SPECIFICATIONS AND DESIGN CRITERIA FOR A PACKAGING SANITATION SOLUTION FOR PERI-URBAN AREAS IN DEVELOPING COUNTRIES

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ABSTRACT

Elizabeth Morris: Specifications and design criteria for a packaging sanitation solution for peri-urban areas in developing countries
(Under the direction of Dr. Jamie Bartram)

2.6 billion people lack access to adequate sanitation which contributes to preventable diseases. The purpose of this thesis is to explore the feasibility of and develop specifications and design criteria for a packaging sanitation solution for peri-urban areas. Safe containment of excreta requires the packaging meet a storage period (4 weeks), a storage capacity (tertiary packaging storing 105 bags of individual defecations), gas permeations, odor control, and pathogen containment that were based on expected use and published research. Data from focus groups in Peru regarding preferences and willingness-to-pay (WTP) for sanitation indicated a WTP of $2.16 per month for a pit latrine but $5.42 for a flushing toilet. The proposed specifications are a primary bag that holds the excreta, a secondary bag that lines a tertiary unit, and a tertiary unit that provides the support structure for the user and storage for the used bags until final treatment and disposal.

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1.0 Introduction

In 2000, 189 member states of the United Nations joined in a commitment, called the Millennium Declaration, to a new global partnership to reduce extreme poverty (United Nations, 2010). Target 7.C of the Millennium Development Goals (MDG) is to halve, by 2015, the number of people without sustainable access to safe drinking water and sanitation (United Nations, 2010). The United Nations says countries are on-track to meet the MDG target for drinking water by 2015, but are in danger of not meeting the sanitation target. Considerable investment has been made in sanitation, yet a significant proportion of the world's population still does not have access to improved sanitation. The World Health Organization (WHO) and United Nations Children's Emergency Fund (UNICEF) estimates that about 2.6 billion people have either no access to sanitation facilities or access only to unimproved sanitation facilities (WHO and UNICEF, 2010). Roughly 30 percent of the population of Africa has access to improved sanitation. Although eighty percent of the populations of Latin America and the Caribbean have access to improved sanitation facilities, millions of people in those areas do not (WHO and UNICEF, 2010). Additionally, of the 2.6 billion people without access to improved sanitation, 72 percent live in Asia (WHO and UNICEF, 2010).

The absence of clean drinking water, sanitation and hygiene has been estimated by the WHO to cause 88 percent of all cases of diarrhea. Diarrheal diseases contribute to more than 1.5 million deaths per year, mostly among children (WHO and UNICEF, 2006). Diarrheal diseases due to unimproved sanitation cause the annual loss of 443 million schooldays worldwide (United Nations Development Programme, 2006). Providing sanitation can reduce diarrheal diseases by 36 percent (Curtis and Cairncross, 2003).

An important contaminant of water is fecal matter (Curtis and Cairncross, 2003). One of the best possible interventions to protect against diarrheal disease is providing water for hand-washing and sanitation (Curtis *et al*, 2000). Providing clean water without first providing a place to collect fecal matter and keep it out of the water stream is not always possible. The lack of sanitation also contributes to malnutrition, intestinal nematode infections and other diseases that could be prevented by implementing improved sanitation (WHO and UNICEF, 2006).

For every dollar invested in sanitation and water supply, benefits can be valued at between $5 and $46 (Hutton *et al,* 2007). It would cost an estimated $95 billion to achieve universal sanitation by 2015, but it would save as much as $660 billion (Hutton *et al*, 2007).

1.1 The Sanitation Ladder

The sanitation ladder is a way to categorize the type of sanitation accessible to a population. The ladder has four rungs: improved sanitation facility, shared sanitation facility, unimproved sanitation facility, and open defecation (WHO and UNICEF, 2010).

Improved sanitation facilities ensure hygienic separation of human excreta from human contact. Flush or pour-flush toilets that go to a piped sewer system, septic tank, or pit latrine; ventilated improved pit (VIP) latrines; pit latrines with a slab; and composting toilets are considered improved sanitation (WHO and UNICEF, 2010).

Shared sanitation facilities are used by two or more families. According to WHO and UNICEF, a sanitation technology must be private to be considered improved. Therefore, shared sanitation facilities are not considered improved, even if the technology is considered to be an improved sanitation facility (WHO and UNICEF, 2010).

Unimproved sanitation does not ensure hygienic separation of human excreta from human contact (WHO and UNICEF, 2010). A pit latrine is a common toilet technology found in developing countries and is considered safer than open defecation because the excreta are contained. While some pit latrines, such as the VIP latrine or the pit latrine with a slab, are considered to be improved sanitation facilities, not all pit latrines are considered improved because they can still result in exposure to pathogen-laden excreta, can attract insects, and can pose a safety hazard, since the user could fall into the pit. Open pit latrines (latrines without a slab or platform), hanging latrines, or bucket latrines are examples of unimproved sanitation facilities and are considered to be on the third rung of the sanitation ladder (WHO and UNICEF, 2010).

Open defecation, the fourth rung of the sanitation ladder (WHO and UNICEF, 2010), is practiced by 1.2 billion people (WHO and UNICEF, 2010). It is dangerous because it does not remove the possibility of human exposure to the large number of pathogens contained in the excreta. When open defecation occurs, flies feed on the excreta and carry some of it on their bodies. When flies land on food, they can leave small amounts of excreta that are later ingested by a human. Open defecation also can contaminate drinking water sources. In cultures that prefer to use water for anal cleansing, open defecation usually occurs near water sources that can become fecally contaminated through the practice of anal cleansing (WHO, 2011).

Many people believe children's feces are harmless and open defecation is a suitable option for children. The disposal of children's feces in open areas has been determined to be a significant contaminant in the household environment (Gil *et al*, 2004).

1.2 Peri-urban Areas and Sanitation Access

Peri-urban areas are informal communities commonly known as squatter settlements, marginal settlements, shantytowns, urban slums, or illegal settlements. Peri-urban areas are characterized by uncertain or illegal land tenure, minimal or no public services and facilities, low incomes, and a lack of recognition by governments. Peri-urban areas usually do not have electricity, water and sanitation systems, or other forms of infrastructure that are usually a government responsibility (Hogrewe *et al*, 1993).

Peri-urban areas use types of latrines that range from the unimproved to the improved. Latrines are often poorly constructed and not always used by all members of the community. In peri-urban areas with a constant, reliable water supply, it is possible to have pour-flush toilets. All types of sanitation technologies require maintenance through either the emptying of latrines and proper disposal of excreta or the care of the pipe system and its treatment site. However, in peri-urban areas, they are often poorly maintained and are a cause of disease (Hogrewe *et al*, 1993).

1.3 Community and Consumer Demand and Preference for Sanitation: Peru as a Case Study

Sanitation technology designs must respond to what people want, rather than what is believed they should have (Cairncross, 2004). A sustainable approach to meeting the need for sanitation in developing countries is to use social marketing (Cairncross, 2004).

Marketing has been successful in changing the behavior of people and their use of sanitation technologies when they can see the direct personal benefits (McKenzie-Mohr, 2011). Benefits of sanitation include improved health, convenience and comfort, privacy and safety, avoidance of sexual harassment for women and girls, dignity and social status (Cairncross, 2004).

While paying for sanitation is a household decision, it has benefits for the entire community. The individual household's sanitation solution is a private affair, and the household is willing to pay for its benefits (Cairncross, 2004). The other components of the system, such as final treatment and disposal of the wastes, affect the entire community and needs public management and maintenance (Cairncross, 2004). Social marketing is used to reach consumers and persuade them to buy and use sanitation technologies (McKenzie-Mohr, 2011). Social marketing ensures that people choose to receive what they want and are willing to pay for. Usually, a range of different products are needed to suit a variety of consumers and circumstances (Cairncross, 2004). There are both supply and demand aspects of sanitation that influence consumer and community choice and willingness to pay.

Using several communities in Peru as case studies, this thesis provides initial results regarding consumer demand and preference for sanitation on the basis of the value of different sanitation technologies to individuals in the communities. This study also provides a modified method to assess the value of sanitation by showing the influence of price on an individual's sanitation preferences.

In 2008, 68 percent of Peru's population had access to improved sanitation, with 81 percent of the population in urban areas having access to improved sanitation and 36 percent of the population in rural (including peri-urban) areas having access to improved sanitation (WHO and UNICEF, 2010).

Because sanitation designs must respond to what consumers want, focus groups on sanitation conducted as part of this thesis were used to estimate the value each individual placed on different sanitation technologies by determining an individual's Willingness-To-Pay (WTP) the cost of having different technologies in the household. WTP refers to the highest amount an individual is willing to pay for a hypothetical good or service. A common method to assess WTP is a survey-based field method called contingent valuation (CV). The CV survey estimates the WTP for a service, such as drinking water or sanitation, which is not traded in a conventional market. The survey analyzes a consumer's WTP for a service or commodity under a given condition or circumstance. Designing a hypothetical market scenario allows the elicited WTP values of a service or commodity to be estimated on projected demands for water and sanitation services and estimated tariffs and subsidies, and can identify needed improvements in the performance of utilities (Gunatilake *et al*, 2007). The World Bank, the United States Agency for International Development (USAID), and other funding agencies have taken an interest in CV studies as a means for assessing the demand for sanitation services (Alberini and Cooper, 2000).

1.4 The Use of Packaging for Sanitation

To reach the sanitation access target of the MDG sanitation, a range of effective solutions should be identified. Effective solutions could include making existing latrines better, more attractive to consumers, more accessible, and more affordable. In addition to traditional methods of sanitation, such as latrines and pour-flush toilets, there should be consideration of innovative alternatives and options, such as packaging solutions, urine separation toilets, and the possible use of excreta as fertilizer and energy, to ensure sanitation is affordable, is scalable and penetrates into previously unreached markets. Plastics and other packaging materials, while not widely used, are being tested as a solution to the sanitation problem. PeePoo bags, the Shit Box, and X-Runner (Section 2.3.2) sanitation solutions use plastics and other materials to provide consumers a safe place to defecate because they contain the excreta and prevent exposure of the excreta to both people and the environment. PeePoo Bags, X-runner, and disposal technologies such as bio-digestion and composting are also recovering value in the excreta by converting it into fertilizer or energy.

In peri-urban areas where there is a lack of water services and water can be expensive and not consistently available, packaging materials may provide a way to design sanitation technologies that do not require water or a piped infrastructure. The use of packaging materials is a potential option for excreta management in peri-urban areas because such materials are versatile and, once used, can be stored, and disposed of, in a variety of ways that limit human and environmental contact with the untreated excreta. Packaging options may be easy to store when space is limited. Also, methods exist or can be developed to treat or amend packaging materials so as to kill the pathogens in excreta.

1.5 Purpose

The purpose of this thesis is to develop specifications and design criteria for a packaging material solution for excreta management in peri-urban areas. Considering the peri-urban environment, the conditions for the solution included the ability to contain the excreta for disposal, potential for recovering value in the excreta, such as using it for fertilizer or energy, and avoiding the use of pipes and water. Preconditions for the development of the specifications and design criteria for a packaging material solution for the proposed sanitation technology are that it achieve containment, destroy pathogens and potentially result in value added residual material. In order to evolve towards a sustainable society, there is a need to use available nutrients and energy, reduce water consumption and minimize the energy needed to operate sanitation systems (Jenssen, 2002)

This thesis has six sections that lead to specification and design criteria for the three components of the proposed solution. Section 2 is a literature review of the properties of excreta, end-of-life options available for a packaging solution, and different types of toilet technologies currently available. Section 3 includes both the methods used to determine the properties of the optimal packaging solution and the methods used to form the focus groups that were conducted in Peru. In Section 4, the results of the properties of the optimal packaging solution and the data from the focus groups in Peru, showing that there are a variety of preferences that need to be taken into account for toilet design. Section 5 describes the design criteria of the proposed toilet technology and technology's benefits for peri-urban areas. The last section of this thesis contains summary comments on the proposed solution and discusses the steps for future research.

