiarities. These same factors vary across different communities, but they will help establish more adequate treatment and disposal of waste.

It is essential to identify the alternative technologies needed to reduce the ecological footprint that is generated from inefficient waste management practices. It is also important that technical solutions are consistent with the social and economic aspirations of the community so as to inspire and sustain contributors' support. Recycling, which is a crucial component of waste management, must be included in the plan as well.

3. Evaluation of Sanitation Facilities

Figure 3: Communal toilets (left) and currently functioning toilets (right).





All 25 communal facilities in 6 different districts in Mekelle were visited over the course of two days. The districts visited are Adhaqi, Hadnet, Hawelti, Kedamaywayane, Lemlemfaero and Sewhinguse. The majority of facilities consisted of pit latrines made from slab. There were numerous portable urinals as well, but they were usually closed. Ventilated pit latrines without slab or improved pit latrines were also seen but such sightings were relatively rare (Figure 3 - left).

Hygienic conditions were awful as a result of water shortages (Figure 4 - left). Sinks with flowing water were absent from all of the observed communal toilets. What little water was observed came from untreated rainwater, collected in barrels straight from rooftops and was reserved for anal cleansing (Figure 4 - right). Some toilet facilities charged an entrance fee of 2 ETB (approximately 0.10 USD). This fee granted entrance as well as 2 'hygienic' papers (used notebook sheets). An extra sheet cost 0.5 ETB.

The toilet structures were severely damaged or poorly constructed in the majority of locations visited (Figure 4 - left). There were virtually no cleaning or management systems in place and fecal overflows were a common sight. There was often openly visible defecation near many of the units.

Figure 4: Poor hygienic conditions (left) and rainwater collection from rooftops (right).

3.1 Zone Analysis

The number of toilet units situated in the district of Kedamaywayane, which consists of the more central area of Mekelle City, differs considerably from the number of toilets in other locations due to the high quantity of portable urinals in Kedamaywayane (Figure 5). However, as previously mentioned, many of these units were found to be inoperative when visited.

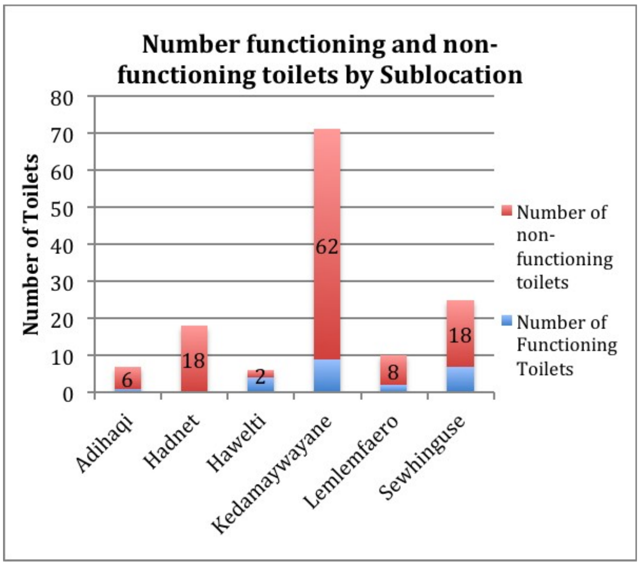


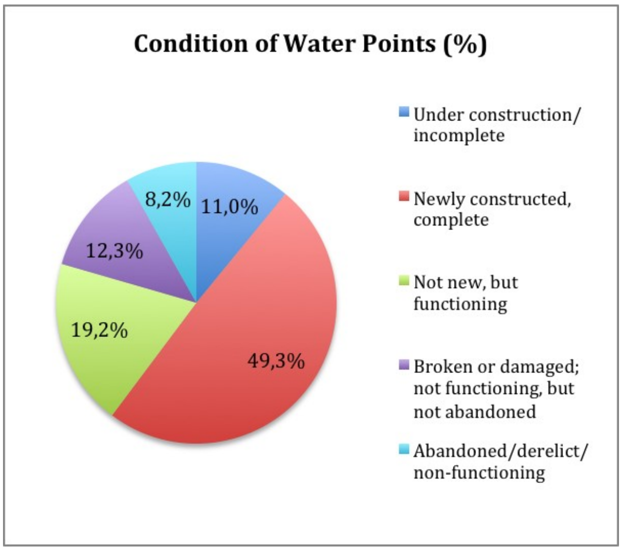
Figure 5: Number of functioning and non-functioning toilets by sub-location.

