Waste Management in Rural India

EWB Challenge 2011

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Executive Summary

This year’s Engineers Without Borders Challenge focuses on Devikulam, a small village fraught with problems like much of rural India. This challenge has been presented to all first year students to develop a solution to one of the many tribulations facing the people living there. Recognising that sanitation has a direct link to the health and well being of the people, the group decided on focusing our efforts on creating a sustainable sanitation system to be implemented for each household. Through extensive research and discussion to find a suitable design, a sound choice was selected that fulfils the criteria of the dilemma.

The final design came down to deciding whether biodigestion or composting was the right choice. Biodigestion offered the production of biogas but in the end it was calculated that the feed needed to supply such a system was not available to every household. Although a community system could have been developed, it would be too costly to execute. Composting toilets have already been successful in developing countries, are cost effective and sustainable. This became our group focus.

The final design consists of a simple two chamber mouldering toilet with urine separation. Built from local materials it can be incorporated easily into the town’s infrastructure without much effort. This design was decided on as it offered a simple solution that was effective. Built to accommodate the needs of a family it requires little maintenance part from the emptying of chambers once composted and offers a secure, secluded place for the men, women and children to go about their business.

The system works by the natural process of aerobic bacteria consuming organic waste producing humus that is a useful end product. This process kills off the majority of pathogens, making the compost safe to handle and use on orchard crops. The urine that is separated can be used directly as a fertiliser and in the evaporation bed for fruiting trees such as bananas or jackfruit.

Although pricing for the construction of the toilets cannot be calculated for the region as access to pricelists for Indian products are unavailable, it has been proven that these systems can cost as little as US$350 to build. The impact of such a system can only have positive effects for the people. It can directly affect the social, economic and environmental aspects of village life having short and long term effects for the people adopting this method of sanitation.
It is critical that the system be supported by a well developed method of education for children and adults of the village. The implementation of the toilet system is directly influenced by the success of the education program. If it is insufficient, the project will be set up to fail, leaving the village without a suitable means of treating their waste. It has been proven already in parts of India that it is possible to educate the people to change the way they defecate, leading to a healthier way of life.

Upon the success of the education program and the construction of the toilets, the people will come to accept and embrace this new method of waste management. This project is not designed to force the people of Devikulam to change the way they live but to show there is a better and healthier option that will improve their lifestyle. By implementing these systems in the village, one hopes that the benefits will convince more people that an affordable, sustainable solution is available to them and that it will influence them to change the way they live for the better.
Team Reflection

When starting a group project, one of the most difficult challenges is getting to know your team members. After all you will be spending numerous weeks together researching, planning and discussing the best solution to the problem at hand. Having a balance of three engineering students to three students in other disciplines, a person would have though it was likely that there would be conflict but that was not the case. We decided unanimously that the design project would be water and sanitation. This would prove to be the way in which the group would work together, with no conflicts and a clear grasp on the task at hand.

At the beginning we held meetings once a week in our tutorial class where we began discussing and assigning tasks for each individual. Farah was assigned the job of recording the meeting minutes where upon completing was submitted through the Pebblepad website. Ivan had the duty of bringing the information together and, as the project progressed, assigning topics of each member to research and write up. As time passed and we began to narrow down our design options, we did meet during our study break and when needed to discuss important matters such as the change in direction from a biodigester design to composting toilets. This was an important aspect of bringing all our ideas and research together and every team member understood that. If they did not attend they notified a member and anything they missed out on they were informed about.

Being a purely theoretical project, there were not specific areas in which we had to analyse individually. For workload reasons, group members were assigned different areas of the report from the final design stage so there was no confusion on what needed to be done. Gerald and Jonathan and Angelo concentrated on the education section which would not be directly affected by our choice of sanitation system. Due to one of our team members departing from the group due to family reasons, some of the tasks needed to be reassigned leading to Angelo handling Impacts and Farah researching case studies and funding options. This did mean that the workload was shifted around, but in the end it seemed to have worked well for the group dynamics.

Early on the group had decided on a project that focused on the purification of the water supply. When talking to our tutor though, he informed us that this was a popular topic out of
the groups participating in the challenge. Upon learning this, the project focus shifted to sanitation, or more specifically the sanitary disposal of human waste.

There was another point during the project where we had to change direction once again. This was when it was calculated that a single biodigester per household would not be able to receive the necessary amount of organic material to produce the biogas needed to cook 3 meals per day. Community toilets were also out of the question as the pipe work to a biodigester would be expensive and the villagers would most likely not use them. Due to this the backup choice, a mouldering composting toilet, was chosen and the problem was diverted.

There were no major obstacles we had to overcome as a team apart from the change in focus due to the need to be individual in our proposal and calculations proving a method was not ideal. Even though no problems were encountered we would have surely had the capability to tackle them head on.

Through good teamwork, cooperation and consideration, we achieved an end result that none of us could have accomplished by ourselves. If we could go back and change anything we would probably spend more time on composting toilets rather than wasting time on a biodigester design. Biodigesters can be complicated systems and usually simplistic designs are the better solutions. We would also make sure we met twice a week compared to just meeting when we had our designated tutorial class.

For the team members studying engineering, working on a real world problem proved to be an enjoyable aspect of the EWB challenge. It gave the chance for first year students to get an idea on how the industry works and how different factors affect the best choice for that problem. For the students not studying engineering, being able to step out of their comfort zone into an area that may not have been considered before, was interesting to say the least. Understanding how a different science discipline operated, how they tackled problems and presented ideas provided a new aspect on how to deal with theoretical problems in their own fields of study.

The EWB challenge started off as just any other project. Our grades were dependant on an idea that was well written and executed. At the end of it all, we can say that we have all learnt something new and met new people along with the possibility of helping a rural community improve their way of life. It became more than just a task, but something that allowed us to engage with each other and come to a final decision.
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1.0: Introduction

Currently India has 37% of its population living below the poverty line as of April 2011 (The World Bank, 2011) that is 410 million people, which is about one third of the total number worldwide of the people in the same predicament. In spite of increasing economic growth for the country this number is decreasing slower than expected. This means that one in three people don’t have the income to provide more than basic necessities. It has been noted that Indians living below the poverty line has decreased in major cities but increased in the rural districts. In 2003 the rural population accounted for 72% of the total population of India (Nation Master, 2003). It is also said that 75% of impoverished Indians live in rural areas (Trade Chakra, 2008). With increased poverty of this degree in the rural districts, it is a problem that cannot be overlooked.

This year’s Engineers without Borders (EWB) Challenge focuses on a small rural community called Devikulam, which is one of several villages located in the Nadukuppam Panchayat. This is a small sub-division of the Viluppuram District in the state of Tamil Nadu (EWB, 2011). They lack important infrastructure for transport, sanitation and power, and are in desperate need for new buildings to account for the climate as well as ways to become sustainable and create income for individuals and the entire community. The fact that two cases, or social classes, exist in the village makes communication and cooperation difficult. A way to help bring the villagers together also needs to be considered in order to aid in the implementation of new projects that will directly affect their way of life.

1.1: Objective

The team’s objective is not to tackle every problem this town has but to concentrate on one area that was in desperate need of attention. Sanitation is one aspect of life in first world countries that many take for granted. In places like rural India the infrastructure doesn’t exist to service this need so the locals defecate in fields. Women also have social preconceptions which force them to only relieve themselves at night away from other people which can cause problems internally such as weak bowels and bladders. There is no knowledge of the diseases that can be carried in human faeces and this can lead to health problems and even death. So the objective is to create a system that treats human waste, making it safe to the villagers. Creating a useful bi-product would be beneficial as it would help cover the initial cost needed to implement the solution.
It is also necessary to educate the community on the benefits of proper sanitation practices as it is mostly nonexistent in this area. This will be the most challenging part of the project as it needs to be effective enough to convince the population to change the way they dispose of their faecal matter which for some, is something that may not be achieved easily.

### 1.2: Design Criteria

EWB initially set out that the cost of living per person is US$2.00 a day, and this is a major factor that will affect the solution chosen. Choosing sanitation as the area in which we are focusing on introduces other considerations. These include:

- Pathogen reduction
- Economic viability either as a family or community
- Easy integration into everyday life
- Sustainability for the villagers

So in order to fully accommodate the needs of the people living in the village, these are the basic considerations that play a vital role in the choices this team will make.

### 1.3: Ethics

As scientists, it is vital that we act within the interests of the involved parties. Although not all members of the group are engineering students, it is critical that we follow the guidelines of the Australian engineering society, Engineers Australia, in regards to the ethics that should be upheld by the members of the organisation (Engineers Australia, 2010). Without the basic understanding of what implications our choices could have on the people of this village it would be unethical to force them to accept a solution that they themselves would not consider to be appropriate for them.

The guidelines state that we should “act on the basis of a well-informed conscience”, “be honest and trustworthy”, and “respect the dignity of all persons”. We should also “balance the needs of present with the needs of future generations”. During this project ethics became a vital aspect for the way we chose the method of sanitation. The EWB challenge outline provided via their website stated that some methods would not be well received and upon further development of our project this lead to a change in the technique in which to treat human faecal matter.
The above only accounts for the ethics of Engineers Australia but the ethics of The Institute of Engineers, India (aka IEI) should also be addressed. Their code of ethics refers to the concern the engineer must place in ethic standards, social justice, social order, human rights, environment, and public safety and tranquillity. A member must also “utilise his/her knowledge and expertise for the welfare, health and safety of the community without any discrimination for sectional or private interests” (IEI, 2004).