2.0 Literature Review and Background

2.1 Properties of Excreta

The chemical and biological properties of excreta are important to consider when designing a packaging toilet technology because the candidate materials used must be able to contain the excreta.

2.1.1 Urine

The average adult produces from 275mL to 2400mL of urine per day (Lentner, 1981). Urine is considered to be sterile due to its filtration through the kidneys; it is possible for it to contain some systemic, genitourinary, and enteric micro-organisms and can become further contaminated during collection, storage and handling (Schonning, 2002). Urine does not have as much odor upon excretion as it develops during the subsequent breakdown of the urea into ammonia and carbon dioxide (Niwagaba, 2007). Urine contains 94 percent of the nitrogen-phosphorus-potassium (NPK) that is found in human excreta (Niwagaba, 2007). The average adult human produces excreta containing 4.4 kg per year of nitrogen, 0.66 kg per year of phosphorus, and 0.81 kg per year of potassium (Polprasert *et al*, 1981).

2.1.2 Feces

Viruses, bacteria, protozoa and helminths are found in human feces along with limited beneficial nutrients that can be used as fertilizer. Viruses are the smallest infectious agents found in feces. The viruses found in feces include those not pathogenic to humans, such as bacteriophages, and those that are human pathogens of the gastrointestinal and respiratory tracts. Human pathogenic viruses are found in the feces of infected people even when they do not show symptoms (Melnick *et al*, 1978). Feces contain 150 types of pathogenic human enteric viruses, among them noroviruses, adenoviruses, Hepatitis A, Hepatitis E, and rotaviruses, capable of producing infections in people (Schonning and Strenstrom, 2004). For some viruses, such as enteroviruses, there is an increase of viral shedding during the summer months and a decrease during the winter. The reverse is the case for other viruses, such as noroviruses, which are more prevalent in the winter in temperate environments (Tasuke *et al*, 1978). Viruses can persist in the environment and travel great distances in water and soil environments (Melnick *et al*, 1978).

Many species of bacteria inhabiting the lower gastrointestinal tract are important to physiological processes and are not harmful to humans; however, high concentrations of pathogenic bacteria, such as *Escherichia coli, Salmonella, Shigella,* and *Vibro cholera*, are found in feces of infected people (Schonning and Strenstrom, 2004). For bacteria to reproduce, they need an appropriate environment. Fecally shed bacteria can survive and be transported in the environment depending on conditions such as temperature, salinity, pH and other factors (Roszak and Colwell, 1987). Bacteria also produce methane and other gases that cause odor. Feces produce a smell as a result of bacterial metabolic and degradation reactions (McNamara *et al*, 1972).

Unlike bacteria, protozoa, such as *Giardia intestinalis* and *Entamoeba histolytica*, do not reproduce in the environment outside of the host (Schonning and Strenstrom, 2004). The mature cysts can survive under a variety of environmental conditions and can be ingested through polluted water and food just as viruses and bacteria can (Barker and Brown, 1994).

Helminths, such as *Ascaris lumbricoides, Schistosoma*, and hookworms, cause high morbidity rates, but low mortality rates in infected humans (Schonning and Strenstrom, 2004). One to 2 billion people are infected with them (WHO, 2011), which cause faltering growth, decreased physical fitness, and, in children under age 15, reduced IQ levels (Scolari *et al*, 2000). The eggs of helminths can be viable for one to two months in crops and for many months in soil and water. Helminths can survive much longer in unfavorable conditions than other microorganisms can (O'Donnell *et al,* 1984).

Feces also have potentially beneficial and useful constituents. The average adult human produces 9.4 kg per year of organic carbon content. Carbon provides energy to help decompose excreta into fertilizer (Polprasert *et al*, 1981).

2.2 End-of-Life Options for Excreta

To prevent exposure and illness to pathogens in excreta, it is important that urine and feces be managed and disposed of in a safe and satisfactory manner (Nelson and Murray, 2008). When a latrine is used, waste is collected in a pit; when the pit fills up, it is either covered or the excreta are pumped out. If the filled latrine pit is covered, a new one must be built. The nutrients in the pit can be utilized by planting a tree over the site of the pit but this is not always possible in peri-urban areas because available space is limited. If the excreta are removed, the safest way to dispose of the excreta is through a municipal sewage system or by an alternative managed waste treatment process. Often, however, a managed waste treatment process is not available or not used, if available, and the waste extracted from pit latrines is not treated before being released into the environment.

2.2.1 Burning as a Disposal Method

In peri-urban slums, burning is a common method of getting rid of all waste because municipal trash collecting does not occur (Noji, 1997). Materials that are burned include household trash, such as plastics and paper products, and dried human and animal feces. However, burning trash produces smoke and toxic gases that can cause public health problems. The toxic chemicals released during burning include nitrogen oxides, sulfur dioxide, volatile organic compounds (VOCs), and polycyclic organic matter (POMs). Burning plastic and treated wood also releases heavy metals and toxic chemicals such as dioxin (United States Environmental Protection Agency, 2011). The released chemicals can cause ocular and nasal irritation, headaches, breathing difficulty, coughing, and other adverse respiratory health effects. People with existing respiratory diseases are more sensitive to these health risks. The chance of human health problems occurring depends mostly on the concentration of air pollutants in people's breathing zone (the air that is around the nose and mouth) (United States Environmental Protection Agency, 2011).

Even when managed trash collection or excreta removal is available normally, burning may be used in emergency situations, for instance natural disasters or refugee situations, when excreta and other refuse overwhelm the usual disposal alternatives. Burning removes the excreta quickly, preventing diarrheal diseases that might otherwise be caused by a lack of available sanitation facilities (Noji, 1997).

Burning can be used for excreta disposal in peri-urban areas because it does not require government investment, and is already commonly used for other waste disposal. It is not the most desirable option for disposal because of the effects on air quality. Furthermore, the need to reduce the moisture content of the waste prior to effective burning makes this a less feasible option for management of human excreta.

2.2.2 Bio-digestion as a Disposal Method

Bio-digesters, through the microbial breakdown of organic wastes in the absence of air, convert wastes such as human and animal excreta into useful by-products, such as a nutrient rich fertilizer or an energy source (Preston and Rodríquez, 2002). Bio-digestion helps to prevent contamination and disease caused by the use of untreated manure as fertilizer (SNV, 2010).

A bio-digester traps methane making it available for heating, cooking and electricity (Laichena and Wafula, 1997). It keeps methane from being vented into the atmosphere through the use of a dome and is a sustainable substitute for gas and firewood that is usually used for cooking and heating (Laichena and Wafula, 1997).

As excreta are processed in a bio-digester, the effluent that remains after gas production requires further treatment and then can be used as a high quality organic fertilizer that can be used safely on food crops (Gunnerson and Stuckey, 1986).

There are three main areas of application for bio-digestion in peri-urban areas: individual household units, community plants, and municipal plants. The feasibility of these different applications depends on the amount of excreta that can be added to the bio-digester and the economic benefits to the user to use the energy and fertilizer that is produced (Gunnerson and Stuckey, 1986). Bio-digesters can work well in warm climates and seasons but tend to work poorly in colder climates, unless an external heat source is used. Bio-digesters are best suited to rural areas where human excreta can be mixed with animal excreta (Gunnerson and Stuckey, 1986).

2.2.3 Composting as a Disposal Method

Composting is the biological decomposition of organic materials through the use of biologically produced heat. Composting has the potential to produce a product free of pathogens that can be beneficial when applied to the land (Jenkins and Curtis, 2005). The composting process occurs in two major stages. In the first stage, microorganisms decompose the composting feedstock into simpler compounds, producing heat as a result of their metabolic activities and reducing the size of the composting pile. Carbon is needed to provide energy for the decomposition to occur. In the second stage, the compost product is "cured" or finished. Microorganisms deplete the supply of readily available nutrients in the compost, which, in turn, slows their activity. As a result, heat generation gradually diminishes and the compost becomes dry and crumbly. When the curing stage is complete, the compost is considered to be stable and ready for use (Haug, 1993).

2.2.3.1 Home Composting

Home composting can be maintained by the household or community. It does not require transportation and collection that is organized by the government or private sector. Human excreta can be composted with vegetative and animal wastes; however, because of the excreta, extra curing time is needed to ensure that all of the harmful pathogens are rendered dead or inactivated. Wood chips or other bulk vegetative matter should also be added to the compost heap as a carbon source. The treated compost solids then can be used as fertilizer (Haug, 1993).

In peri-urban areas with more access to land, home composting could be an option; however, in areas with limited space, composting may not be feasible.

2.2.3.2 Municipal Composting

Municipal composting systems are increasingly being installed as a waste-management alternative to landfills. Municipal composting is a controlled form of composting but on a larger scale and generally better managed than home composting. The process is controlled in that it is managed with the aim of accelerating decomposition through increased heat, increasing the rate of pathogen inactivation. The rate of decomposition depends on the type of technology used as well as on such physical, chemical, and biological factors such as composting microorganisms present, oxygen levels, moisture content, mixing conditions, and temperature. Composting works best when these factors are monitored carefully and controlled (United States Environmental Protection Agency, 1994).

Environmental concerns involved with municipal composting include air and water pollution and odor. Many of these concerns can be minimized through the proper design and operation of a facility. Water pollution from leachate or runoff is a potential concern at composting facilities. Leachate is a liquid that has percolated through the compost pile and that contains extracted, dissolved or suspended material from the pile. Leachate generation can be reduced or prevented by monitoring and correcting the moisture levels in the composting pile. Compost piles do not usually produce air pollution, but many stages of the composting process release odorants into the air which can be a challenge to control (United States Environmental Protection Agency, 1994).

Municipal composting is not a feasible method in peri-urban areas for excreta disposal because it requires collection and transport as well as management in the form of maintenance and operations. There is usually limited collection and effective transport of waste in peri-urban communities. The handling of fresh excreta can be a danger to both the household and collectors. Municipal composting also requires local government or private sector investment for effective management and construction.

2.2.4 Landfill as a Disposal Method

Excreta can be disposed in landfills which are sites for waste disposal by burial. Proper landfilling of waste involves confining and covering it with material and therefore, requires earth moving equipment typically not available in peri-urban areas. Excreta disposal in unregulated landfills is less well managed and often associated with ground water pollution and vector attraction that can be a public health risk (Hass *et al*, 1996).

Landfills require a system of collection and transport of waste, usually are maintained by municipalities and governments, and need to be regulated to ensure environmental health and proper conditions. Because peri-urban communities often have their own dump sites which are not properly regulated or maintained effective management and operation of this type of system is rare in peri-urban slums (Zurbrugg and Schertenleib, 1998). Therefore, landfills are not a feasible option for excreta disposal.

2.2.5 Waste to Energy as a Disposal Method

Another method to treat bio-solids and municipal solid waste is to use it to produce electricity (Alter and Dunn, 1980). Waste to energy (WTE) facilities produce energy through the combustion of municipal solid waste in specially designed power plants equipped with pollution control equipment to reduce emissions. Trash volume is reduced by 90 percent (Alter and Dunn, 1980). The ash then can be used as part of a landfill cover or in road construction (Wiles and Shepherd, 1999).