3.2 Water points

The main source of Mekelle City's water supply is ground water extracted from boreholes that range from 32-250 meters deep. The distribution system depends primarily on gravity, but the network also relies on pumps. Water is pumped to surface reservoirs where it's treated with chlorine and is then distributed to households (Castro and Maoulidi, 2009).

With the exception of the most central areas in Mekelle, water is not piped to households. Normally, water is provided through community water taps. Although these taps are situated strategically, a large number of these taps are non-working (Figure 6).

Figure 6: Water point conditions.



Residents typically collect and carry water, by hand, in 60 liter barrels; an arduous task exclusively carried out by young women (Figure 7 - left). When water is available, residents usually place their barrels forming a long line (Figure 7 - right). People are charged by barrel or bucket. There is one designated community member stationed at each water tap. This individual is responsible for the maintenance and administration of the tap.

Figure 7: Women carrying buckets by hand (left) and long cues for water (right).

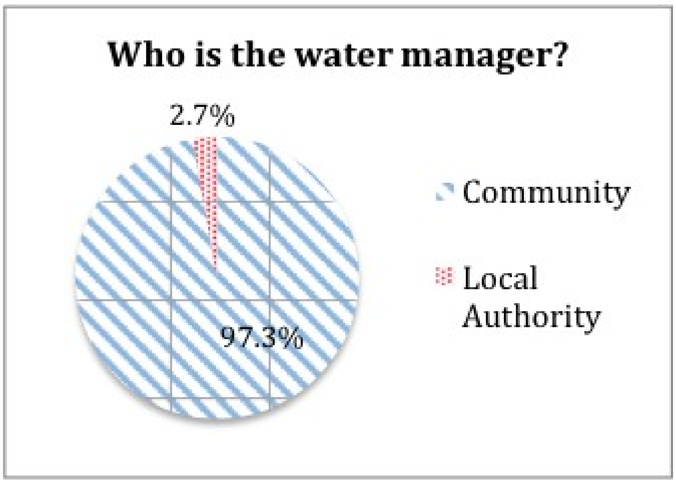
The municipality is mainly responsible for the development of the water points, locations where people collect water. As can be seen in Table 1, 95.9 percent of the water points are developed by the local authority.

Table 1: Water source developers.

Who Developed the Water Source?		
	Total Number	**Percentage**
Local Authority	70	95.9%
International	3	4.1%

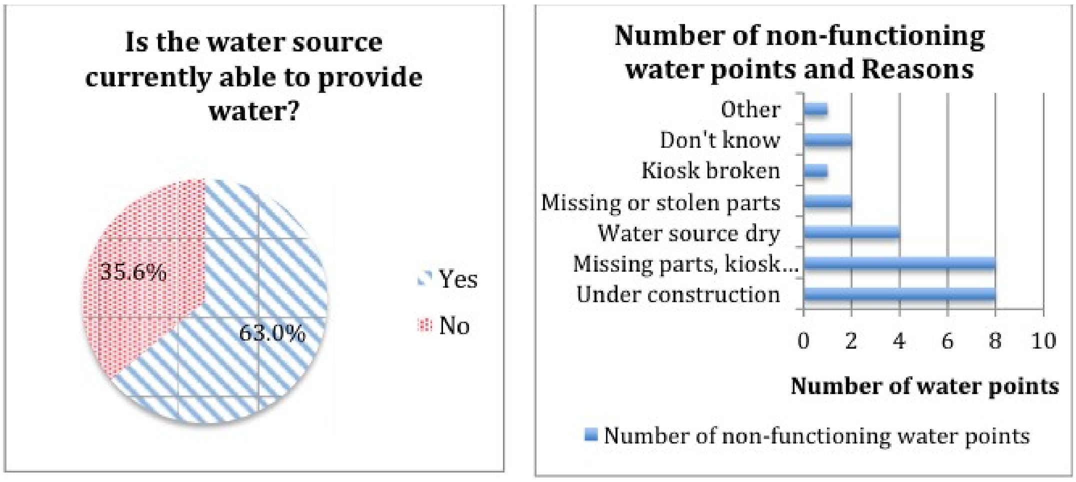
The local authority, Mekelle City Administration (MCA) is responsible for managing most water points, as depicted in Figure 8.

Figure 8: Water source managers.