Due to the absence of existing sanitary practises it is necessary to fully inform the local population of the changes that would happen to their daily lives. Without the support of the community, the project, no matter what area the group specialised in, would not work and possibly lead to the abandonment and return to previous habits. So it is important that the people’s needs have been considered and that all risks, which are most likely minimal, be explained and discussed to their full extent. Their role in maintaining the system is also an important ethical consideration. The villagers need to understand how the waste management system operates and their role in keeping it functioning. By understanding and respecting the population, this project can be helpful and hopefully successful in improving their way of life.

2.0 Background:

India is part of Southern Asia bordered by Pakistan to the west, Bhutan, the People’s Republic of China and Nepal to the northeast with Bangladesh and Burma bordering the nation to the east. The Indian Ocean lays to the south with Sri Lanka and the Maldives off the coast. India also has islands under its rule that border Thailand and Indonesia. The country is ranked the seventh largest for the overall area it covers and is the second most populated country behind China with 1.2 billion people (Census of India, 2011). It is also the most densely inhabited democracy in the world. The Indian economy is ranked the tenth largest by their Gross Domestic Product (GDP) which is the final market value of all goods and services from the nation for a given year. In comparison, Australia is ranked thirteenth (International Monetary Fund, 2010).

The economic growth seen over recent times has lead to financial freedom for the government to try and reduce the number of people living in poverty. This figure roughly sits at 37%, or a third of the total population of India. This figure has been on the decline but to analysts, it has not decreased at the rate expected. The percentage of citizens living in poverty has decreased
in major cities but in rural areas it has not changed or has indeed increased above the national average.

### 2.1: Devikulam, Tamil Nadu

The EWB challenge focuses on a small village called Devikulam. This town is located in the state of Tamil Nadu in the province of Villupuram (EWB, 2011).

![Figure 2.1: Location of Devikulam (Google Maps, 2011)](image)

### 2.2: Climate

This region is classed as tropical semi arid zone, where evaporation and transpiration exceeds that of annual rainfall. The average precipitation per year in this region is approximately 950 millimetres but can vary greatly depending on monsoonal rain (India and Indians, 2011 and Government of Tamil Nadu, 2006).
Figure 2.2: Annual Rainfall for Villupuram from 2004 to 2009 (Indian Meteorological Department, 2009)

It is a drought prone area and has sporadic rainfall patterns due to the lateness or complete lack of the southwest and northeast monsoons. The close proximity to the coast also affects its annual rainfall as these areas receive more than the average annual rainfall. As seen in figure one and from the seasonal crop reports from the 2005-2006 seasonal crop report it shows just how much the rainfall can change over one year with an increase of 36.1% over the average values expected. These climatic conditions would account for the town’s dependence on bore water for drinking as well as a lake to the north west of town. The main water tank centrally located is fed by bores so water is a precious commodity here and should be treated as such.

2.3: Infrastructure

Devikulam is a village “blessed with a beautiful landscape full of tropical plants and wildlife which is seen as one of the communities’ most valuable assets”. Although this is true, the village has little infrastructure and what does exist is in a poor state. This would be due to the village being located in the most under developed area of Tamil Nadu. In spite of this, most of the residents do have access to electricity, but this tends to be in short supply due to power outages that can last for weeks at a time. They do have a communal water pump fed by a large
water tank filled by two bores, one currently inoperative. The main concern is salinity and contamination from faecal matter seeping in and spreading through the pipe works.

There has been no outbreak of disease so far. But bacteria have been detected, although at acceptable levels. One bore has been quarantined in order to prevent any increase that would cause acute to severe health issues for the residents.

The villagers rely heavily on kerosene and wood with a smaller emphasis on LPG to cook which is polluting and costly for the community. These biomass burners are inefficient, and the smoke in concentrated amounts can be deadly. Finding a clean burning method would be ideal in order to prevent death from asphyxiation.

2.4: Income

The household income in the village is usually acquired by irregular agricultural work as labourers. Further out, where some residents own larger plots of land, they tend to cultivate their own crops such as tapioca or watermelon. These people tend to work in excess of 20 days per month whereas the people in the central colony may work less than 20 days. Some of the youth have left for better prospects in the larger towns and cities in the district. The average income of the families is approximately 30000 rupees or about US$670 per year in the central colony with the outer villagers earning up to 60000 rupees. This comes down to a figure of approximately US$2.00 per day for living expenses. This yearly income barely covers the basic necessities, and many families would earn under this amount per year. Some households survive solely on old age pensions of 400 rupees per month (approximately US$8.90) and they would be in a worse position than other families. Since most of the villagers live below the poverty line, there are not enough funds to help significantly improve their way of life without the help of others. Another stumbling for the community is that 2 main castes that exist, which causes a lack of cohesiveness. Breaking this social hierarchy is paramount in order to create a common sense of purpose between the villagers, which does not exist at present.

2.5: Pitchandikulam Forest Organisation

Pitchandikulam Forest, an organisation dedicated to recovering and preserving the local tropical dry evergreen forest has been involved with Devikulam and surrounding communities over the last twelve years. They have been running dedicated programs to teach the people of
this impoverished area about “sustainable land use” and “eco friendly practises”, as well as expanding into “environmental education”.

The organisation has also encouraged the teaching of women’s empowerment and health programs. Pitchandikulam Forest is the initiator of the innovation project for Devikulam aimed at turning the village into a sustainable and eco friendly place. The project also aims at providing additional employment opportunities and training programs to help the locals “develop skills and ensure environmental values are firmly established among the local population”.

With so many problems existing in such a small place, it is difficult to choose just one design area. In the end, waste management was the choice. Sanitation is an important part of any community as it aids in the control of harmful pathogens that can cause illness and in extreme cases, death. In places where there is little to no infrastructure or education regarding the health issues associated with human excreta, there is a direct correlation between the lack of facilities and diseases that are born from faecal matter. Although it was mentioned earlier that there have been no outbreaks of disease directly related to human waste, it is best not to ignore such a vital aspect of everyday life. The facilities needed to process this harmful waste need to be implemented so that human waste is no longer a health risk for the local residents.

2.6: Case Precedence

Implementing sustainable sanitation systems in third world countries is not an uncommon practice. When the health of the people can be directly affected by unsanitary waste management practices, it has been the goal of governments and non-profit organisations to encourage development of systems that can aid in the breaking down of old traditions. This is no easy task and can be met with hostility in extreme cases. But with support and knowledge comes an understanding of the effect that safe waste management can bring.

The success of implementing new sanitation practises to villagers who, prior to the involvement of Pitchandikulam Forest and Engineers without Borders, would defecate in fields rather than build toilet systems will be a difficult challenge. But as the following case studies show it is possible to achieve the goal of this project, a free, cheap and sanitary method of treating human waste. The similarity in living standards and way of life also show that the people of
Devikulam are like many other people in rural and impoverished regions of the world and that introducing a system that may initially be met with indifference can in theory and with adequate support help the villagers in the short and long term.
2.6.1: Christmas Island (Maher & Lustig 1997, 5-7)

Kiritimati (Christmas Island) where, like other coral atolls in the Pacific, water is a scarce resource, AusAID has resolved to develop a “Pacific Island Composting Toilet”, and Environmental Management has been involved in its development since 1997. The experience on Kiritimati was that the principles of composting toilets are relatively straightforward, and it was the social acceptance of the toilets that was crucial to their success. As a result, developing the Pacific Island Compost Toilet was an exercise in community consultation and in designing a toilet that was easy to build and use.

Kiritimati has low rainfall, shallow groundwater and infertile soils. The main reasons for considering composting toilets were that they use no water, are located above ground and produce material useful for gardening. As these physical conditions are common on coral atolls throughout the Pacific, AusAid reasoned that the composting toilet developed on Christmas should be applicable throughout the Pacific, in effect a “Pacific Island Composting Toilet”.

As an example of this, Photo 1 shows a composting toilet with a bathroom placed right next to it. This bathroom and washing area would not be placed anywhere near smells or flies.

![Photo 1 Composting toilet with bathroom to left of toilet](image)

It was found that once the Christmas composting toilet was seen to be working well, with no smell and no flies, people began to view them more positively. As a result, more and more families are requesting the composting toilet, with the local doctor and leading Government of Kiribati personnel already having them on their land.
2.6.2: Prolit Village, Cambodia (Ecodana 2010,1)

Initially all of the toilets in the village of Prolit in Cambodia were shallow squat toilets. These have been designed so that the human waste is disposed of into the ground at a depth of around 1.5 metres. At this depth, the waste can easily contaminate the surface water table and this poses extreme health threats to the local community, especially when they are accessing their drinking water from shallow depths as is frequently the case.

The toilet is a very simple device, called a ‘loveable loo’ by Joseph Jenkins (writer of the Humanure Handbook), which is basically just a wooden box with a toilet seat on top and a bucket inside. When the bucket is full, it is simply sealed and then left to compost for 6 months. Because of the high levels of heat in Cambodia, composting occurs incredibly fast here: we’ve been using these toilets at our NGO HQ over the past couple of weeks and the contents composts so fast that you can actually use an entire bucket of cover materials and still not fill the toilet bucket up!

Compost Toilet

They dispose of and recycle human waste far more effectively and hygienically than their squat counterpart. The human waste from the toilets is fully composted and then used as a rich fertiliser for local agriculture.
2.6.3: Kigali, Africa (Nakkazi 2009, 1)

Walk through the main roundabout in Kigali and you’ll see a sight that is unique in the developing world: public toilets that are tidy, clean, inexpensive, and a prime example of how sustainability in sanitation can work. Rwanda Environment Care (REC), one of Water For People–Rwanda’s local development organization partners, built and manages the public composting toilets.

However, REC knew that it wasn’t enough just to have more public toilets; they had to be managed well. This is accomplished by charging a small maintenance fee—each user pays 50 Rwandan francs (about 9 cents) to use the toilet. The staff collects payment, hands out toilet paper, and ensures soap and water is available for hand washing. And it works! REC has found that users are willing to pay to use the toilet as long as it’s clean and comfortable.