There are additional benefits to countries implementing WTE. It helps to create employment, offers a reduction of dependency on outside energy sources, and provides better waste control by limiting the amount of trash that goes into a landfill. However, the investment in the technology required can limit the availability of WTE facilities in developing countries.

WTE for excreta disposal in developing countries could be feasible; however, due to its required investment of the government or private sector for management and construction, it is not a feasible option for peri-urban communities. The use of excreta in WTE plants also requires collection and transportation of the waste that is not usually available in peri-urban communities.

2.3 Toilet Technologies

The purpose for this section is to review the range of toilet technologies that might be considered for peri-urban areas or that have features that are relevant for a packaging toilet technology design. Flushing toilets were reviewed because they are on the top rung of the sanitation ladder, and latrines were reviewed because they commonly used in peri-urban areas.

Toilet technologies benefit the community through proper care of human excreta, ease of maintenance, protection for the health of the user and the community, and cultural sensitivity for usage. Not all toilet technologies have all of these properties.

2.3.1 Common Toilet Technologies

2.3.1.1 Flushing toilets

Figure 1: Flushing toilet

Flushing toilets are the most sought-after type of toilet technology (Austin, 2007). Flushing toilets connected to a sewage or septic system are the type of technology commonly used in developed countries and are considered to be the top of the sanitation ladder (WHO and UNICEF, 2010). However, flush toilets require infrastructure and government or private sector support that most peri-urban communities do not have. Flush toilets use pipes and water to carry the waste away from the user and use a water seal bend pipe to prevent odors.

Ideally, the toilet is connected to a septic system or to a sewage system that leads to a municipal wastewater treatment plant. The user does not exert much effort with this type of technology (Tilley *et al*, 2008). Some households use flushing toilets but do not have connections to a treatment system; those flushing toilets can lead to environmental and health problems similar to open defecation. Those flushing toilets remove the excreta from the household, but the excreta can still end up in a ditch, canal, or alleyway and be further disseminated in the environment. Depending on the type of treatment system used with the flushing toilet, anal cleansing materials are either deposited directly into the toilet to be flushed away or have to be disposed of separately. Durable anal cleansing materials, such as rocks and leaves, must be disposed of separately because they can cause damage to the pipes or can clog the system.

Flush toilets are easy to use because the user is not part of the end treatment. Once the user flushes the toilet, there is no more contact with the excreta. As long as the flush toilet is connected to an end-of-life treatment, there are health benefits, as the excreta are removed from the user and treated to reduce public health risks and undesirable environmental impacts.

2.3.1.2 Latrines

Figure 2: Basic pit latrine slab

Different types of latrines have different places on the sanitation ladder. Latrines in general can be built and maintained by a household. A latrine consists of a pit or two pits in the ground with a covering slab that also provides a place for the user to squat and can be changed and upgraded. Alternatively, the latrine can consist of one or two above ground vaults into which the waste is deposited, also with a covering slab or other flat surface for the user to squat or sit. The basic designs can be inexpensive to build. Latrine pits and vaults eventually fill up and must be emptied or covered; in some designs, especially with a single in-ground pit a new one must be built. Space must be available to build new latrines when the existing ones are filled unless the existing ones are emptied of their waste contents. Finding a way to empty the filled latrine can be a physical challenge. The contents of the latrine require treatment if the pathogens are to be killed. Latrines also do not remove the waste from the user and still leave the possibility of disease transfer (Tilley *et al*, 2008). The two pits or double vault system allows one pit or vault to be used while the other full pit or vault is cured and emptied. The two pit latrine requires a larger area for the latrine. Latrines are best suited for rural and peri-urban communities where there is appropriate soil for digging a place into which the effluent can be absorbed and the constituents of the excreta can be converted to less harmful or objectionable forms. In wet seasons, latrines can overflow, and their effluent absorption field can become saturated with water, thereby causing treatment failure that spreads harmful contaminants (Mohanty, 1993). A latrine is one of the least expensive options to build. There are health risks from flies and other insects that have access to the excreta in the pit or vault, but the risks can be minimized with a cover over the slab and the use of mesh over a ventilation pipe to exclude flies. A latrine can accommodate the different types of anal cleansing methods (Tilley *et al,* 2008). All anal cleansing materials can be discarded into the pit, but doing so can shorten the life of the pit and make emptying it and managing the waste more difficult.

2.3.2 Packaging Toilet Technologies

The purpose of this section is to examine existing sanitation technologies that use plastics and other packaging materials to contain excreta in both developing and developed countries. Packaging technologies differ from flushing toilets and latrines because packaging technologies self-contain the excreta and can be disposed of in different ways. Both PeePoo bags and the X-Runner also allow for disposal options that can use the excreta for its nutrients.

2.3.2.1 Flying Toilets

Flying toilets are most commonly used in Africa (Ricco, 2004). Plastic bags (e.g., grocery bags) are used to hold the waste. Once the user is finished with the bag, it is flung away. There are several benefits to the user with this type of technology. It removes the waste from the user and safely contains the waste immediately after use. However, once the bag is flung, there is a high chance that the bag will split open upon landing. If the bag breaks, other people could be at risk of coming into contact with the waste and disease could be spread. The flying toilets do not require any infrastructure, but this technology does not dispose of the waste in a safe and environmentally appropriate manner.

2.3.2.2 PeePoo Bags

Figure 3: PeePoo bag

PeePoo bags are a personal toilet that can be carried with the user. They are an elongated, slim bag with a thin inner layer of gauze that opens to form a tunnel. The gauze prevents the user from coming into contact with the excreta. The bag can be used while sitting, squatting, or standing. The inside of the bag is coated with urea, which is a non-hazardous chemical that is intended to make excreta usable as fertilizer (PeePoo Bags, 2011). Through an enzymatic reaction, urea breaks down some of the constituents in the excreta into ammonia and carbonate. This chemical change raises the pH of the waste in the bag, and pathogens die in the inhospitable environment (Wells and Varel, 2008).

The PeePoo bag is odor free for 12 to 24 hours after use (PeePoo Bags, 2011). It does not require immediate special storage after use and can be placed anywhere inside or outside the house. It does not require any water or pipes for use or additional infrastructure. According to Peepoople, the company that manufactures PeePoo bags, anal cleansing water can be deposited in the bag, but anal cleansing materials should be disposed of separately because they could influence the rate of decomposition of the bag (PeePoo Bags, 2011).

The bag is made of a degradable bio-plastic that disintegrates into carbon dioxide, water and bio-mass (PeePoo Bags, 2011). PeePoo bags can be buried after two weeks and provide a beneficial fertilizer to the soil.

There is no structure to hold the bag during use to make it easier for the user. The PeePoo bag creators suggest that users insert the bag into a small bucket or cut plastic bottle, but this option does not necessarily make it easier for the user due to the small opening.

2.3.2.2.1 PeePoo Bag Case Study

A consumer trial was conducted for PeePoo bags in Bangladesh by Mymensingh Municipality on the initiative and with the support of GTZ Good Urban Governance Bangladesh. A 10-day study was done with 100 users in poor, urban settlements of Mymensingh. A total of 738 PeePoo bags were used throughout the study. Participants were interviewed before and after the 10-day trial to provide a comparison of attitudes toward the PeePoo bags. This study was re-evaluated in this thesis to help determine the acceptability of a packaging option in developing countries.

The PeePoo bag consumer trial found a high acceptance and usage rate by participants, as only eight participants dropped out of the study. Participants also perceived the bags to be cleaner and more useful than other toilet technologies available in Mymensingh. Bags were typically used only for feces, even though they can hold feces and urine. An average of eight bags was used per participant as users claimed that they did not need to defecate every day (Jachnow, 2009).

There were some concerns about the lack of privacy with the bags. There was also some spillage due to the design of the bag and there being no secondary holder. After the field test, 88 percent of the participants indicated that the using the PeePoo bag had benefited them in some way. Twenty-eight percent of the participants cited that PeePoo bags allowed more frequent use of the toilet than their current technology. Eighty-one percent of the participants worried about storing the bags after use before they tried them (Jachnow, 2009). Without a secondary holder to conceal and store the bags, they would have to be stored openly in the house. There were some concerns about the lack of a collection system for the used bags. Fifty-three percent of the participants would not continue to use the bags unless there was a collection system (Jachnow, 2009).

The study also showed that 92 percent of the participants thought it was a good idea to produce fertilizer from excreta using the PeePoo bags, and 85 percent of the participants would be interested in selling their used bags for this purpose (Jachnow, 2009). However, the short length of the trial may not portray the long-term usability of the PeePoo bags accurately.

2.3.2.3 Shit Boxes

Figure 4: Shit Box

The Shit Box is manufactured by the Brown Corporation in the United Kingdom and is a collapsible, reusable toilet that is made from 70 percent recycled cardboard. A box can tolerate human body weights of up to 127 kilograms.

Excreta are collected into primary bags called poo bags. The poo bag contains the "P-Life" additive, which enables the bag to harmlessly degrade with the assistance of water and CO_2 over a fixed period of time (Shit Box Specification, 2011). "P-Life" is a catalyst which turns polymers such as polyethylene and polypropylene, considered as non-biodegradable polymers, into "Oxo-Biodegradable Plastics" (P-life, 2006). The poo bags have a short shelf life and will begin to degrade within one year even if they are not used. The poo bags are for one-time use only; these bags are biodegradable and can be buried, placed into a landfill, or burned. If burned, benefits are lost because of the pollution from the burning. The boxes have an opening at the bottom and cannot be used to contain the used poo bags. The Shit Box is easy to use and compact, as it folds up to save space. The Shit Box is not yet used as an option to provide excreta management to peri-urban communities. However when improperly used the outer, cardboard, support structure of the Shit Box can be destroyed easily through crushing or not being folded properly. The Shit Box also is sensitive to moisture. If left outside in wet conditions, the box can be destroyed. It is recommended for short-term outside use when the weather is dry (Shit Box Specification, 2011).

2.3.2.4 X-Runner

Figure 5: X-Runner

The X-Runner is a portable squatting toilet designed for individual households in poor urban areas where the population does not own land and lives in small crowded spaces, and a sewage system is not available.

Only feces are collected into a tank under the toilet surface. There is a seal on the tank to make it an odor-proof container and ensures that the feces are safely concealed. When the device is full, it is converted into a roll-able device that can be brought to a collection point where the feces are dumped by a household member. Collection points are public toilets or bio-digesters that process the feces into methane gas for cooking and lighting. Anal cleansing materials and water must be kept separate from the X-Runner, as it can only be used for feces (X-Runner, 2011). This technology does not require household infrastructure because water and pipes are not involved. The plastic container, using a static charge coating, repels urine and dirt to help keep the toilet technology clean.

The X-Runner does not provide a disposal option for urine or anal cleansing materials and water, which means households need another sanitary disposal method. This requirement also can make it difficult for women to use, due to the need to keep urine and feces separate.

2.3.3 Diaper Holders

Diaper holders are included in this thesis because they are plastic storage containers used to contain human excreta through the use of plastic bags. The Diaper Genie manufactured by Playtex and the Diaper Champ manufactured by Baby Trend both contain excreta by providing a place for diapers to be disposed. They both can be lined with trash bags or special odor containing bags that can be purchased separately. The main structure is hard plastic that is easy to clean and is meant to contain odor. The diaper containers have different flushing mechanisms though.

The Diaper Genie uses smaller primary bags that use the AIR-TITE® System, a multilayer film that uses antimicrobials to contain odor. Diapers are placed into a primary bag and then "flushed," which seals the diaper into the primary bag and moves the primary bag and diaper into the storage space (Chomik *et al*, 2008).