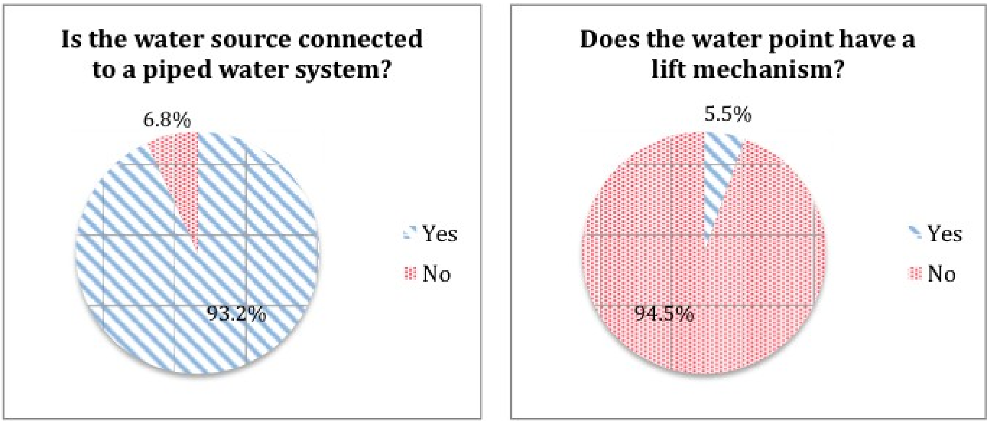
However, due to the lack of financial resources, there is a high number of non-operate taps. As shown in Figure 9 – left, 63 percent of the water points were unable to provide water. There are several reasons for this. In some cases, the water source was dry (15.4 percent), but there were also water points with missing or stolen parts (7.7 percent), kiosks that were broken (3.8 percent) and water sources that were missing parts (30.8 percent).

Figure 9: Water availability (left) and reasons for water unavailability (right).



The vast majority of water points were connected to a piped system (Figure 10 – left) although 94.5 percent of those water points did not have a lift mechanism (Figure 10 – right).

Figure 10: Water source piping (left) and presence of lift mechanism (right).



4. Capacity-Building – Technical Assistance

Figure 11: Original waste situation (left) and improved, compost-toilet situation (right).

The types of water supply and sanitation technologies that have been developed in industrialized countries are inappropriate for the 2.9 billion people in need of adequate water supplies and the 4.2 billion people in need of adequate sanitation by the end of 2025. These technologies are impractical because they are exceedingly expensive for communities in developing countries and because the amount of water required is not available. As a result, the main priorities for water supply and sanitation technologies are efficiency and affordability and that is what we have hoped to achieve with our pilot toilet (Mara, 2003).

A user of the pilot toilet system begins by depositing one's organic refuse (feces and urine) into a plastic, clay or other non-corrodible waterproof receptacle with a capacity of approximately 60 liters.

Sometimes, these systems are also called cartage systems or bucket systems (Figure 12 - left), as the manure is often carried to the compost pit, chamber or bin in buckets or other waterproof vessels. The feces and urine are kept covered with a clean, organic material such as sawdust, peat moss, or soil in order to prevent odors, absorb urine, and eliminate any fly-related nuisance and a lid is kept on the receptacle when not in use (Figure 12 - right). The only difference between the compost-based toilet and conventional toilets in industrialized nations is the use of wooden shavings instead of a flushing mechanism.

Figure 12: Bucket system (left) and sawdust covering (right).

When the bucket is full, it is carried to the composting area (Figure 13) and deposited into the pile (Figure 14 - left). The deposit is then immediately covered with a layer of clean, bulky, organic material such as straw or weeds to eliminate odors and trap air (Figure 14 - right).

Figure 13: Composting area adjacent to the toilets.

Figure 14: Emptying the full bucket (left) and covering with carbon rich materials (right).

The bucket is thoroughly scrubbed with small quantity of rain or wastewater and biodegradable soap, if available. A long handled toilet brush (Figure 15 - left) works well for this purpose. The soiled water is then poured (Figure 15 - right) on the compost pile (Jenkins, 1999).

Figure 15: Scrubbing the dirty bucket (left) and pouring the soiled water on the compost pile (right).

Food waste or animal manure can also be added to the pile to provide humidity and nutrients thereby improving the soil quality. The bucket is then returned to the toilet area. The inside of the bucket can be dusted with clean, dry sawdust after which it will be ready for reuse.