The toilets are popular with both users and government authorities. Users find the toilets to be neat and clean and, most impressively, without any odour. The authorities of the city of Kigali and other members of government find these toilets to be a positive alternative to the often-mismanaged public flush toilets and overly full pit latrines while offering protection to the environment. With few to no wastewater treatment options in Rwanda, composting toilets are seen as an effective option.

2.6.4: Bangalore, India (Vishwanat 2005, 1)

In India (population 1028.61 million) Karnataka is the 8th largest state in India with a population of 52.85 million in 2001. Bangalore or Bengaluru as it now called is the capital city. To combat the practice of open defecation and to bring access to safe sanitation the Total Sanitation Campaign (TSC) was launched by the Government of India in 1999. The first urine diverting dehydrating toilets (UDDT) in India were built by Paul Calvert as early as 1994 (www.ecosolutions.org). His work has influenced almost all subsequent works on what are now called UDDT’s but are also known as eco-sanitation systems or eco-san. His ‘Eco-pan’ was the first pan developed as a source separating squatting pan in India, where traditionally most Indians are squatters and washers.
In Karnataka, one of the first eco-san UDDT was built in 2003, where the pan was sourced from China. It was a urine separating pan but had no anal wash area. This was designed in Bangalore by Architect Chitra Vishwanath and manufactured by a company called N-Fibro Private Limited in Fibre-reinforced Plastic. The pan has undergone several refinements based on feedback received from women wearing the ‘sari’ a traditional Indian dress and has now become the eco-squat.

So it can be seen that from just a few examples, one from India itself, that sanitation systems have been implemented where people previously had no access to suitable toilets. This illustrates that it is indeed possible that providing the right sanitation system to the people of Devikulam will not only improve their way of life, but help to reduce illness and can aid in improving the fertility of the local soil for crop use.
3.0 Human Waste Management Systems

For this project it is necessary to assess all possible methods of sanitation and choose which one would best fit the needs of the people of Devikulam. The methods discussed fall into two main types, on-site treatment and centralised systems. There are also the different treatment methods of effluent streams from systems like septic tanks and baffle reactors.

3.1: Centralised Systems

Centralised systems, in other words sewage systems, are the favoured choice for western societies to handle their excrement. It was one reason for the cleanup of London as there was no centralised system prior to its inception. The introduction of such a system reduced diseases as all waste was transported away from the city and processed accordingly. The reason for such a method being implemented in London was because there was the money to build such a grand system for the people. In India the country may have one of the largest economies in the world but a sewage system being built for such a small town as Devikulam would not be feasible. The following table lists the advantages and disadvantages of a centralised system.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>No thought about treatment needed, handled off-site</td>
<td>No completion of nutrient cycle</td>
</tr>
<tr>
<td>Popular among western societies</td>
<td>Nitrogen is lost where it could be implemented to improve crop production</td>
</tr>
<tr>
<td></td>
<td>Costly</td>
</tr>
<tr>
<td></td>
<td>Labour intensive</td>
</tr>
<tr>
<td></td>
<td>Experienced people need to treat waste off-site</td>
</tr>
<tr>
<td></td>
<td>Would require complete rebuild of town</td>
</tr>
</tbody>
</table>
3.2: On-site Treatment

The other main choice for waste disposal is on-site treatment. This is more labour intensive but is usually more cost effective than centralised systems. These systems do tend to need more technical support as the knowledge is needed on how to maintain these systems compared to sewage infrastructure.

3.2.1: Biodigestion

A biodigester is a system that utilises anaerobic bacteria to aid in the decomposition of faecal matter to produce biogas and a nutrient rich exit stream that is suitable for fertilising plants. Anaerobic bacteria are bacteria that can survive without oxygen. This is the primary type of digestion used in sewage plants to treat human waste. There are two main types of anaerobic digestion, mesophilic and thermophilic, as different bacteria survive at different temperatures. Mesophilic bacteria usually thrive in a temperature range of 35-40°C. The human body is approximately 37°C. Thermophilic bacteria on the other hand thrive at higher temperatures, usually in the region of 55-60°C. The latter is the ideal temperature range as this helps to kill off pathogens that exist in human excrement. A biodigester may operate between the ranges allowing a mixture of both types of bacteria to co-exist. The process itself is a four stage process that takes place in a batch or continuous reactor. The order is (Biogas and Anaerobic Digestion, 2006):

- Hydrolysis
- Acidogenesis
- Acetogenesis
- Methanogenesis

The different stages in the end produce a gas consisting of carbon dioxide and methane (AIDG, 2011). The methane content can vary but ideally the higher the percentage the better in order to combust and be suitable for cooking.

There are a few main types of biodigesters, such as salchicha and dome biodigesters. Both are continuous systems but differ in complexity and cost.
Salchicha biodigester:

Salchicha is Spanish for sausage, and this describes the shape of the biodigester. As in other industries, tubes are a relatively efficient shape for chemical reactions, providing retention time is accounted for which would affect both the diameter and the length of the system. It’s relatively popular due to its relatively low cost depending on size. The feed is at one end while the effluent comes out the other. The gas is collected via a tube and collected in another bag until ready to use.

![Salchicha Biodigester](image)

Depending on location and plastic used, these last less than other biodigesters and can be around 5 years. The plastic then needs to be replaced but the fittings can be reused. Due to its low cost the replacing of the plastic tube is not problematic.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Lack of Longevity</td>
</tr>
<tr>
<td>Simplicity</td>
<td>Space</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Needs adequate feed material</td>
</tr>
<tr>
<td></td>
<td>Thorough support needed</td>
</tr>
</tbody>
</table>
**Fixed Dome reactors:**

More labour intensive to construct than salchicha digesters, these are usually constructed underground using brick and mortar. It is the same process as the salchicha reactor but can last up to 20 years. The bonus of it being labour intensive is it creates jobs for those skilled enough to build it, or learn to build such a system. They should be supervised by experienced technicians though to ensure that the reactor is not porous which would allow effluent escape or oxygen to enter.

![Fixed Dome Biodigester](CD3WD. 2006)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low initial costs</td>
<td>Uses masonry materials. More costly than salchicha so out of reach for low income families</td>
</tr>
<tr>
<td>Longevity</td>
<td>Special sealants needed and high technical skills to ensure no leakage</td>
</tr>
<tr>
<td>Basic design</td>
<td>Fluctuating pressure</td>
</tr>
<tr>
<td>Space saving</td>
<td>Exact planning of levels needs to be completed</td>
</tr>
<tr>
<td>Creating employment opportunities</td>
<td>Plant operation may not be readily</td>
</tr>
</tbody>
</table>
Floating Dome biodigester

This is a common style in India, where the drum collects the gas and floats in the fermenting slurry or in a separate water jacket. The dome has a guide to keep it stable and as gas collects it rises slowly. As gas is collected the drum lowers. The feed system is the same as the fixed dome as shown in the diagrams below:

![Figure: floating dome reactor (CD3WD, 2006)](image)

![Figure: Water jacket floating dome biodigester (CD3WD, 2006)](image)
3.2.2: Composting toilets

A composting toilet is a system that utilises aerobic bacteria to break down faecal matter to a fraction of its original volume. It relies on the presence of air and naturally occurring bacteria and fungi to decompose and transform the organic waste into a usable additive for gardens known as humus. This process helps to complete the nitrogen cycle by returning the nutrients consumed back into the soil where it can complete the cycle once more. There are different types of composting toilets that are commonly used and these include (Composting Toilet World 2010):

- Owner built two chamber mouldering systems. These are cheap and basic but effective.
- Owner built, concrete block constructed, inclined base design. These are usually constructed within the house foundations
- Large scale produced, small, self contained systems suitable for part-time use
- Large tank, inclined base design suitable for full-time use
- Vacuum flush units
- Full flush systems

There are many more designs as the development of this industry is growing due for the need of sanitary systems where sewage, septic and other traditional methods are not a suitable solution. These should not be confused with pit latrines which is decomposition in an uncontrolled environment where the waste may penetrate into the ground water and contaminate it. Pit latrines also offer very little reclamation of nutrients where composting toilets do.

Most of the above systems are too expensive for use in India, apart from the 2 chamber mouldering system which has been implemented in countries with similar living conditions to India with much success.
Figure 1: Mouldering design composting toilet (Clavert, P. 2006)

The design is based around aerobic digestion which is the same process utilised in compost heaps. There is only a single stage to this process, unlike anaerobic digestion in biodigesters, where the process releases carbon dioxide and heat as by-products and the humus as the main product. So it works just like a normal toilet, minus the water to flush it down the pipes. Due to the need for a moist environment, not wet, saw dust or ash is added after each deposit. This helps reduce odours (Morgan, P. 2007). In more expensive systems this is not needed as exhaust fans are implemented to remove the gases produced (Jenkins, J. C. 1999).

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of little to no water thus reducing total water consumption</td>
<td>Higher maintenance then traditional systems meaning the owners must commit to upkeep</td>
</tr>
<tr>
<td>No waste water apart from urine separation</td>
<td>Can be unpleasant removing the final product if system is not properly installed and maintained and possibly be a health hazard</td>
</tr>
<tr>
<td>Low to no power consumption depending on design</td>
<td>Using inadequately composted humus on edible crops may cause health problems</td>
</tr>
<tr>
<td>Self contained systems limit the need to transport waste to be properly treated</td>
<td>Too much liquid in the composter may disrupt or stop aerobic digestion</td>
</tr>
<tr>
<td>Useful by-product for non-edible plants and trees</td>
<td>Can produce unpleasant odours if improperly installed and maintained</td>
</tr>
<tr>
<td>Diverts effluent containing pathogens and nutrients away from surface water, ground</td>
<td>Insect infestation</td>
</tr>
</tbody>
</table>
water and soil.