Figure 6: Diaper Genie

The Diaper Champ does not use a primary bag to contain the odor of the diaper. It only uses the liner bag. It is recommended by the manufacturer that the liner bag manufactured by Baby Trend be used. The bag is a multi-layered plastic that contains odor. Trash bags can also be used, which do not necessarily aid in containing the odor. The flushing mechanism is a cylinder with a handle, that when pulled moves the diapers into the bag below. There is no sealing mechanism as in the Diaper Genie.

Figure 7: Diaper Champ

Both the Diaper Genies and Diaper Champs require that their liner bags be disposed with the diapers in landfills. The bags are one-time use only and do not provide a way for the waste to be composted and used as fertilizer.

2.4 Conclusions

Excreta are made up of urine and feces and need to be managed through sanitation technologies and proper disposal to reduce exposure to the pathogens in excreta. Treatment and disposal of excreta occurring through bio-digestion, composting, and WTE allow for excreta to be used for fertilizer or energy. Excreta can also be disposed in landfills or burned. The traditional technologies for excreta management are the flushing toilet and latrines; however, more innovative technologies using plastics are being introduced. PeePoo bags and the X-Runner are products made of plastics and are designed for use in developing countries. The Shit Box is designed for developed countries and uses a cardboard support structure and bio-degradable plastic bags for temporary containment of excreta. The diaper holders discussed in this section are plastic units used to store plastic bags that contain human excreta.

Table 1: Packaging toilet options and their possible disposal methods

Disposal Method	Flying Toilets	PeePoo Bags	Shit Boxes	X-Runner	Diaper Holders
Burning	Possible if collected	Possible but would lose use of nutrients	Possible	Possible	Possible
Bio-digestion	Possible if collected and removed from bag	Not needed	Possible if removed from bags	Current disposal method	Not possible
Home Composting	Must be removed from bag	Possible	Possible	Possible	Not possible
Municipal Composting	Must be removed from bag	Possible	Possible	Possible	Not possible
Landfill	Possible	Possible but would lose use of nutrients	Current disposal method	Possible	Current disposal method
Waste to Energy	Possible	Possible	Possible	Possible	Possible

3.0 Methods

3.1 Demands on Packaging Materials

The goal of a packaging sanitation solution is to contain waste for a pre-determined length of time and to protect the user from the pathogens in excreta. Several requirements must be satisfied to achieve reliable safe containment of excreta through a simple configuration for the proposed toilet technology. These requirements are storage period, gas permeations, capacity restrictions, and odor control. These requirements were considered to be the most relevant to meet that goal based on user requirements for sanitation technologies.

Storage period was calculated based on two conditions: the time needed to kill the pathogens in feces and the storage capacity of the system components. The time needed to kill pathogens was determined from published results.

Gas permeations were determined to allow for the lowest possible release of methane to prevent explosions from a build-up of the gas (Demirbas, 2010). Published results were used to determine the gas permeation requirements.

Capacity restrictions were based on the amount of excreta produced by a user in one day to provide the minimum weight that a bag should hold. It was assumed that a person will urinate several times during the day and not all at once, as the average, healthy person urinates no more than eight times per day (Irwin *et al*, 2008). Because the average family size ranges from 4.8 people to 5.6 people according to a study conducted by the Population Council (Bongaarts, 2001), the calculations of the minimum capacity restrictions for the tertiary packaging storage unit were based on a family of five using the toilet technology option three times per day for seven days. The odor control was determined by considering additives that would neutralize odor-causing bacteria. A literature review was used to assess the best ways to control odor.

3.2 Case Studies in Peru

The method presented in this thesis followed the Contingent Valuation (CV) method to conduct a WTP study for water using a "bidding game" method (Gunatilake *et al*, 2007); however, this method incorporated the influence of cost on an individual's preference to create a better representation of a community's sanitation technology preference.

3.2.1 Case Studies

Peru was chosen as the case study location due to existing relationships between communities in Peru with the Engineers Without Borders, USA chapter at the University of North Carolina (EWB-USA, UNC). Three communities were identified to be included in the case study based on the difference in both their locations and their current water and sanitation systems: Ciudad de Dios, Cerro Blanco, and Altivas Canas.

Meetings with the community leaders established background knowledge on the amount of government support for services and programs received by the community and the overall community sanitation, trash disposal, and water situations. Also, permission to conduct the focus groups was sought and granted during the meeting (Appendix C).

The focus groups were conducted for nine days over a three-week period in July, 2010. Each focus group contained from four to nine participants for a total of 68 participants who voluntarily took part in the study. Participants were recruited by holding community meetings and through the aid of the community leaders. Participants were over the age of 18, both male and female, and used different types of sanitation technologies. Two all-male and two all-female focus groups were conducted in each of the communities. Each focus group was performed at a time that minimized interference with the householders' daily activities (work, household chores, etc.). Permission was requested at the beginning of each focus group for the sessions to be recorded. The moderator used a script to ask open-ended questions to the participants. The moderator asked follow-up questions depending on the type of answers that were given (Appendix A).

3.2.2 Survey Structure

Focus groups were organized in three communities in Peru. Each focus group encompassed two sections. One section was arranged to obtain a profile of the community's demographics and current sanitation practices. Focus group participants were asked about their current types of sanitation technologies, household abilities to provide types of sanitation, preferences regarding sanitation, the importance of sanitation, and waste disposal. The other section implemented the modified WTP method to assess a community's value of sanitation by evaluating the relationship between the monthly costs to sustain sanitation with an individual's purchasing choices (Appendix A).

The modified method used for the last section of the focus group was an adaption of the CV survey that simulated a market economy to project how costs affect an individual's value for a commodity. The situation proposed that the local government provide subsidies for building the toilet technology as long as each household in the community paid a monthly fee to uphold it. In addition to open defecation, the four options of sanitation technologies offered to the groups were (1) a basic pit latrine, (2) a VIP latrine, (3) a squatting toilet with water, and (4) a flushing toilet (Appendix B).

Based on information from the community leaders, each type of sanitation technology was given a base price. The pit latrine was given the lowest monthly rate, and prices increased in increments of one sol for the VIP latrine, squatting toilet with water, and flushing toilet respectively. If a majority of the participants chose the flushing toilet, the prices for each technology were raised by one sol in the next round. If the majority chose a technology below the flushing toilet, the prices were lowered by one sol. The method was repeated until the maximum prices for each technology were reached. Four to eight rounds were performed for each focus group.

The method was developed at the University of North Carolina but had to be modified in Peru due to the differences in the colloquial language and formal Spanish. The Institutional Review Board (IRB) of the University of North Carolina approved the use of human subjects for focus groups in Peru (Study #: 10-1060).

3.2.3 Data Analysis

The recordings of the focus group discussions were transcribed and translated. Individual participants were not identified for the first section and were identified with a number for the second section regarding WTP.

The data were coded by organizing each question into a separate spreadsheet to calculate the frequency distribution of the responses. The responses were aggregated by gender and community. The spreadsheet consisted of columns labeling each community and gender and rows of possible responses given by participants. To determine the frequency distribution of a response, a “1” was marked when the response was mentioned by a participant in the focus group, and a “0” was given when the response was not mentioned.

In order to determine a frequency distribution to open-ended questions, a list of all the responses given in the study was made. From the full data set, similar responses were compiled into smaller subsets. The subsets were determined by the type of the answers given to a particular question. A spreadsheet was made, comparing community and gender versus participant responses.

The modified WTP was coded by making a spreadsheet with columns labeled: person identification number, focus group number, gender, community, number of participants in the focus group, number of participants participating in the method, round number, technology type, and the price of the technology in the particular round. A participant’s highest bid for the particular technology was recorded in the spreadsheet. A participant could be counted for a maximum of four times in the spreadsheet: a participant could have chosen each technology during the survey due to the price fluctuations in each round.

The relationships between WTP and community (as well as between WTP and gender) were examined using two types of statistical methods, since the price for a particular technology was neither sufficiently continuous nor comprised of few categories. For the first method, the price participants were willing to pay for a certain technology was treated as a categorical variable. The association between community and price was assessed with a Mantel-Haenszel Row Mean Score chi-square test. This test allows for assessment of the relationship between two categorical variables (e.g., community and price) after adjusting for other factors such as technology type or gender. The Row Mean Score statistic was calculated using modified ridit scores, which allow for categories of bid price that are not necessarily equidistant (e.g., if price categories were 2, 4, and 5 soles, modified ridit scores do not treat the distance between 2 and 4 the same as the distance between 4 and 5 soles).

The second method was a parametric analysis using Analysis of Variance (ANOVA). This method treats price as a continuous variable, and appropriate statistical tests assessing the relationship between average price and other factors can be conducted. Additionally, pairwise comparisons of different communities for each technology type were conducted. Factors were treated as nested effects if the factor was not present for all levels of another factor (e.g., all three technology types were not available in all three communities). Unlike the first method, ANOVA method assumes price follows a normal distribution and the independence of the individuals in the study. Due to modest sample sizes, the focus group method, and the strong possibility of correlation among individuals, these assumptions may be unverifiable and the Mantel-Haenszel analysis (which does not make those assumptions) may be preferred. All analyses were conducted using SAS 9.2 (SAS Institute, Cary, NC).

4.0 Results

4.1 Analysis of the Demands on Packaging Materials

The materials should have a sufficient storage period, allow for gas permeations, have a certain capacity, and provide control odor. It was decided that the use of plastic bags and plastic storage container would be able to meet these demands over the use of other materials such as paper and cardboard. They have a high strength-to-weight ratio, versatility, non-toxicity and durability at a relatively low lifetime cost compared with other materials (Andrady and Neal, 2009).

4.1.1 Storage Period

The storage period for the primary and secondary bags is determined, primarily, by the time needed to kill the pathogens in feces. Urea combined with water in the excreta produces ammonia which makes conditions within the bag too basic for pathogens to survive (Wells and Varel, 2008). It takes two to four weeks for the urea to kill the pathogens including *Ascaris* depending on temperature and the concentration (Nordin *et al*, 2009b). It has been reported that *Ascaris* eggs in feces were not inactivated in temperatures below 14 ^{o}C, even when urea is used (Nordin *et al*, 2009a). The pH inside the bags would have to be maintained for urea to produce ammonia. There is evidence that urea and its hydrolysis ammonia are not that effective at rapidly inactivating some viruses or Ascaris eggs, especially at lower temperatures (Nordin *et al,* 2009a). A urea lining on the primary bags would achieve the preliminary removal of pathogens. End of life treatment would be necessary to kill all pathogens in excreta. Thus, while, the secondary bags should be emptied as needed from the tertiary container, the design criteria should be for them to be stored in the tertiary storage unit for one week, and then disposed, even though not all of the pathogens will be inactivated. Biodegradable and compostable bags should not begin breaking down in the compost pile for 2 for 4 weeks. That will allow for households that do not remove the primary packages every week and prevent the decomposition of the primary bag before its removal. This time consideration was included in the storage period to ensure there was some initial pathogen inactivation.

4.1.2 Gas Permeations

Feces produce methane and other noxious gases, which can be explosive when their concentration rises above 15 percent of the air (Demirbas, 2010). When the primary bag is first sealed, there must be enough oxygen present to ensure the initial methane concentration is less than 15% of the air. The primary and secondary packages must allow for adequate gas permeation, once the packages are sealed to ensure the safe concentration levels of methane gas within the bags and the tertiary unit and limit the risk of explosion and to prevent the dissipation of both odor and ammonia. The tertiary storage unit is not air tight because it should have a lid that can be lifted when in use allowing for ventilation.