Drawbacks of this system include the inconvenience of carting buckets of excrement on a regular basis; having to look and smell the excreta (mixed in sawdust), having to clean the bucket after the emptying; and having to keep a supply of clean, organic material (e.g. sawdust, peat, clean soil, straw/hay, weeds or leaves) available for use as cover materials, which is absolutely essential to the success of this sort of system. Furthermore, when the bucket gets full, it cannot be used until it has been emptied regardless of any personal sense of urgency. There is a degree of conscientiousness and a sense of responsibility required for this composting system to work well.

The advantages include low financial cost in the creation of the facilities and low, or no energy consumption in its operation. Also, such a simple system, when the refuse is thermophilically composted, has low environmental costs, as little or no technology is required for the system's operation and the finished compost is a relatively benign material (Jenkins, 1999).

Large, non-biodegradable composting chambers are not required. Additionally, it is not necessary to have any composting facilities in or near one's living space. No electricity is needed and with the exception of the small amount of water required for cleaning purposes, no water is required.

The compost, if properly managed, will heat up sufficiently to kill all pathogens and can be used for gardening purposes. A complete natural cycle is maintained. Finally, the composting process is fast, because the organic refuse is converted quickly (within a few days) into an inoffensive substance that will neither attract rodents nor flies. The end result is less waste and a cleaner environment.

There are many people who cannot elect the convenience of more conventional forms of waste disposal, as they do not have access to electricity, running water, or garbage pick-ups. Consequently, there are many people who can gain from this thermophilic composting model (Jenkins, 1999).

4.1 Description of Capacity Building Project

Figure 16: Capacity building workshop.

The main objective of this project was to pilot a compost toilet system at Mekelle University's College of Health Sciences (CHS) in order to explore a sustainable and economical solution to the city's waste management issue and to establish a hygienic, user friendly toilet scheme at Mekelle University in Tigray, Ethiopia. The Project is divided into thee stages: 1. Planning; 2. Implementation and 3. Monitoring & Evaluation (M&E) and is taking place between July 2013 and September 2014.

During the planning phase, some background information was collected and the concept of heat composting was presented to the research team, which in turn, carefully created a logical framework (see appendix) that included specific objectives, outputs, activities, inputs, 'SMART' (specific, measurable, achievable, relevant and time-bound) indicators, risks and assumptions as well as a Gantt chart.

The second phase consisted of the construction of the compost toilets themselves, 8 in total, as well as the construction of aggregated structures or compost bins for excreta collection. The excreta include fecal material, urine, toilet paper and carbon-based cover material. The implementation stage aimed to mobilize an operations team and train users on how to deal with the whole system.

Lastly, the monitoring stage seeks to ensure the efficacy of the heat composting and evaluate whether or not it has killed disease organisms and can be used for the improvement of horticulture and vegetation at CHS in the form of soil. An objective of this project was to learn more about how to integrate decentralized, sustainable sanitation systems at Mekelle University.

5. Challenges, Best Practices, and Lessons Learned.

This project has served to highlight the importance of identifying, testing, validating and disseminating potential strategies, with a specific focus on technical and environmental effectiveness, affordability, and simple appropriation by local actors in different locations.

The incorporation of local agents was a critical component of achieving more effective participation and promoting a sense of autonomy within communities.

Development strategies for many large (national and international) agencies are decided upon by bureaucrats and politicians with little knowledge of and usually no experience in the countries they seek to help. Most guidelines for aid are based on the projection of conditions in donor countries and as a result, mostly fall short of achieving their objectives. Smaller organizations that require their workers to familiarize themselves with the country context and learn from their own, personal experiences have much better prospects of succeeding. These types of initiatives should be prototypes for organizations with sufficient funds to implement large-scale development programs (Molvaer, 2007).

6. Conclusion

The analysis shows that the major barriers to instituting efficient sanitation practices include current laws and regulations, the insufficient prioritization of water and sanitation schemes and a perception issue regarding the usefulness of water and nutrient schemes.

Additionally, the technical knowledge and skills required to motivate community members to accept and implement new technologies are inadequate. In many cases, ideas became more important than the physical aspects of a project.

Development is complicated and multifaceted. It is difficult to understand and even more difficult to undertake. Interaction between donors and recipients is indispensable because it is necessary to understand each stakeholder’s motives and objectives. Information, motivation and long-term education, in addition to training, are essential aspects of changing behavior.

The author believes that this solution is replicable in other, similar communities and that that the health bureau should take it upon themselves to validate, disseminate and promote composting-toilets.

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