3.2.3 Baffle Reactor

Baffle reactors (see fig 3.2.3.1) are one of the prominent technologies for treating wastewater (The Water Treatment Plant, 2011). They are in fact predominantly used to treat water streams that have a high percentage of non settling suspended solids and low COD/BOD ratio. Baffled reactors combine within themselves several anaerobic process principles like fluidized bed reactor, septic tanks, and the USAB.

Figure 3.2.3.1: Anaerobic Baffle reactor (Morel et al, 2006)

In baffle reactors, usually there are various compartments in an existing primary basin. These compartments initiate and help in an anaerobic biological degradation of the primary sludge in situ, which reduce the amount of sludge activity within the primary tank. Separation of the solids retention times (SRT) from the hydraulic retention times (HRT) is the key to the successful operation of an ABR. Due to this fact a baffle reactor is considered as the best alternative to aerobic treatment and/or primary settlement. The pond and baffle reactor solution has a proven track record in local communities, though one disadvantage of this system is the requirement to provide a pump and the costs associated with implementation and maintenance of the pump.

<table>
<thead>
<tr>
<th>Advantages (Spuhler, 2010)</th>
<th>Disadvantages (Spuhler, 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely stable to hydraulic shock loads</td>
<td>Needs expert design</td>
</tr>
<tr>
<td>High treatment performance</td>
<td>Long start-up phase</td>
</tr>
<tr>
<td>Simple to construct and operate</td>
<td>Needs strategy for faecal sludge management</td>
</tr>
<tr>
<td>No electricity needed</td>
<td>Clear design guidelines not readily available</td>
</tr>
<tr>
<td>Construction material can be locally sourced</td>
<td>Needs water to flush</td>
</tr>
<tr>
<td>Low capital and operating costs depending on economy of scale, ability to partially separate between various phases of anaerobic catabolism</td>
<td>Effluent requires secondary treatment and/or appropriate discharge</td>
</tr>
<tr>
<td>Low sludge generation leading to reduced clogging</td>
<td>Requires experts to construct</td>
</tr>
</tbody>
</table>
**3.2.4: Septic Tank**

A septic tank is simply a big concrete or steel tank that is buried in the yard. The tank might hold 1,000 gallons (4,000 liters) of water. Wastewater flows into the tank at one end and leaves the tank at the other. The tank looks something like fig 3.2.4.1 in cross-section:

![Schematic of a Septic Tank](image)

In figure 3.2.4.1, you can see three layers. Anything that floats rises to the top and forms a layer known as the scum layer. Anything heavier than water sinks to form the sludge layer. In the middle is a fairly clear water layer. This body of water contains bacteria and chemicals like nitrogen and phosphorous that act as fertilizers, but it is largely free of solids.

The need for only minimal maintenance is one of the major benefits of septic systems. Most septic tanks are energy efficient because little energy is required for operation. The initial installation of building and installing the tank, distribution box, and lines are the major energy users. Preventing plant growth on the septic field is the most energy required for maintenance after installation.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fed directly by toilet</td>
<td>Regular emptying needed to remove sludge</td>
</tr>
<tr>
<td>Minimal maintenance</td>
<td>Initial cost is high</td>
</tr>
<tr>
<td>Energy efficient</td>
<td></td>
</tr>
</tbody>
</table>
3.3: Post – Treatment Methods

3.3.1: Horizontal Wetlands

Horizontal drainage field, also known as a wetland, is a type of constructed field that is used to treat the effluent from a septic tank. As the name suggests the effluent flows horizontally where reeds filter the water removing the nutrients making it safer than from when it entered the field.

![Figure 3.3.1: horizontal flow wetland (akvopedia, 2009)](image)

The main advantage of a drain field is that it provides a greater drainage area and can therefore deal with a higher volume of wastewater. Drain fields are often the only practical alternative to sewerage networks for the disposal of significant quantities of wastewater. Well designed and maintained drain fields are an effective way to remove disease-causing micro-organisms from septic tank effluents. Maintenance consists not only of periodic septic tank emptying, but also alternation in the use of parallel drain fields, in order to restore the infiltration capacity of clogged fields.

Drain fields are prone to clogging, particularly when the septic tank is not de-sludged regularly so that solid material is carried over into the drain field. In some systems, branches of the drain field are taken out of service for a year to renew their absorption capacity. Aquatic plants, such as reeds, can help with the clogging, see selected publications for more for the use of aquatic plants and constructed wetlands. Note that aquatic plants are not likely to thrive immediately after the septic tank due to the strong anaerobic effluent.
<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage field handle high volumes</td>
<td>Drainage fields can become water-logged</td>
</tr>
<tr>
<td>Moderate pathogen removal</td>
<td>Needs large area of land for leach field</td>
</tr>
<tr>
<td>Short term employment opportunities</td>
<td>Initial cost is high</td>
</tr>
<tr>
<td>No energy required</td>
<td>Can encourage mosquito breeding and possibly disease transmission</td>
</tr>
<tr>
<td>No major issues with insects and odours</td>
<td>Long start up time</td>
</tr>
<tr>
<td>Aesthetically pleasing</td>
<td>Needs experts for design and supervise</td>
</tr>
<tr>
<td></td>
<td>Moderate cost (land, liner and plants)</td>
</tr>
<tr>
<td></td>
<td>Not suitable for untreated waste water</td>
</tr>
</tbody>
</table>

**3.3.2: Vertical Flow Wetlands**

Vertical flow drainage fields are an alternative type of drainage field compared to the more common horizontal drainage field mentioned above.

![Vertical flow wetland diagram](image)

Figure 3.3.2: Vertical flow wetland (akvopedia, 2009)

This type of bed is fed from the top of the field and percolates down though the roots of the reeds. It can be constructed above ground or in a pit but like the horizontal wetland, it needs to be lined to ensure untreated effluent doesn’t penetrate into the zone of the water table. The main difference is the treated effluent is dosed over the wetland, not like the former type where it was constant.
## Advantages and Disadvantages of Lagoons

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less clogging than horizontal wetland</td>
<td>Needs constant energy supply</td>
</tr>
<tr>
<td>Provide short term employment</td>
<td>Materials might not be readily available in different regions</td>
</tr>
<tr>
<td>High reduction of suspended solids and pathogens</td>
<td>Requires experts to design and supervise</td>
</tr>
<tr>
<td></td>
<td>Moderate costs</td>
</tr>
<tr>
<td></td>
<td>Pre-treatment is necessary</td>
</tr>
<tr>
<td></td>
<td>Dosing complicates design</td>
</tr>
</tbody>
</table>

### 3.3.3: Lagoons

Lagoon systems, also referred to as oxidation ponds or waste stabilisation ponds, are holding basins used for secondary wastewater treatment where the decomposition of organic waste is taking place naturally. These ponds are usually shallow bodies of water contained in a man-made basin where the wastewater stream enters and is retained for a certain time where after this period has passed a well treated effluent flows out. The lagoon is able to work on a complex process dependant on algae and bacteria to reduce pathogens and stabilise the waste.

![Bacteria and algae cycle in waste water lagoons](Figure 3.2.5.1: bacteria and algae cycle in waste water lagoons (The Water Treatments, 2010))
Like most natural environments, conditions inside facultative lagoons are always changing. Lagoons experience cycles due to variations in the weather, the composition of the wastewater, and other factors. However, in general, the wastewater inside facultative lagoons naturally settles into three fairly distinct layers or zones. Different conditions exist in each zone, and wastewater treatment takes place in all three.

The top layer in a facultative lagoon is called the aerobic zone, because the majority of oxygen is present there. The depth of the aerobic zone is depends on climate, the amount of sunlight and wind, and how much algae are in the water. The wastewater in this part of the lagoon receives oxygen from air, from algae, and from the agitation of the water surface (from wind and rain, for example). Aerobic bacteria and other organisms live in the aerobic zone and contribute to wastewater treatment. This zone also serves as a barrier for the odours from gases produced by the treatment processes occurring in the lower layers.

The anaerobic zone is the layer at the very bottom of the lagoon where no oxygen is present. This area includes a layer of sludge, which forms from all the solids that settle out from the wastewater. In the anaerobic zone, wastewater is treated by anaerobic bacteria; microscopic organisms, such as certain protozoa; and sludge worms, all of which thrive in anaerobic conditions.

Names for the middle layer include the facultative, intermediate, or aerobic- anaerobic zone. Both aerobic and anaerobic conditions exist in this layer in varying degrees. Depending on the specific conditions in any given part of this zone, different types of bacteria and other organisms are present that contribute to wastewater treatment.

While in the lagoon, wastewater receives treatment through a combination of physical, biological, and chemical processes. Much of the treatment occurs naturally, but some systems are designed to also use aeration devices that increase the amount of oxygen in the wastewater. Aeration makes treatment more efficient, so that less land area is necessary, and aerators can be used to upgrade some existing systems to treat more wastewater.
Every lagoon system must be individually designed to fit its specific site and use. Designs are based on such factors as the type of soil, the amount of land area available, the climate, and the amount of sunlight and wind in an area.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>cost effective</td>
<td>require larger area then comparable systems</td>
</tr>
<tr>
<td>less energy consumed compared to other</td>
<td>odour can be problematic</td>
</tr>
<tr>
<td>waste water treatment methods</td>
<td></td>
</tr>
<tr>
<td>simple to operate</td>
<td>experts needed for design and maintenance</td>
</tr>
<tr>
<td>can handle variation of input</td>
<td>may encourage mosquito breading</td>
</tr>
<tr>
<td>efficient at removing pathogens</td>
<td></td>
</tr>
<tr>
<td>final effluent ideal for irrigation due to</td>
<td></td>
</tr>
<tr>
<td>high nutrient content and low pathogen content</td>
<td></td>
</tr>
</tbody>
</table>

### 3.3.4: Sand Filtering

Sand filtration is one of the oldest wastewater treatment methods in use today. It is an effective method of producing an acceptable effluent stream so long as it is well designed, constructed and maintained. They are used to ‘polish’ the effluent obtained from treatment processes such as septic tanks before it is absorbed into the land as the final step of the treatment process.
A sand filter works to purify the wastewater in three ways:

- Filtration – straining of particles
- Chemical sorption – contaminants stick to the surface of the sand and to the biological growth on the sand surface
- Assimilation – aerobic microbes eat the nutrients present in the feed stream. The success of the system depends on these microbes so air is an important factor in this filtering system.