4.1.3 Capacity Restrictions

A healthy adult human produces 1 to 2 liters of urine daily and approximately 49 liters of feces annually or 100 to 200 grams per 24 hours (Niwagaba, 2007). Eighty percent of the population releases feces one to two times daily. Feces are 80 percent water, which is important for the urea to react with to produce ammonia. Diarrhea can cause a person to produce more than 200 grams of feces per 24 hours and can have water concentrations higher than 80% (Varnholt, 2010).

Overall, the primary material must be able to hold a minimum of 200 grams of feces and up to 2 liters of urine to ensure the bag does not rip after it is filled. The primary bags are one-time use and are meant to hold both urine and feces. Each primary bag must hold daily production of feces and part of the daily urine amount but are designed to hold the total amount of total daily production of urine. This capacity allows for the extra weight of diarrhea and anal cleansing by-products. Depending on the culture, water or toilet paper is commonly used for anal cleansing. The bags should allow for the direct disposal of the anal cleansing by-products along with the excreta to ensure that all waste is properly contained and disposed of safely.

The tertiary storage unit must hold one week's worth of excreta production by a family. Based on a family of five using the toilet three times per day, the tertiary storage unit must be able to hold 105 primary bags. The primary bags are flushed into a larger secondary bag which serves as a liner in the tertiary storage unit. The secondary bag should hold a minimum of 15 primary bags to allow for portability. Once the secondary bag is full at the end of one day of use, it can be sealed and stored within the tertiary storage unit. At the end of the week, the secondary bag can be removed to the end of life treatment available to the household.

4.1.4 Odor Control

The odor produced by feces must be contained as part of a packaging solution. Anti-microbials can be used to control odor (Zweifel *et al*, 2009). As bacteria are killed, odor production stops. In addition, it might be possible to help control odor through the use of an external ventilation pipe.

4.2 Results of Case Studies in Peru

4.2.1 Community Profiles

4.2.1.1 Ciudad de Dios

Ciudad de Dios is a small community of about 70 families of Trujillo, Peru. Although children attend primary and secondary school, most adults in the community have a primary school education. The main sources of income in the community are agricultural labor and small-hold farming with an average income between 150 to 300 USD per month.

With the help of Moche, Inc. and EWB-USA, UNC, a water system connecting the houses to a nearby natural spring was installed in Ciudad de Dios in 2008. To obtain water from its household tap, each family paid five soles (1.81 USD) to connect to the water line and three soles (1.08 USD) a month to maintain it.

Residents of Ciudad de Dios currently use pit latrines and VIP latrines. Residents without sufficient income for supplies to construct a latrine use either open defecation despite the threat of disease or a neighbor's latrine. The community also has public facilities with squatting toilets located next to the public school. The public facilities are kept locked because there was a lack of maintenance of the facilities by the users.

4.2.1.2 Cerro Blanco

Cerro Blanco is an economically divided community located approximately two km from Ciudad De Dios on the outskirts of Trujillo, Peru. Cerro Blanco consists of 100 families whose average household incomes range between five and a few hundred USD a month despite education levels similar to those in Ciudad De Dios. The main source of income is from agricultural labor and store ownership. Most children receive at least some secondary school education.

Cerro Blanco has a water system that is supplied by a natural spring approximately five km away from the community. Households have individual taps and pay two soles (0.72 USD) per month for unlimited water. To cover the initial implementation and building costs of the system, each family paid either 470 soles (169.68 USD) or donated 47 work days to help build the system.

Cerro Blanco has a flushing toilet at the Women's Clinic. Some families utilize a VIP, but most families use pit latrines or open defecation because of a lack of incentives or subsidies from the government. About 20% of the households in the community have access to latrines.

4.2.1.3 Altivas Canas

Altivas Canas is a 250 family community located near Cusco, Peru. Because Cusco, due to tourism, has a larger economy than Trujillo, both males and females in Altivas Canas are able to find work in the city as day laborers and taxi drivers. The average household income is approximately 140 dollars per month.

Altivas Canas is in the process of building a new water system with the help of the local municipality that will provide water to each home. Currently there are two public taps in the community. Each family presently pays six soles (2.17 USD) per month to receive four buckets (approximately 20 gallons) of water per day from the public taps.

According to community leaders, every household in the community has a pit latrine, squatting toilet with water, or a flushing toilet. Currently, the most common types of sanitation technology used in Altivas Canas are flushing and squatting toilets with water. Open defecation is still a problem among children. The community does not maintain public sanitation facilities since all families have access to household sanitation facilities.

Table 2: Characteristics of test communities that were part of the case study in Peru

	Ciudad de Dios	**Cerro Blanco**	**Altivas Canas**
Number of Families	70	100	250
Income Level (per month per household)	$150-$300	$5-$300	$140
Main Sources of Income	Agricultural labor and small-hold farms	Agricultural labor and store ownership	Day labor and taxi drivers
Payment for Water (per month)	$1.08 for unlimited water	$0.72 for unlimited water	$2.17 for 4 buckets of water per day from a public tap
Types of Sanitation Technologies Used	Pit latrines, VIP latrines, pour flush squatting toilets with septic tank, open defecation	VIP latrines, pit latrines, flushing toilets, open defecation	Pit latrines, pour flush squatting toilets with septic tank, flushing toilets

4.2.2 Results from Case Studies in Peru

4.2.2.1 Sitting vs. Squatting

There was no precise quantification of the proportion of individuals who preferred one option over another and that therefore, the recorded preference is based on which option was chosen by the focus group as a consensus or majority choice. In Ciudad de Dios, Cerro Blanco, and Altivas Canas, all of the women's groups preferred to have sitting toilets. In Ciudad de Dios and Cerro Blanco, the men's groups preferred to have sitting toilets, while the men's group in Altivas Canas preferred to have squatting toilets.

According to the women's group in Cerro Blanco, sitting does occur on the earth or on a grate positioned over the hole, but the men in Cerro Blanco said only squatting occurs. There is a third method of sitting that is done on four poles that are positioned to provide support for someone using the toilet in Cerro Blanco. The men in Altivas Canas did not answer the actual method used in their community, but according to the women, squatting is used the majority of the time by both men and women in the community. Both men and women in Ciudad de Dios said the method used was squatting.

Table 3: Preferred method of toilet usage

	Ciudad de Dios	Cerro Blanco	Altivas Canas
Women	Sitting	Sitting	Sitting
Men	Sitting	Sitting	Squatting

4.2.2.2 Location Preference

The focus groups showed no preference for inside or outside latrines. The focus groups reported advantages and disadvantages to both options.

According to the women's groups in Ciudad de Dios, there were three main advantages to having toilet technologies indoors: a constant renewal of water because it would be connected to the water system, no worries about light, and the toilet technology would be kept cleaner. However, the women in Ciudad de Dios were worried about possible contamination and illness, a lack of space in their houses, and flies by having a toilet technology inside. The men's groups in Ciudad de Dios stated that having toilet technologies indoors would be safer at night and more convenient.

The women's groups in Cerro Blanco thought that toilet technologies indoors would get rid of the need for disinfectants, but they were also worried about insufficient water and money for an indoor flushing toilet. According to the men's groups in Cerro Blanco, toilet technologies indoors are safer at night, more convenient, do not attract animals, and give more privacy; they noted disadvantages as a lack of space indoors and odor.

The Altivas Canas men's group did not participate in answering questions about the advantages and disadvantages of having toilet technologies indoors. The women's group stated that having a toilet technology indoors would be more convenient, but would be expensive.

The women's groups in Ciudad de Dios thought that the advantages to having a toilet technology outdoors would be more ventilation. The men's groups in Ciudad de Dios stated that an advantage of outdoor toilet technologies is that they have fewer odors. They also described several disadvantages: outdoor toilet technologies can cause contamination and illness, someone could fall into the pit, there is limited safety at night, weather could cause overflow or prevent the usage of the toilet technology.

According to the men’s groups in Cerro Blanco, toilet technologies outdoors had fewer odors, more space, and kept bugs out of the houses. The women’s groups in Cerro Blanco stated that outdoor toilet technologies had bad odor, and they were worried about excreta contaminating the area.

The women’s groups in Altivas Canas stated only disadvantages for outdoor toilet technologies: contamination and illness, limited safety at night, the lack of privacy, and attraction of animals.

Table 4: Advantages and disadvantages of having toilet technologies (inside or outside)

	Ciudad de Dios		**Cerro Blanco**		**Altivas Canas**	
Inside	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
Advantages	Constant renewal of water, more light, cleanliness	**Safer at night, more convenient**	No need for disinfectants	**Safer at night, more convenient,** does not attract animals, privacy	**More convenient**	No response
Disadvantages	**Contamination and illness, lack of space,** attraction of insects	No response	Lack of available water, **expensive**	**Lack of space indoors**, odor	**expensive**	No response
Outside	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
Advantages	More ventilation	**Fewer odors**	No response	**Less odor**, more space, bugs were kept out of the house	No response	No response
Disadvantages	**Contamination, illness, possibility of falling in, limited safety at night, weather**	**Contamination, illness, possibility of falling in, limited safety at night, weather**	Bad odor, **contamination**	No response	**Contamination, illness, limited safety at night**, lack of privacy, animals	No response

4.2.2.3 Anal Cleansing Method

The preference for anal cleansing in all three communities is toilet paper. This question always made the participants in the focus groups laugh. They could not imagine not using toilet paper and thought the question was silly. However, once the moderator asked some clarifying questions, different anal cleansing methods were mentioned when toilet paper was not available. The alternative anal cleansing materials to toilet paper that were used were stones or newspaper.

4.2.2.4 Other Considerations in Peru Case Studies

According to the participants of the focus groups, children begin to use the toilet technology of the household by the time they are 6 years old. However, it is common in every community that participated in the focus groups that children use the outdoors away from the community or the street for urinating and defecating. It is also common for children to use a slop jar or basin inside the house that is emptied into the toilet technology or dumped outside.

4.2.3 Results of Willingness-to-Pay Case Study in Peru

Analysis of the data derived from the modified WTP method show that participants are willing to pay no more than 6 soles (2.16 USD) per month for a pit latrine but are willing to pay up to 15 soles (5.42 USD) per month for a flushing toilet (Figure 8). Two main differences between responses given by males and females are the type of technology each gender prefers and why they value these technologies. When comparing technology preference, 76% of women are willing to pay a monthly amount to have a flushing toilet and 8% of women are willing to pay for a squatting toilet with water; whereas 30% of men are willing to pay a monthly amount to have a flushing toilet and 32% are willing to pay for a squatting toilet with water (Figure 9). Women are only interested in the pit latrine or squatting toilet with water when the monthly rate for the flushing toilet is too high; however, men in all three communities value the squatting toilet with water as well as the pit latrine. Some men in Cerro Blanco and Ciudad de Dios also mention that the squatting toilet with water is their preferred method of sanitation over the flushing toilet. Participants in Altivas Canas are only willing to pay monthly rates for a flushing toilet.

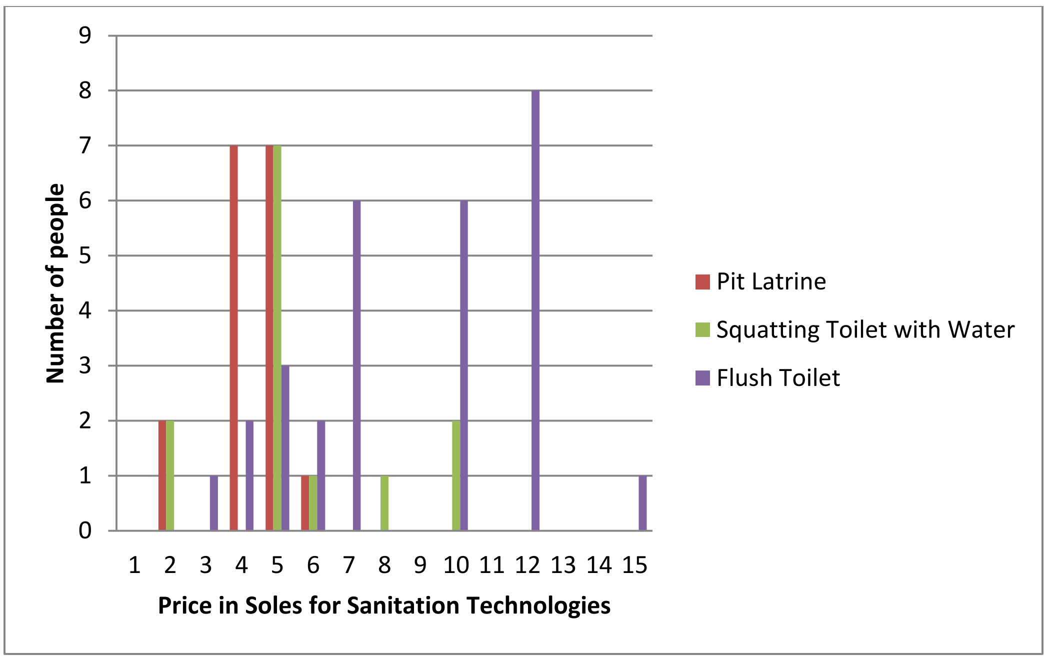

Figure 8: The frequency distribution of the price participants are willing to pay for sanitation alternatives

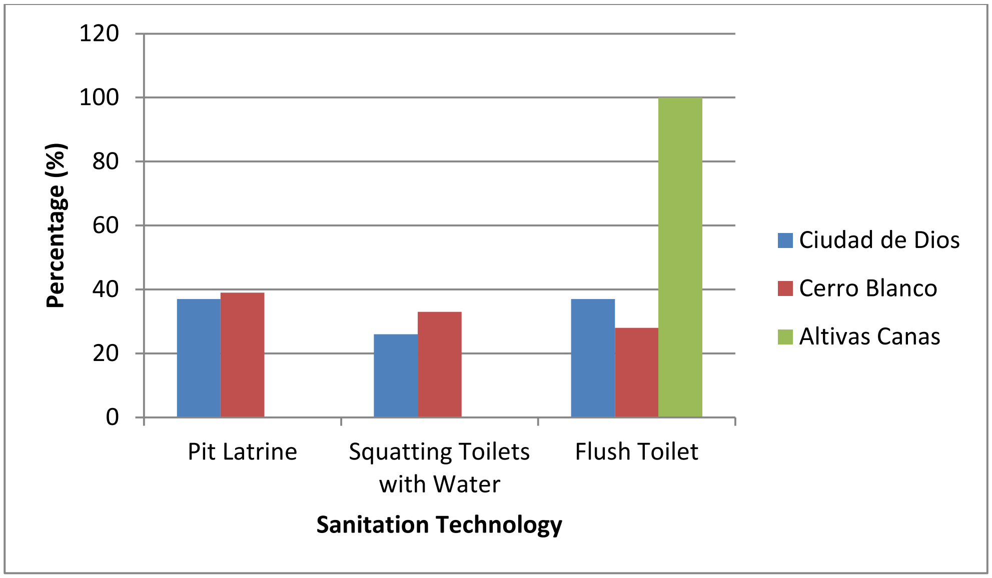

Figure 9: The percentage of community members who are willing to pay for sanitation alternatives

Ciudad de Dios and Cerro Blanco focus groups are willing to pay a monthly rate for all three technology models whereas Altivas Canas focus groups are only willing to pay for a flushing toilet (Figure 10). When asked, participants from Altivas Canas commented that all households currently had a pit latrine or squatting toilets with water, thus it was irrelevant to simulate monthly costs to maintain them.

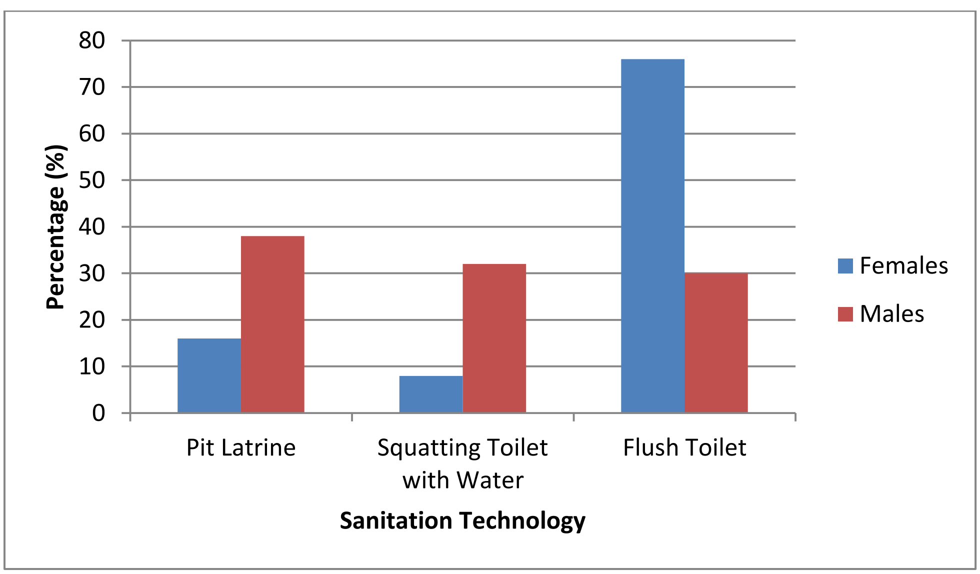

Figure 10: The percentages of females vs. males willing to pay monthly rates for sanitation alternatives

4.2.3.1 Statistical Analysis of the Results from the WTP Case Study in Peru

Responses from forty-one individuals were available for the analysis. Means and maximum prices for each technology (by community and gender) are presented in Table 1. Generally, average bid prices are observed to increase as one moves from the pit latrine up to flushing toilet. In Ciudad de Dios, both men's groups had similar prices they would be willing to pay for the pit latrine and squatting toilet. Men in this community indicated a higher average bid price for flushing toilets than women. In Cerro Blanco, the men in group 6 tended had average bid prices higher than the men in group 7 for squatting toilet (9.3 vs. 5.0) and flushing toilet (10.0 vs. 6.0). Women in Altivas Canas had the highest observed average bid price for the flushing toilet in the three communities. Generally, the individual with the maximum bid price in the group mirrored the average bid price for the group.

Using the non-parametric statistical analysis methods, and controlling for technology type and community, there was no statistical association between gender and WTP ($p=0.1248$). However, when controlling for technology type and gender there was a statistical association between community and WTP ($p=0.0254$).

In an ANOVA model which adjusted for technology type (as a nested effect within community), community, gender (as a nested effect within community), all three factors were associated with average price ($p=0.0022$ for technology type, $p<0.0001$ for community, and 0.0356 for gender). In examining further differences by community, adjusted for gender, statistical differences in the average bid prices for Ciudad de Dios and Cerro Blanco were not found for a pit latrine ($p=0.9897$), squatting toilet ($p=0.4799$), or flushing toilet (0.2948). However, there was a statistically significant difference between the average bid price for a flushing toilet between Altivas Canas and the other two communities ($p<0.0001$ for both comparisons). In examining further differences by gender, no pairwise statistical differences in average bid price between men and women were found in Ciudad de Dios ($p=0.1054$) or Cerro Blanco ($p=0.8992$) after adjustment for technology type. In summary, while both the non-parametric and parametric analyses support the association between community and WTP (after adjustment for gender and technology type), this association appears to be reflected in a higher WTP for a flush toilet in Altivas Canas than the other two communities. However, the association between gender and WTP, adjusted for community and technology type, is supported by the parametric model and not by the non-parametric analysis. Since the statistical assumptions of the parametric model may not be satisfied, the non-parametric analysis results may be better regarded.

5.0 Discussion

5.1 Case Studies in Peru

The advantages of the method presented include its flexibility. Open ended questions give the method the ability to adapt to a community's concerns by allowing participants to voice their opinions on their living standards in addition to their future projects to achieve sustainable sanitation.

The method presented uses focus groups, rather than one-on-one surveys conducted by local enumerators. The time required for one-on-one surveys permits the survey to be discussed and participants can be influenced by others in the community to make pre-formed judgments (Alberini and Cooper, 2000). The use of focus groups allows the research team to see the interactions between community members and understand how participants are being influenced.

The focus groups were held on a voluntary basis; thus participants who attended the focus groups tended to already have a predisposition for sanitation. Some of the participants were also family members or close friends of the community leaders. These factors might have led to biased responses and might not be truly representative of their communities.

5.1.1 Sitting vs. Squatting

The answers provided by the method also present differences between male and female respondents. There was a distinction between genders for preferred sanitation technologies. Some males in each community commented on their preference for squatting toilets with water to flushing toilets due to its comfort and costs whereas females unanimously agreed that the flushing toilet is a better option for their comfort and convenience. The data presented in this thesis are qualitative and therefore it was not possible to perform conventional statistical analysis as could be done for quantitative data.

5.1.2 Anal Cleansing Method

Toilet paper is the preferred preference of the participants in the focus groups, regardless of gender and community. Water was not mentioned as a method of anal cleansing in any of the communities. However, water is a method used in other parts of the world and must be taken into consideration for toilet design.

Anal cleansing materials that are disposed of separately can still be fecally-contaminated, and the spread of disease remains possible should the materials not be disposed of correctly (Tilley *et al*, 2008).

A packaging sanitation solution can accept toilet paper and other dry types of anal cleansing material, like leaves. The dry anal cleansing materials can also be used as an additional carbon source for composting.

5.1.3 Willingness-to-Pay Case Study in Peru

Despite the need for more testing to determine a better representation of WTP for sanitation in other parts of Peru and in developing countries, the WTP method presented in this thesis is a realistic methodology to determine a community's value for sanitation by portraying how a participant will react in a market with fluctuating costs for materials and maintenance. Information from the method will give insight on the type and cost each community is willing to pay for each technology. Such information is important because it illustrates the type of sanitation a community and individual favors. From this information, it is possible to determine which type of technology will be sustainable and in demand by households. The method used in this study differs from other CV studies that focus on sanitation because in those studies "sanitation" tends to refer to sewage pipes not individual sanitation technologies (Whittington *et al*, 1993). In typical CV studies, households must decide if they support a collective decision by the community and if they are willing to pay to connect to a community sewage system (Whittington, 1998). The method presented in this thesis shows each technology as a household decision, and what one household is willing to pay would have no influence on what other households would have to pay. According to the statistical analysis, there is no association between gender and WTP. It is possible that an association exists between gender and WTP; however due to the sample size there is not enough data to reliably determine that association.

Many of the participants who preferred the flushing toilet over squatting toilets with water commented that they would choose a squatting toilet with water over a flushing toilet due to its economic price. According to the female participants, they are more willing to pay for flushing toilets over other types of sanitation technologies, because of convenience and comfort. Male participants in each community commented that they were more willing to pay for squatting toilets with water above flushing toilets because of comfort and cost of the squatting toilet with water.