Several factors affect the filter’s performance, including two important environmental conditions: aeration and temperature. Oxygen needs to be available within the pores so that microbes can break down the solids in the wastewater. If the filter has poor air movement, such as when it is covered with heavy clay, the system can clog. Temperature directly affects the rate of microbial growth, chemical reactions, adsorption mechanisms and other factors that contribute to the stabilization of wastewater. Lower temperatures usually slow the rate of material breakdown. Maintenance requirements for sand filters depend on the type of filter. Buried sand filters are designed to limit the need for maintenance. The most important maintenance for them is to make sure the pre-treatment system is working properly. Applying solids, grease or scum to the surface of a buried filter greatly reduces its life. Otherwise, a correctly designed and installed buried sand filter should require no additional maintenance.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable in drainage areas of 1-10 acres</td>
<td>Waste needs pre-treatment</td>
</tr>
<tr>
<td>Require less space than other drainage systems</td>
<td>Expensive to install and maintain</td>
</tr>
<tr>
<td>Efficient pollutant removal</td>
<td>Not suitable for areas with high water tables</td>
</tr>
<tr>
<td>Can be used effectively in urban areas</td>
<td>No quality control</td>
</tr>
<tr>
<td></td>
<td>No idea for areas expecting high sediment loads</td>
</tr>
</tbody>
</table>
4.0: Evaluation

When choosing the solution to Devikulam’s sanitation problem there are five main factors that will affect choice. These factors are:

- Cost
- Complexity
- Space
- Maintenance
- Sustainability

To evaluate the option an Evaluation Matrix is an ideal method of narrowing down the choices. The choices were assigned a number from 1 to 8 for each factor, with 1 being the most applicable and 8 being the least applicable for the town of Devikulam.

<table>
<thead>
<tr>
<th>system</th>
<th>Cost</th>
<th>Complexity</th>
<th>Space</th>
<th>Maintenance</th>
<th>Sustainability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodigester</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Composting Toilet</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Baffle reactor</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>32</td>
</tr>
<tr>
<td>Septic Tank</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>Horizontal wetlands</td>
<td>6</td>
<td>1</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Vertical Wetlands</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>Lagoon</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Sand Filter</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>32</td>
</tr>
</tbody>
</table>

Note: sewage has not been considered as it is far too complex for this application and does not fit into the villagers needs.

Figure 4.0: Evaluation Matrix

These factors remove all but two of the choices from the different sanitation systems analysed. It leaves the biodigester and composting toilet. To decide on which one would be better for the people of the village each method of treatment needed to be analysed. One method was to determine the rate at which human waste would have to be added to each system.
4.1: Evaluation of Biodigesters

In order to evaluate the relevance of a biodigester, the number and size of the biodigesters needed for community or household systems needed to be calculated:

Number of people in the village of devikulam: 322 (EWB, 2011)

Due to many factors such as age, diet, body mass index (BMI), gender and other lesser variables there is no exact data regarding the faecal production of a person per day. In western countries though, this tends to be between 100-200g per day in a healthy person where as in cultures where rice and bread is a staple, unlike western cultures where higher meat/fat diets are more common, the average stool weight ranges from an average of 300-400 grams for women and men respectively (Hosseini et al). Children, depending on the age would be much less then this (as small as 90g) and should be factored in but due to the variation per day this becomes problematic. The variation in adult stool weight can vary 100g either way so this can help to account for children.

Since an Indian diet is largely made up of rice with little meat it can be assumed that there is a relation to the Iranian study where the stool weight is higher due to the increased fibre intake. This is the closest data found to describe the average faecal production of an Indian found due to the high variation from person to person.

Average daily stool weight per person:

371.5g (average of male and female weights)

Average stool production per day:

0.3715x322 = 119.623kg

Percentage of volatile solids (VS): 3% (Ram, 1993)

Amount of VS produced per day:

0.03x119.623 = 3.589kg
Ratio of stool to water ration to avoid scum buildup: 1:4 (an et al, 1997)

Volume of water needed per day:

\[ 119.623 \times 3 = 358.869 \text{kg} = 358.869L \]

Gas production from 1kg of VS: 0.5m$^3$ (500L) (Hill, 1983)

Percentage of methane in Biogas: 60% (this is an average and does vary)

Daily production of biogas from VS assuming only 50% digestion:

\[ 1.7945m^3 = 1794.5L \]

Daily production of Methane:

\[ 1.0767m^3 = 1076.7L \]

Gas consists only 20% of total biodigester volume. 80% is liquid and waste. The average temperature in the region is 20-30°C, the ideal operating conditions for a biodigester system.

Recommended retention time:

\[ 18 - 44 \text{ days} = \text{average 31 days (Lapp et al, 1975)} \]

1 biodigester:

Volume of liquid phase:

\[ 31 \times 478.492(\text{water and faeces}) = 14833.252L = 14.833252m^3 \]

Total volume including gas:

\[ 14.833252/0.8 = 18.54m^3 \]

Considering the diameter of the urethane plastic which comes as 0.8, 1.25 and 2.0m wide (Rodriguez et al, 1997), the length required for each size would be:

\[ \text{Length} = 4 \times \text{Volume} / \pi / \text{Diameter squared} \]
For each size plastic sheeting:

\[ \text{Length} = 4 \times 18.54/\pi/0.82 = 36.88\text{m} \]

\[ \text{Length} = 4 \times 18.54/\pi/1.252 = 15.11\text{m} \]

\[ \text{Length} = 4 \times 18.54/\pi/2.02 = 5.90\text{m} \]

These are large sizes and would be beneficial to make them more manageable and spread out so waste does not need to be carried long distances or the need for pipelines and pumps to be installed which would be costly. A biodigester should be 5-10 times longer than the diameter in order to achieve recommended retention time of a diameter of 2m is too large. If one biodigester was too be used, a diameter of 1.25m is adequate with a length of 15m.

For individual biodigesters where 120L of methane is needed in order to cook 3 courses throughout the day, which would work out to about a gaseous volume of 200L assuming 60% of the gas is methane. The volatile solids needed to produce this would be:

Volatile solids (VS) needed per day for 120L of methane: 0.5kg assuming only half of the VS is broken down

Average proportion of VS per person, per day

\[ 0.03 \times 0.3715 = 0.0111\text{kg} \]

Assuming the households have an average of 5 members the daily VS input would be:

\[ 0.0111 \times 5 = 0.0557\text{kg}. \]

The number of 0.0557kg is well below the VS quantity that is needed per day in order to produce the game needed for an individual home to use. Other items can be put into the digester such as animal waste or kitchen scraps. The disadvantage of this is that not all households own animals and the kitchen scraps need to be in small pieces in order to digest fast enough. Another obstacle is that the villagers indifference towards the technology (EWB, 2011), or more precisely the use of human waste as a by-product for soil improvement. The
effluent that comes out of the system is ideal for this but like the stigma associated with it in western cultures, it exists here.

4.2: Evaluation of composting toilets

With the composting toilet, although there still is the stigma regarding the use of human refuse as fertiliser, the end product can be disposed of in a hole in the ground and a tree can be planted in it. It does not need to be used for agriculture but due to it not fully removing all pathogens; it’s more suited to applications on orchards, not root vegetables and low growing plants where possible transmission can occur.

Composting toilets provide a solution to many obstacles in third world countries. Composting toilets are ideal in areas where:

- Land is at a premium, such as the centre of Devikulam
- Soil is either too rocky to dig into or too sandy for drainage pits
- Water is not in constant supply. Since Devikulam’s drinking water is supplied by a bore, it can be said that water is a precious commodity and waterless toilets are an ideal solution
- Groundwater levels. If high pit toilets can lead to contamination of the local water supply causing health issues
- Money and the price it costs to build/maintain a traditional toilet is too expensive

Composting toilets can be easily built with cost dependant on materials and complexity but is easily suited for community and household systems. There is no minimum input per day like biodigesters so here is less to worry about if you are one of the villagers. The time the composting takes is a longer period than the biodigestion, which is a faster process, but this also aids in the simplistic nature of the mouldering toilets. It could take a year or more to fill a chamber, depending on the size, and just as long to fill the second chamber meaning that the vaults are only emptied at a maximum of once a year, assuming correct operation.

So the final design to be chosen for this challenge is the home built, mouldering toilet for is cost effectiveness, easy implementation and its greater applicability compared to the biodigester.
5.0: Design Choice

As mentioned previously in section 3.2.2, the most cost effective compost toilet design is the home built, mouldering design. This is the basis for the design to be implemented for the people of Devikulam.