5.2 Design Criteria

The design criteria of the proposed toilet technology should have features that are sensitive to cultural preferences and provide a clean, hygienic place to store excreta until disposal. The case studies in Peru provided base data to help develop design features that would be sensitive to their culture, but the concept of a packaging toilet was not discussed in the focus groups to avoid confusion. The Diaper Genie and Diaper Champ provided a base concept of a hard plastic support structure with the use of bags to contain odor.

The use of a hard plastic storage container would provide a waterproof option that is easy to mold into different shapes to allow for both sitting and squatting. The antimicrobial additive used in the primary package could be used in the tertiary unit to add extra odor protection. There is limited evidence of the effectiveness of approaches to control odor in the form of volatile compounds released by packaged or stored waste. Information is limited and not well substantiated or documented by the manufacturers making claims about odor control or evidence from independent sources. There should be a lid that can be closed to help control odor when the toilet technology is not in use.

The tertiary unit would need to be a standard volume to ensure it can hold at least 105 primary bags. The use of toilet paper, leaves, or water as an anal cleansing method could be disposed of with the excreta; however, testing of sanitary napkin and tampon breakdown would be necessary. Leaves and toilet paper could act as a carbon source for composting of the excreta.

hard plastic tertiary unit would allow for use in an outhouse or inside the house depending on household preference. The waste is entirely contained within the tertiary unit and does not require a pit or significant land space. The tertiary container is intended to be impervious to liquids, in case the primary and secondary bags leak. The use of a hard plastic material also allows for cleaning and disinfection.

The feces of children are often treated differently from that of adults because children's feces are not considered to be harmful. This assumption is a common misconception of adults in developing countries (Buttenheim, 2008). There could also be an insert provided for children so their waste is dealt with the same as adults. The insert would make the hole in the tertiary unit smaller and a better fit for children.

5.3 Material Specifications

Based on the constraints and considerations discussed in this thesis, the optimal materials for the primary and secondary bags should meet the following specifications:

It should be lined with urea and possibly other compounds to help kill the pathogens in the excreta. It would be able to contain and store the excreta for up to four weeks after use without decomposing to ensure that the urea has enough time to break down to ammonia and accomplish initial pathogen inactivation in the excreta. For ammonia to have its antimicrobial effects, pH within the primary and secondary bags should be maintained at a high enough level to achieve a high proportion of ammonia as NH_3 rather than ammonium as NH_4^+. Odor must be controlled and may be controlled by the use of anti-microbials as an additive to the plastics of the packaging (Zweifel *et al*, 2009). However, the extent to which odor is effectively controlled by antimicrobial additives or other alternatives is based on independent evidence that is uncertain and requires further investigation. Optimal packaging also should allow for the methane to be released in small amounts, but be able to contain the ammonia that is produced. Based on resource constrains the exploration of options for candidate packaging materials that would potentially have the properties to retain ammonia and odorants and allow methane permeation was not included in this thesis. The primary material will come into direct contact with the excreta and will hold the excreta until it is disposed of in the manner available to the household.

The secondary material should have similar properties as the primary material except that it is large enough to hold the primary bags, which could affect the tensile strength and is disposed of in the same way. It is a liner and adds an extra layer of protection from leaks and spills for the tertiary unit as a health safeguard. It also makes it easy for the user to carry multiple primary bags at one time for disposal. The sealability and tensile strength of the primary and secondary bags will depend on the type of material selected.

The primary package would be “flushed” into the secondary package that is lining the tertiary storage unit. The flushing mechanism would need to be developed but would involve a handle that when pushed would seal the primary bag, drop it into the secondary bag and replace the primary bag with a clean one ready for use.

The type of end-of-life option that is used to dispose of the ideal packaging and excreta are dependent on the community; therefore the primary and secondary packaging should be designed to the most stringent requirements for biodegradability and compostability. The primary packages should be biodegradable and at-home compostable because at-home composting places the most demands on the packaging material. At-home composting requires that a material be compostable at lower heat levels than municipal composting. The other end-of-life options do not require the material to be biodegradable or compostable. The end-of-life option preferred for this toilet technology is at-home composting as it limits the need for collection and transportation. It also does not require government support for treatment.   The management of at-home composting would have to be determined by the household or community to ensure that the compost pile contains enough carbon as bulk material for proper decomposition. The main concerns for the suggested end-of-life option are that there is limited space for at-home composting in some peri-urban areas, that users will not empty the secondary bag at proper times or that people will resist emptying it, and there would be no government or private sector regulation and monitoring. In general, composting and use of excreta as fertilizer would not be recommended in colder climates because there is not enough heat generation to kill pathogens. The other end of life treatments presented in this thesis, such as landfills, WTE, or burning could be further explored as effective options in cold climates.

5.4 Impact on Peri-Urban Areas

Sanitation in peri-urban communities, combined with access to clean water, increases public health for both adults and children. A study conducted in a peri-urban community in Peru found that children who lived in households without adequate excreta disposal were on average 1.8 centimeters shorter than children in households with sanitation (Checkley *et al*, 2004). It is important to promote the use of sanitation in peri-urban areas through the use of creative and constructive communication and cooperation between decision makers, experts, and the users to improve public health in peri-urban areas. Peri-urban areas vary greatly from location to location, depending on context, so the toilet technology would be need to adapted and changed to ensure effectiveness, use and positive benefits on public health (Norstrom, 2007).

The toilet technology that is proposed in this thesis has the potential to meet the needs of peri-urban areas because government or private sector help is not necessary, nor does it require the use of water. It also has the potential to provide the user fertilizer or energy depending on the end-of-life option that is utilized. It has the ability to impact the household in which it is implemented by limiting contact with excreta and therefore possibly protecting health. There are limitations to where the proposed packaging sanitation solution can be implemented. It is not recommended for use in cold climates or seasons or in areas where anal cleansing with water is commonly used until further testing is conducted to determine pathogen control and the ability to hold excess water is confirmed.

6.0 Conclusions

The purpose of this thesis is to develop specifications and design criteria for a packaging material solution for excreta management. Conditions for the solution included: (1) that it be able to contain the excreta for disposal, (2) have the potential to add value to the excreta, and (3) avoid the use of pipes and water. There are criteria of the packaging solution to have the capacity to hold excreta for a storage period of up to 4 weeks, effectively contain and control pathogens, odorants and allow for the permeability of some gases but not others. Individuals, households, and communities might not be driven primarily by health gains in decision making. Convenience, peer perception, and peer pressure might be more important. Responses should address what communities want and what will protect and improve health (Bartram *et al*, 2005). The proposed option has design features based on consumer focus groups which add geographical and cultural constraints, understanding that sanitation is driven by consumer wants and needs and not necessarily perceived health benefits.

The packaging material specifications and design criteria presented in this thesis have three components: the primary bag, the secondary bag and the tertiary storage container. The primary bag contains the waste and then is “flushed” into the secondary and tertiary components. The secondary component is a bag that lines the tertiary bag and allows for the easy transport of the primary bags to an end of life treatment. The secondary bag is made of the same material as the primary bag. The tertiary component is a hard plastic box and is the storage unit and allows for user comfort. Its shape will depend on the culture and preferences where it is used. All three plastic components will have an antimicrobial additive to ensure that odor is abated and that pathogens are initially killed to some extent. The bags should be biodegradable and compostable, to allow for the excreta to be composted into fertilizer.

Table 5: List of criteria for proposed toilet technology

Criteria	Primary Bag	Secondary Bag	Tertiary Component
Storage Period	4 weeks	4 weeks	1 week
Pathogen Control	Use of urea and a pH control agent	Use of urea and a pH control agent	N/A
Gas Permeations	allows for methane permeations, but contains ammonia and odors	allows for methane permeations, but contains ammonia and odors	Use of lid
Capacity Restrictions	Must hold up 200 grams of feces and 2 Liters of Urine	Hold 15 primary bags	Hold 105 primary bags
Odor Control	Use of anti-microbials and possibly other chemical agents	Use of anti-microbials and possibly other chemical agents	Use of anti-microbials and possibly other chemical agents
Water-Proofing	N/A	N/A	Use of hard plastic

6.1 Next Steps

Resource limitations resulted in research constraints including the lack of laboratory testing of the proposed system. The demands upon the material for a packaged human waste collection, containment and management system are not common to most plastics. Further research would have to be conducted to determine which materials might meet such demands. Lab testing would have to be done on such materials that allow for selective gas permeations so that methane is released but ammonia and odorant are kept inside.

Additionally lab testing would also have to be done on the use of urea and other compounds for initial pathogen inactivation, the types of additives that could be used to maintain pH within the primary and secondary bags and the types of additives that would control odor.

Research also would be conducted into the end-of-life options with the proposed system. The ideal end-of-life option would be composting within the individual communities or households so that large government infrastructure is not needed. However, specific end-of-life options would have to be tailored to each community and its needs. It could be possible for the proposed toilet technology to provide an employment opportunity for users. Users could sell the composted fertilizer to farmers or sell the primary and secondary refill bags within their communities.

The next step would be material testing. Tensile strength testing, sealability, and shelf life testing for containment of excreta and odor control can begin. The ability of the primary bags to acquire and hold anal cleansing water would have to be tested to ensure there were no leaks. At the same time, composting and other disposal tests can begin. The ability to compost will be measured by examining the properties, pathogen inactivation, and key constituents in the remains of the materials in different composting situations.

Toilet design would be concurrent with the material testing, and a prototype toilet should be prepared for testing. Testing of the toilets would include ease of use, strength and durability, and odor resistance through a mock user trial. The design could then be modified for cultural preferences and tested again for ease of use.

The last phase of the plan is preliminary field testing to present the prototypes. Participants would be asked for feedback on the design through focus groups and community meetings. Additional field tests in other communities and countries would be needed. Following the field testing, all data would be examined and the specifications for the final design would be produced.

A recent cost-benefit analysis by WHO showed that achieving the global MDG target in water and sanitation would have benefits that include an average global reduction of diarrheal episodes of around 10 percent (Bartram, 2005). Currently, 40 percent of people in the world do not have access to even a simple pit latrine (Bartram, 2005). The sanitation solution presented in this thesis, if eventually documented to be technologically feasible and effective, and if accepted and used by consumers, would help to increase the number of people who have access to adequate sanitation considered to be at the top of the sanitation ladder, comparable to a flushing toilet with proper wastewater treatment and disposal.

Appendix A: Focus group guide used in Peru

Introduction to the project and focus group:

Thank you for taking the time to meet with me.

My name is _______. I am a graduate student from UNC who is collaborating with on a project that looks at alternative sanitation methods in developing countries. The purpose of our discussion today is to hear your thoughts and experiences as a resident of ___ Community and as someone who works with this community. Specifically, I'd like to learn about any current sanitation practices in your community, learn about how much the community would be willing to pay for sanitation services, and features of the systems that you like or dislike.

The information I gather today and through other interviews will be summarized and shared with Project members for the purpose of informing and designing alternative sanitation methods.

I will be interviewing you today and taking notes during our discussion. This discussion should last about an hour. Your opinions and experiences are important, so please let me know what you think. If there are any questions you do not wish to answer, please let me know. There are no right and wrong answers and you may stop the interview at any time. Thank you for taking the time to participate.

Consent Fact Sheet

Now I'm going to review some project information about your consent and the confidentiality of your answers. ***Review informed consent sheet with participant.***

Confidentiality

Your answers and comments will remain confidential. I will be reporting summaries of the comments made by various community members. However, I will not specify names or other identifying information from the individuals I interview.

I would like to record this interview. We can stop recording at any time. Following the completion of the project, any information from interviews or recordings will be kept in a secure location.

Do you agree to participate in this project?
Do I have your permission to tape record this interview?

Have participant sign consent form. One copy stays with participant and signed copy you keep for the project team.