5.1: How Composting Works

Compost, as defined by The American Heritage Science Dictionary, is:

- A mixture of decayed or decaying organic matter used to fertilize soil. Compost is usually made by gathering plant material, such as leaves, grass clippings, and vegetable peels, into a pile or bin and letting it decompose as a result of the action of aerobic bacteria, fungi, and other organisms

The chemistry behind this process is simple as it depends on naturally occurring microbes and the availability of carbon and nitrogen along with a constant oxygen supply. Composting usually takes place at temperatures below that of the human body and is a slower process due to this and the microbes that is actively digesting the organic matter. This does affect retention time and reduction of pathogens but that will be discussed later.

5.1.1 Aerobic Bacteria

Aerobic digestion is one of four ways in which to treat human waste and one of the 2 ways that produce a usable product. Aerobic microbes, also known as aerobes, are microbes that are able to live and grow only where free oxygen, in gaseous form, is present. These are the microbes that decompose organic matter in compost bins where kitchen scraps, grass shavings and other various materials are deposited. This type of composting usually takes advantage of organisms such as fungi that can break down lignin and cellulose to a greater extent than anaerobic bacteria. Generally the process that takes place is the consumption of oxygen and carbon to form water and carbon dioxide. These are the stable forms of the elemental components. When this process takes place in an environment where the biodegradable material contains valuable nutrients like sulphur, phosphorous, nitrogen and potassium, the final product
contains their respective oxides. The majority of energy that was locked up in the organic content is released as heat since the reactions taking place are exothermic in nature.

In comparison anaerobic bacteria performs more efficiently when decomposing organic waste but needs a specific environment in order to survive. Since biodigestion has already been ruled out, this point has become irrelevant.

5.1.2: Importance of Carbon/Nitrogen Ratio

The analysis of how composting works is not complete without an understanding of the ratio of carbon to nitrogen needed in order to achieve a perfectly functioning compost pile. Ideally in a compost heap a ratio of 20/1 to 35/1 should be achieved by the different components added to the heap. The reason for this ratio has to do with the aerobic bacteria not being able to fully utilise nitrogen if it is in a too higher concentration. In the event that there is a high concentration of nitrogen, the microorganisms can’t utilise it and is converted to ammonia gas, a noxious smelling gas that also allows for the loss of the nitrogen from the pile.

<table>
<thead>
<tr>
<th>Initial C/N Ratio</th>
<th>Nitrogen Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>38.8</td>
</tr>
<tr>
<td>20.5</td>
<td>48.1</td>
</tr>
<tr>
<td>22</td>
<td>14.8</td>
</tr>
<tr>
<td>30</td>
<td>0.5</td>
</tr>
<tr>
<td>35</td>
<td>0.5</td>
</tr>
<tr>
<td>76</td>
<td>-8</td>
</tr>
</tbody>
</table>

Figure 4.1.2: Nitrogen Loss and C/N Ratio (Jenkins, 1999)

Although it is not expected that a person would measure the ratio within the compost bin, it is ideal to know how the system works in order to solve issues, such as smell, if they occur. An understanding of this process is necessary if it is to be used by a family who wish to be sustainable and improve their way of life.
5.1.3: Feed Material

Just like a traditional composting bin, there are many sources of carbon and nitrogen that can be used to create the ideal ratio of carbon to nitrogen. These include, but are not limited to:

- Grass clippings
- Leaf litter
- Saw dust
- Cooking ash
- Leaf trimmings
- Vegetable scraps
- Fruit scraps

So there is a limitless supply of material for composting if you know what is appropriate. Items like bones and rotten meat are not ideal as they can attract unwanted pests so it’s best not to add these.

When talking about a composting toilet the main source of nitrogen would be the faeces itself. This would be both human and animal but as Jenkins states in his book, The Humanure Handbook (Jenkins, 1999), human waste has a carbon nitrogen ratio of 5-10 meaning it needs a higher carbon component to ensure that no smell is emitted while the composting process is taking place. Composting human waste is just like composting kitchen and garden scraps, as long as the balance is right, the process will be vigorous and the end product will be safe to handle, as long as the retention time is met. It has been shown to be successful in many countries including India, Vietnam and Cambodia where different systems processing human waste have been implemented to help improve the way of life of the people willing to learn and change their perspective towards a ‘waste’ that can become a commodity.
5.1.4: Retention Time

The time the components spend in a compost pile determines the degree of aerobic digestion that takes place. When handling garden and kitchen waste, it is safe as there is no pathogens present in the feed material. When it comes to human excrement, the retention time becomes vital in ensuring that the majority of pathogens are killed off by the time spent in the heap. The longer the heap takes to compost the better it will be and being in a warmer climate benefits this process. In a composting toilet when a chamber is filled it cannot be forgotten about. Constant monitoring is needed to see if bug infestations occur or if odours start to rise from the pile. These are easy problems to sort out but it shows that it needs support from non-profit organisations and the community in order to guarantee success.

5.1.5: Pathogens

Human excrement being composted and used for agricultural purposes does not necessarily pose a threat to the health of the people of Devikulam as evidenced by the implementation of such systems in Vietnam since the 1950’s, yet it can. Faeces can harbour diseases, germs and bacteria that can make their way into the environment to infect the people like in medieval Europe. You don’t need to be sick, just a carrier to pass pathogens through faeces and urine can even contain disease germs.

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonella typhi</td>
<td>Typhoid</td>
</tr>
<tr>
<td>Salmonella paratyphi</td>
<td>Paratyphoid fever</td>
</tr>
<tr>
<td>Leptospira</td>
<td>Leptospirosis</td>
</tr>
<tr>
<td>Yersinia</td>
<td>yersiniosis</td>
</tr>
</tbody>
</table>

**Worms**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Schistosomiasms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schistosoma haematobium</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.1.5-1: Potential Pathogens in Urine (Feachem, 1980)

This partly illustrates that urine, thought to be sterile, can indeed be a receptacle in which diseases can be passed. So it is important to show just how harmful untreated waste can be
and how much improvement in health can be witnessed if sanitary practises are improved in regions where hand washing and use of unprocessed human excrement are common.

Human waste can harbour pathogens that can harm a person to a greater extent than what can be found in urine. They fall into four groups. These groups are viruses, bacteria, protozoa and worms.

<table>
<thead>
<tr>
<th>Virus</th>
<th>Disease</th>
<th>Symptomless Carrier?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotaviruses</td>
<td>Diarrhoea</td>
<td>Yes</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Infectious Hepatitis</td>
<td>Yes</td>
</tr>
<tr>
<td>Adenoviruses</td>
<td>Varies</td>
<td>Yes</td>
</tr>
<tr>
<td>Reoviruses</td>
<td>Varies</td>
<td>Yes</td>
</tr>
<tr>
<td>Coxsackievirus</td>
<td>Varies</td>
<td>Yes</td>
</tr>
<tr>
<td>Echoviruses</td>
<td>Varies</td>
<td>Yes</td>
</tr>
<tr>
<td>Polioviruses</td>
<td>Poliomyelitis</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 4.1.5-2: Possible Viral Pathogens in faeces (Feachem, 1980)

There are dozens of viruses that can be passed though faeces and they can be deadly. For instance 1.5 million children under the age of five die each year from the result of diarrhoea. It is said to be the second most common cause of child deaths worldwide (UNICEF India, 2011).

Bacteria, or more specifically the genus Salmonella, can cause typhoid fever, paratyphoid, and gastrointestinal disturbances. Shigella, another bacterium passed in faeces causes’ dysentery (Feachman, 1980).

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Disease</th>
<th>Symptomless Carrier?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonella typhi</td>
<td>Typhoid fever</td>
<td>Yes</td>
</tr>
<tr>
<td>Salmonella paratyphi</td>
<td>Paratyphoid fever</td>
<td>Yes</td>
</tr>
<tr>
<td>Other Salmonellae</td>
<td>Food poisoning</td>
<td>Yes</td>
</tr>
<tr>
<td>Shigella</td>
<td>Dysentery</td>
<td>Yes</td>
</tr>
<tr>
<td>Vibrio cholera</td>
<td>Cholera</td>
<td>Yes</td>
</tr>
<tr>
<td>Other Vibrios</td>
<td>Diarrhoea</td>
<td>Yes</td>
</tr>
<tr>
<td>E. Coli</td>
<td>Diarrhoea</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 4.1.5-3: Possible Bacterial Pathogens in Human Faeces (Feachem, 1980)
Pathogenic Protozoa are another group found with faeces. In their cyst stage the single cell amoeba die quickly outside of the body as they need to be kept moist in order to remain viable.

<table>
<thead>
<tr>
<th>Protozoa</th>
<th>Disease</th>
<th>Symptomless Carrier?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balantidium coli</td>
<td>Diarrhoea</td>
<td>Yes</td>
</tr>
<tr>
<td>Giardia lamblia</td>
<td>Diarrhoea</td>
<td>Yes</td>
</tr>
<tr>
<td>Entamoeba histolustica</td>
<td>Dysentery, colonic ulceration, liver abscess</td>
<td>yes</td>
</tr>
</tbody>
</table>

Figure 4.1.5-4: Potential Protozoa in human Faeces (Feachem, 1980)

Finally there are parasitic worms. They pass their eggs in faeces and urine and can be the most problematic when it comes to treating faeces via composting.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Transmission</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hook worm</td>
<td>Human – soil – human</td>
<td>Warm, wet climates</td>
</tr>
<tr>
<td>Giant intestinal fluke</td>
<td>Human/pig – snail – veg – human</td>
<td>S.E. Asia, China</td>
</tr>
<tr>
<td>Thread worm</td>
<td>Human – human</td>
<td>Warm, wet climates</td>
</tr>
<tr>
<td>Round worm</td>
<td>Human – soil – human</td>
<td>Worldwide</td>
</tr>
</tbody>
</table>

Figure 4.1.5-5: Potential Worms in Human Faeces (Feachem, 1980)

This is why it is of the upmost importance to treat faeces properly to kill all or the majority of these pathogens so they don’t harm the people of Devikulam. The composting of faeces should therefore be undertaken with a serious approach, not haphazard and in a frivolous manner. The pathogens in excrement have varying survival times outside the human body dependant on the conditions and possibly lead to the re-infection of people. Nevertheless there is no proven, natural, low tech method available to the masses other then the composting, whether that is thermophilic or mesophilic composting.

When composting human waste Feachem suggests a minimum retention time of 3 months is needed to kill off most of the pathogens. Since moulder toilets don’t generally maintain a temperature equivalent to or greater than the human body, roundworm eggs can survive the composting process (Feachem, 1980 and Jenkins, 1999). This just limits the use of the compost
to root and ground vegetables but it is still perfectly adequate for orchard use. If this is a concern, the compost can be added to a traditional pile and thermophilically treated to kill the roundworm eggs.

6.0: Final Design

The most intensive part of constructing a mouldering composting toilet is building the 2 chambers in which the human waste is deposited into. Sa mentioned this sort of design only works when there is 2 compartments as once the first is filled, the family switches over to the second chamber to let the composting process continue. Assuming a family consists of 5 people, the calculation of the chamber sizes should be worked out first.

6.1: Chamber Size and Material

The Indian diet compared to a westerner’s diet consists of a higher percentage of fibre and carbohydrates in the form of rice. Since fibre passes right through the digestive system, stool weight would be different due to this. The stool weight has been based on an Iranian study as the diet also consists of a high fibre diet in the form of rice and bread (Hosseini et al). The mean weight for men and women are 432 and 311 respectively. The average of these two values is 371.5g. The moisture content of human excrement is 66-80% of total weight and from this we can assume that it is approximately the same density of water although this would differ from diet to diet. Assuming that stool weight to volume ratio is the same as water will aid in the calculation of the chamber size needed for the mouldering toilets.

Waste volume calculation:

1. Family of 5 faecal production

\[ 371.5g \times 5 = 1857.5g \]

2. Volume to weight ratio of water:

\[ 1000g = 1L \text{ of water} \]

3. Volume of waste per day for family of 5:

\[ \frac{1857.5}{1000} = 1.8575L \]
Since mouldering toilets generally cannot produce or sustain thermophilic composting, the retention time within the compartment will need to be long enough to destroy most of the pathogens found in human waste. It is suggested that 9 months is sufficient for composting after the chamber has been filled but this would vary due to the size (Calvert, 2006). A minimum of 3 months retention time is also suggested (feachem, 1980) so from these two values a minimum of 9 months should be the goal. For ease of use for the families, the less they have to empty the vaults the better. So a 12 month retention time will be used. Due to the variation in daily faecal production per person it may take longer to fill each chamber of the toilet but the longer the retention time is, the larger the percentage of pathogens are killed. In Vietnam a double vault design was implemented where it used urine separation which reduces the chances of smells being emitted from the chamber. Combining this design with the mouldering toilet will help to ensure that the facility dies not smell causing the owners to abandon it. It also suggests that a size of 1.2m wide, 0.7m high and 1.7m long is required for a family of five to ten people (Jenkins, 1999). This size can be compared to

Calculation of volume of chambers:

4. Daily waste production:

\[1.85L \text{ per day}\]

5. Waste production over 12 month period

\[1.85L \times 365 \text{ days} = 675.25L = 0.675m^3\]

6. Volume of chambers in Vietnam double vault design

\[1.2m \times 0.7m \times 0.85m = 0.714m^3\]

So these are indeed similar values for the calculation made above in point 5.

So the final chambers should be of an internal volume of 0.7m³ each in order to achieve a retention time that will ensure the majority of pathogens are killed off while the excrement is composted. The brick sides will need to be constructed on a concrete foundation to ensure that
any waste does not seep into the ground and eventually the water table and ensuring that there is no movement once constructed.

The chambers are the most important aspect of the design as is what needed to be addressed prior to construction. If there are larger families or eventual applications as public toilets, the size of the chambers will need to be recalculated to ensure an appropriate retention time is achieved.

6.2: Wall and Roof Materials

The walls, door and roofing can be made from local timber and thatching materials such as palm leaves which is assumed is readily available. If this is not the case, Pitchandikulam Forest may be able to aid in the procurement of materials. Alternatives include bricks, concrete blocks, ferro-cement sheets, and recycled building materials where needed. Since the women are known to make weaved bags (EWB, 2011) they can aid in construction by preparing the walls of the mouldering toilet. This can aid in bringing to community together by holding this in the community halls or on site so they can witness the construction and realise their importance in the construction process.

6.3: Urine Separation

The urine separation is an important aspect of making this process effective. By no collecting it in the chamber, which in turn would increase the water content causing anaerobic digestion seen in biodigesters, this in turn would cause smelly gases to be produced. Since urine is high is urea, a common fertiliser, it can be utilised straight away. Assuming that Indians indeed use water to wash themselves after defecation then the waste water stream can be combined with the wash water stream and collected into a bucket. Since constant maintenance would be an issue, Calvert’s compost toilet uses an evaporative plant bed where the urine will be utilised immediately by the plants removing the need to handle and dispose of the urine and water. Such plants that can be planted include fruiting trees and would provide an additional source of food for the family. If toilet paper is the preferred method of cleaning ones self this can be added to the chamber.
6.4: Depositing of Your waste

It is recommended that after each deposit into the chamber that a source of carbon is added in order to maintain the ideal carbon nitrogen ratio. If this is not achieved then nitrogen is converted to ammonia, which is an unpleasant smelling gas (Jenkins, 1999). Such sources include sawdust, raw or composted, with composted being the ideal form, or kitchen ash. This has two main objectives, to soak up additional moisture to ensure and odourless toilet, and to maintain the appropriate carbon nitrogen ration of 30:1. A bucket in the toilet would contain which ever material is easily accessible to the family along with a bucket of water for cleansing.

6.5: Maintenance

Since the chamber is wider than the hole that defecation takes place it, it is necessary to even out the pile when it gets too high. This can be done simply with a stick. Not the ideal solution but needs to be done. This should be the responsibility of the household, not an individual person. If the door and baffle option is preferred, this can be done though the hatch and not the defecation hole.

When a chamber becomes full for the first time, prior to closing it up the remaining room left after levelling the pile is to fill it with leaves, straw or sawdust to supply enough carbon for the composting process. The hole should then be covered and let to sit for at least 9 months.

When it comes to the time when you need to move back to the first chamber, the compost needs to be checked to see it is completely decomposed. If left to the right period of time this should not be a problem. Empty the contents and bury in holes for orchard trees of dispose of the same way. Check on the urine collection pipework and disconnect the fittings to make sure there are no blockages. Line the base with dry organic content, leaves, straw etcetera, and cover the other hole until it comes time to swap back.

The chambers only need to be accessed when the compost is ‘ripe’ so the most efficient method is to brick it up. The design would then have 2 access holes that will be bricked up but not with traditional mortar. Using a mud mortar mix rather than concrete will allow easy access
once it comes time to empty the compost out. The ‘mud’ in this case is clay is a common occurrence on al continents. It is also mentioned by Calvert in his simple compost toilet design (Calvert, 2006). Testing should be done to find the best ratio of water to sand and clay and allowing drying to monitor cracking/contraction of the mixture (Ruskulis, 2005). It is a strong bonding material but easy enough to replace when it comes to removing the bricks it’s an easy process. If this is problematic a baffle and door can be installed but this adds to the complexity and cost. It would be easy enough to install this at a later date if it is found to be of a better alternative.

If it starts smelling that means more dried organic matter needs to be added. Start adding half a bucket every day until the smell dissipates. If it doesn’t this may mean that the pipework has disconnected. If it has been over 9 months since using it, fill with excess organic content and close up then fix pipe work when its time to clean it out. Since there is no more urine draining in and the addition of organic matter is soaking up the fluids, the smell should dissipate over time.

6.6: Materials and Considerations

6.6.1: Location

The first step to building a composting toilet is to find the right location. Finding the right site can be difficult for someone who has not built such a building before but you will need to consider:

- Proximity to house
- Convenience for the family
- Far enough away from the neighbours
- Has enough room for the chambers and the evaporation bed
- If possible avoid removing trees or large shrubs as this provides privacy and shade

6.6.2: Site Preparation

The primary concern of site preparation is to level the ground. It is important to get everything right from the beginning because as you progress further into the project, problems made earlier on become harder to correct.
6.6.3: Tools

These are the basic tools that are needed for the preparation of the construction of the chambers of the composting toilet.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hammers</td>
<td>Nailing wood and using cold chisel</td>
</tr>
<tr>
<td>Handsaws</td>
<td>Cutting wood</td>
</tr>
<tr>
<td>Trowels</td>
<td>Working concrete</td>
</tr>
<tr>
<td>Shovels</td>
<td>Preparing site, mixing concrete</td>
</tr>
<tr>
<td>Spirit level</td>
<td>Levelling blocks and concrete pad</td>
</tr>
<tr>
<td>String line</td>
<td>Measuring out dimensions of concrete pad,</td>
</tr>
<tr>
<td></td>
<td>guide for brick laying</td>
</tr>
<tr>
<td>Measuring tape</td>
<td>Measuring composting toilet dimensions</td>
</tr>
<tr>
<td>Cold Chisel</td>
<td>Breaking bricks/blocks</td>
</tr>
<tr>
<td>36L bucket</td>
<td>Moulding of toilet hole</td>
</tr>
<tr>
<td>Bolt cutters</td>
<td>Cutting rebar</td>
</tr>
<tr>
<td>Pliers</td>
<td>Cutting and fastening tie wire</td>
</tr>
<tr>
<td>Hand Drill</td>
<td>Drilling holes, fastening material</td>
</tr>
<tr>
<td>Carpenter’s Square</td>
<td>Accurate measurements</td>
</tr>
</tbody>
</table>

These may vary depending on what is on hand and power supply for such items like the hand drill. If power is an issue a manually powered one could be used but not ideal as drilling into brick/concrete would prove difficult.
6.6.4: Materials for Composting Chambers

The below materials are for a simplified toilet with no access door but simply a brick shell and top where access comes from a section of the foundation bricked up with clay mortar.