Focus Group Guidelines

Your input is important and I want to make sure that you are comfortable during our discussion.

If at any time while we are talking you feel uncomfortable, don't want to answer a particular question, or would like to end the interview, please let me know.

I would like the discussion to be informal, so there's no need to wait for me to call on you to respond. In fact, I encourage you to respond directly to the comments other people make. If you don't understand a question, please let me know. We are here to ask questions, listen, and make sure everyone has a chance to share.

If we seem to be stuck on a topic, I may interrupt you and if you aren't saying much, I may call on you directly. If I do this, please don't feel bad about it; it's just my way of making sure I obtain everyone's perspective and opinion is included.

I do ask that we all keep each other's identities, participation and remarks private. I hope you'll feel free to speak openly and honestly.

As discussed, we will be tape recording the discussion, because we don't want to miss any of your comments. No one outside of this room will have access to these tapes and they will be destroyed after our report is written.

(If assistants present) Helping are my assistants ______ and _______. They will be taking notes and be here to assist me if I need any help.

Do you have any questions for me before we get started?

Warm-Up:

To get started, I like to know a little more about this community by asking, what is your role in the community?

1) Can you tell me what types of latrines are used in your community?

Be sure to ask if open defecation is used by the community and include it as a latrine option

Clarify that we are talking about community use of latrines and if the subject wants to talk about more personal use, then that should be specified.

Make a list of the latrines and go through them one by one.

Probe for the following:

a. What are the advantages of this type of latrine?

b. What are the disadvantages of this type of latrine?

c. Is there a time of day when the latrine use is restricted?

        i. Why would it be restricted at that time?
        ii. What are the restrictions?

    d. Which latrine is the preferred method for use?

        i. Is that method used by the majority of the community?
        ii. Why or Why not?
        iii. Is there a certain type of household that is able to use the preferred method?

    e. It seems that some of these latrines are used indoors and some outdoors.

        i. What are some of the negative effects of having the latrine indoors?
        ii. What are some of the positive effects of having the latrine indoors?
        iii. Is there a certain type of household that has latrines indoors?

            1. Look for physical size, family size, social status

        iv. What are some of the negative effects of having the latrine outdoors?
        v. What are some of the positive effects of having the latrine outdoors?
        vi. Is there a certain type of household that has latrines outdoors?

            1. Look for physical size, family size, social status

2) What happens to the waste after the latrine is used or full?

Probe for the following:

a. Are latrines used for both defecation and urination?
b. Are the latrines used mostly for defecation?
c. Where do people in the community urinate?

    i. Is the urine collected (i.e in a bucket)?
    ii. Is the urine used for anything?

d. Is the latrine emptied after every use?

    i. Do you feel like the latrine is kept clean?
    ii. Define definition of clean
    iii. Are there flies around the latrine areas?
    iv. Is there an odor?

v. Who is responsible for keeping the latrine clean?

e. Is the waste used for anything?

i. If yes, what is it used for?

3) I would like to discuss now how children and older people in the community use the latrines?

Oft en times latrines are further away from the home and this affects how children and old people can use latrines. We will start with children. First we need to define children.

At what age do children begin using latrines if the community uses the latrines?

This section refers to children who are too young to use latrines.

Probe for the following:

a. Where do the children usually defecate?

i. What is the advantage for having them go there?

b. If the children use the normal latrine, do they use it at night?

i. If No, why not?

c. Is safety an issue?

i. Clarify safety-safety from harm in the walk to the latrine, safety from falling in because of limited sight, safety from animals who might be near the latrine

d. How are the feces usually disposed of?

i. Is that similar to how adult feces are disposed of?

Now I would like to speak a little about older people.

e. Where do old people usually defecate?

i. If they do not use the latrine, why?

f. Are the old people's feces disposed of differently if a normal latrine is not used?

i. Why or why not?

g. Who is responsible for dealing with children and old people waste?

4) We would like to switch gears a little bit and talk about the some of the personal preferences of the community. If you feel like these questions are too personal, please feel free not to answer them. However they are meant to focus on what the community does generally, not what you do personally.

Probe for the following:

a. Some of the latrines let people sit and some let people squat.

   i. Which method is preferred?

   ii. Why is it preferred?

   iii. Is there a certain type of household that has latrines that you can use with the preferred method?

b. How do people clean themselves after using the latrine?

   i. Why is that method used?

   ii. Culture, Tradition, Convenience?

5) Now that we've talked about how people in this community use latrines, I would like to focus on animals and how their waste is handled.

Probe for the following:

a. What type of animals are found in the community?

b. Where are the animals kept?

   i. Where do they defecate?

   ii. Is that near where people live in the community?

   iii. Is their waste collected and used for anything?

6) I would like to understand if the community believes that sanitation is important.

Probe for the following

a. Is it important to you that the community has good sanitation?

   i. Why is it important?

   ii. Why is it not important?

7) The last thing I would like to talk about today about is how much value sanitation has in the community. I want to understand your need and value for different types of latrines and toilets. To do that, I will ask you a series of questions about different prices and availability of these types of latrines and toilets ask you to choose one. I want you to imagine that you did not have any type of latrine available to you.

Suppose that there was a government program that allowed you to have one type of toilet for a reasonable amount of use (typically household use). Assume that you could not have the other services for a number of years. I am going to describe each type of toilet and latrine option in more detail and then ask you which type you would choose.

Now, suppose that these four types of latrines would be available with no initial fees or connection charges.

Shared Pit Latrine

Thi
s latrine is outside and is used by multiple families in the community. It consists of a pit that is dug into the ground and has a slab over it.

Shared Ventilated Improved Pit Latrine

Thi
s latrine is also outside and is used by multiple families in the community. It consists of a pit that is dug into the ground and also has a slab over it. It has an added feature of a ventilating pipe which helps to reduce odor and flies.

Single Family Pit Latrine

Thi
s latrine is outside and is used by single families. It is the yard of the household. It consists of a pit that is dug into the ground and has a slab over it.

Single Family Toilet

Thi
s toilet is inside the home and is used by single families. It is a flush toilet that is connected to a septic system.

Suppose the monthly bill for each service will be shown on this card. In other words, the shared pit latrine would cost $, the shared ventilated improved pit latrine would cost $, the single family pit latrine would cost $, and the single family toilet would cost $, If you could have only one, which would you choose? If you do not want any of the services at these prices you can say none.

a. Shared Pit Latrine

b. Shared VIP Latrine

c. Single Family Pit Latrine

d. Single Family Toilet

e. None

Now, suppose there has been a change and the new monthly bill for each service will be shown on this card. In other words, the shared pit latrine would cost $, the shared ventilated improved pit latrine would cost $, the single family pit latrine would cost $, and the single family toilet would cost $, If you could have only one, which would you choose? If you do not want any of the services at these prices you can say none.

a. Shared Pit Latrine

b. Shared VIP Latrine

c. Single Family Pit Latrine

d. Single Family Toilet

e. None

This is repeated until everybody in the room is picking options a or e.

Wrap-Up:

Is there anything regarding latrines and waste management we haven't mentioned that you'd like to talk about?

Thanks for taking the time to share your thoughts with me; I've enjoyed speaking with you and I've learned a lot about this community. I want to remind you that everything we've discussed today will be kept confidential, and if you have any questions you're welcome to contact the Project Director at any time. *(Show contact info on consent form.)*

Appendix B: Pictures presented to participants in the focus groups in Peru

Figure 11: Pit latrine, Ciudad de Dios

Figure 12: VIP latrine, Ciudad de Dios

Figure 13: Squatting toilet with water, Ciudad de Dios

Figure 14: Flushing toilet, Lima

Appendix C: Guide used with community leaders in Peru

Introduction to the project and community leader meeting:

Thank you for taking the time to meet with me.

My name is _______. I am a graduate student from UNC who is collaborating with on a project that looks at alternative sanitation methods in developing countries. The purpose of our discussion today is to hear your thoughts and experiences as a community leader of ___ Community and as someone who works with this community. Specifically, I'd like to learn about any current sanitation practices in your community, and features of the systems that are in place.

The information I gather today and through other interviews will be summarized and shared with Project members for the purpose of informing and designing alternative sanitation methods.

I will be interviewing you today and taking notes during our discussion. This discussion should last about an hour. Your opinions and experiences are important, so please let me know what you think. If there are any questions you do not wish to answer, please let me know. There are no right and wrong answers and you may stop the interview at any time. Thank you for taking the time to participate.

Consent Fact Sheet

Now I'm going to review some project information about your consent and the confidentiality of your answers. ***Review informed consent sheet with participant.***

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Your answers and comments will remain confidential. I will be reporting summaries of the comments made by various community members. However, I will not specify names or other identifying information from the individuals I interview.

I would like to record this interview. We can stop recording at any time. Following the completion of the project, any information from interviews or recordings will be kept in a secure location.

Do you agree to participate in this project?
Do I have your permission to tape record this interview?

Have participant sign consent form. One copy stays with participant and signed copy you keep for the project team.

Community Leader Meeting Guidelines

As discussed, we will be tape recording the discussion, because we don't want to miss any of your comments. No one outside of this room will have access to these tapes and they will be destroyed after our report is written.

(If assistants present) Helping are my assistants ______ and _______. They will be taking notes and be here to assist me if I need any help.

Do you have any questions for me before we get started?

Warm-Up:

To get started, I like to know a little more about this community by asking, what is your role in the community?

8) **Can you tell me how many people have access to public latrines in the community?**

There are no public latrines in the community anymore. There used to be some 2 years ago, but now there are only latrines at people's houses.   They got flowing water and no longer have public bathrooms because of that. They have dry bathrooms.

Probe for the following:

- How many people use the latrines? Every family has one.
- Is there a charge to use the latrines?
- What is the charge?

9) **I would like to ask you about the cleanliness of the latrines and about human and material waste disposal.**

Probe for the following:

- Are the latrines kept clean by a specific person in the community? By the families that have them. They are cleaned with water. They throw in the dirt so it won't smell.
- Is that person paid?
- How often is the latrine emptied? Most holes are 4 meters.
- What is done with that waste when the latrine is emptied? They cover.
- How is trash disposed of?
- Does someone collect it?
- Is that person paid?

10) **I would like to discuss subsidies from outside sources such as the government or NGOs.**

Probe for the following:

- Are there incentives for the community to build latrines? They get subsidies from NGOS but not for latrines.

- For example, are free slabs provided if someone builds a latrine?
- What type of incentives are there?
- Where do the incentives come from?
- Does community receive any subsidies? Yes
- What are the subsidies used for? For help with kids and for health clinics
- Is there a motivation for people in the community to use the latrines? Everyone has one.
- What are the motivations?
- Where do the motivations come from?
- Is the community recognized by the government? Yes, They have a plaque.
- Does the community have land tenure? yes

11) We would like to change the subject and talk about water use in the community.

Probe for the following:

- Where do people get their water from? From Cusco City. Currently they use community taps (2-3 taps). Each family gets 4 buckets of water per day for all uses. However Cusco is adding pipes and has been for the past 6 months to provide water to each house
- Are there different sources in the dry and wet seasons?
- Do they have to pay for it? Yes
- How much do they pay for it? 6 soles/month
- Did the water system have initial costs? N/a

Wrap-Up:

Is there anything regarding latrines and waste management in your community we haven't mentioned that you'd like to talk about?

Thanks for taking the time to share your thoughts with me; I've enjoyed speaking with you and I've learned a lot about this community. I want to remind you that everything we've discussed today will be kept confidential, and if you have any questions you're welcome to contact the Project Director at any time. ***(Show contact info on consent form.)***

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