<table>
<thead>
<tr>
<th>Material</th>
<th>Number</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard House Bricks (230x110x76)</td>
<td>440-480</td>
<td>Chambers, enclosed opening, stairs</td>
</tr>
<tr>
<td>10mm rebar (6m lengths)</td>
<td>10</td>
<td>Foundation, capping slab</td>
</tr>
<tr>
<td>Cement (20kg Bags)</td>
<td>14</td>
<td>Foundation, capping slab</td>
</tr>
<tr>
<td>Sand (m³)</td>
<td>0.3</td>
<td>Foundation, capping slab</td>
</tr>
<tr>
<td>20mm Aggregate (m³)</td>
<td>0.4</td>
<td>Foundation, capping slab</td>
</tr>
<tr>
<td>Tie wire (kg)</td>
<td>0.25</td>
<td>Foundation, capping slab</td>
</tr>
<tr>
<td>100mm PVC pipe (3m)</td>
<td>2</td>
<td>Ventilation</td>
</tr>
<tr>
<td>Fine sand (m³)</td>
<td>0.4</td>
<td>Mortar, render</td>
</tr>
<tr>
<td>Masonry Cement (20kg Bags)</td>
<td>8</td>
<td>Mortar, render</td>
</tr>
<tr>
<td>Black Plastic (m²)</td>
<td>5</td>
<td>Foundation slab</td>
</tr>
<tr>
<td>36L bucket</td>
<td>4</td>
<td>Moulding of squat hole</td>
</tr>
</tbody>
</table>

Notes:

- Masonry Cement is a mixture of grey cement and limestone negating the need of lime in the mixture. If masonry cement is not available then traditional grey cement can be used with lime to achieve a stronger mortar bond. If lime is not available either, consult local bricklayers of the best mixture for laying clay bricks.
- The stairs have been calculated to use house bricks (144 of them) but can be made put of local stone, wood or other local material such as the mud mixture of local buildings.
Concrete blocks can be substituted for house bricks but amount would need to be recalculated for the change in the block dimensions.

If chamber doors are the preferred method rather than the bricking up of the access holes, then the additional material would be as follows in the table below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Number</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x10cm local hardwood/treated pine (0.72m)</td>
<td>4</td>
<td>Timber frame for chamber door (horizontal piece)</td>
</tr>
<tr>
<td>3x10cm local hardwood/treated pine (0.46m)</td>
<td>4</td>
<td>Timber frame for chamber door (vertical piece)</td>
</tr>
<tr>
<td>3x5cm local hardwood/treated pine (0.0.65m)</td>
<td>4</td>
<td>Access door (horizontal piece)</td>
</tr>
<tr>
<td>3x5cm local hardwood/treated pine (0.49m)</td>
<td>4</td>
<td>Access door (vertical piece)</td>
</tr>
<tr>
<td>10mm thick plywood (0.72mx0.2m)</td>
<td>2</td>
<td>Baffle doors</td>
</tr>
<tr>
<td>Wing nut and bolt</td>
<td>8</td>
<td>Fixing baffle doors</td>
</tr>
<tr>
<td>Galvanised iron sheeting (0.9mx0.9m)</td>
<td>2</td>
<td>Access door</td>
</tr>
<tr>
<td>handle</td>
<td>2</td>
<td>Access door</td>
</tr>
<tr>
<td>Galvanised padbolt</td>
<td>2</td>
<td>Access door</td>
</tr>
<tr>
<td>Door hinges</td>
<td>2</td>
<td>Access door</td>
</tr>
</tbody>
</table>
6.6.5: Materials for Urine Separation System:

Urine separation is probably the most complex part of this design and needs to be installed in order to maintain a clean smelling toilet. There is two ways in which this can be done. UNICEF India builds ecosan (ecological sanitation) toilets that have pre-fabricated plastic moulded squat toilets where there is urine separation and anal cleansing stations together. Contacting them and getting a price for such a system would be beneficial even if it is from just a price point of view. The other method is to mould them into the concrete while it is being cast for the capping of the chambers. For this you would need the following materials:

<table>
<thead>
<tr>
<th>Material</th>
<th>Number</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm flexible piping</td>
<td>10m</td>
<td>Piping to evaporation bed</td>
</tr>
<tr>
<td>20mm 90° fitting</td>
<td>6</td>
<td>Connection fitting</td>
</tr>
<tr>
<td>20mm T join</td>
<td>2</td>
<td>Joining to fluid streams together</td>
</tr>
<tr>
<td>20mm cap fitting</td>
<td>2</td>
<td>To cap end of hose in evaporation bed</td>
</tr>
<tr>
<td>20mm joiners</td>
<td>2</td>
<td>To join perforated and non-perforated piping together</td>
</tr>
<tr>
<td>Silicon sealer (stick)</td>
<td>1</td>
<td>Sealing drainage holes</td>
</tr>
<tr>
<td>30mm PVC piping (1m)</td>
<td>2</td>
<td>Protect the flexy piping from being crushed</td>
</tr>
</tbody>
</table>

6.6.6: Evaporation bed

This is a very important aspect of the design to ensure that the owners have less maintenance to perform. The evaporation bed can be simply a strong plastic lined trench in which the plastic but would ideally have supported walls of brick, stone or concrete blocks. For ease of calculation clay bricks (230x110x76mm) have been used but if a free material can be found then that would be more ideal.
<table>
<thead>
<tr>
<th>Material</th>
<th>Number</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC pond liner (m²)</td>
<td>2</td>
<td>Lining</td>
</tr>
<tr>
<td>Masonry cement (20kg)</td>
<td>1</td>
<td>Mortar</td>
</tr>
<tr>
<td>Sand (m³)</td>
<td>0.06</td>
<td>mortar</td>
</tr>
<tr>
<td>Standard house bricks (230x110x76mm)</td>
<td>96</td>
<td>Evaporation pond surround</td>
</tr>
</tbody>
</table>

Note that if pond liner is unavailable; a 0.5mm strong plastic can be used instead. As long as the plastic will last long enough without deteriorating in the conditions of Devikulam, it will suffice.

6.6.7: Materials for Toilet House

This has not been included as it is a difficult part of the project to cost. There are also many different materials that it can be made from. Such materials include:

- Brick
- Concrete blocks
- Ferro-cement
- Corrugated iron
- Thatch
- Timber
- Plywood

Some of these materials may cost more than others and some may be acquired from local reclamation yards or possibly free from the local area. The materials would also be dictated by the people of the village and what they would prefer to have. In the construction section of this project report a basic outline of the full structure would be shown but no specifics on the toilet building will be provided. The most important aspect of this build is the composting chambers.
7.0: Construction

Part 1: forming the foundation slab

1. Construct the formwork for the foundation on the level ground of the location you have chosen for the toilet. The final length and width of the toilet assuming a 10mm mortar fill be about 1.8m deep by 2.2 m wide. The 2.2, wide side is the entrance location and opposite side is where access to the compost will be. The foundation should be about 0.1m wider in each direction to compensate for any error.

2. Dig down 0.15m

3. Fill and compact the formwork with a layer of stone leaving 0.1m for concrete

4. Cover with plastic

5. Cut the rebar into pieces to go around the slab and creating a grid to reinforce the concrete

6. Use tie wire to form sturdy reinforcing grid

7. Fill framework with concrete mix. This mix should be in a ration of 1 part cement, 2.5 parts sand, and 5 parts aggregate to create a footing ideal for domestic buildings.

8. When finished, the slab needs to be wet and covered so that the concrete doesn’t dry to quick and crack. This should be done for 2 days over the curing period.
**Part 2: constructing the chambers**

1. After letting the concrete cure, remove cover and formwork and wash surface with water.

2. Mark out the dimensions of the chambers which will have an internal dimension of 0.84m by 1.56 m. The wall separating the 2 chambers will be double brick to make sure that the concrete slab that caps the chambers has adequate support.

3. Set up a string line as a guide for the courses of bricks.

4. Lay the first course of bricks including the walls between the two chambers. Each chamber will be approximately 4 and ½ bricks wide (1.08m) and 7 and ½ bricks deep (1.8m). The first layer of bricks will be a complete course; no gap for the doors.

5. The internal dimensions of the chamber will be 6 and ½ bricks deep (1.8m) and 3 and ½ bricks wide (0.84m).
6. On the second course ensure you leave a gap of about 30mm for the piping from urine separation to be fed through to the evaporation bed.

7. Continue laying bricks until you are 7 courses high (0.6m). While building ensure that the walls are straight and level otherwise this will cause problems with it comes to laying the concrete slab on top.

Rear of chamber:

1. Plaster the walls on the interior of the chambers. This helps to make is water proof but also easier to clean out. The ration of masonry cement to sand is 1 to 5 parts respectively. It does not need to be perfect.

Part 3 (optional): Baffles and access doors

2. Frame opening with treated hardwood. You will need a drill with a masonry drill bit. Should end up looking like the picture below:
Figure 6.0: timber frames for access doors (Crennan, 2007)

Door Frames:

- Vertical timber: 3x10cm, 0.46m long
- Horizontal timber: 3x10cm, 0.72m long

Door:

- Vertical timber: 3x5cm, 0.49m long
- Horizontal timber: 3x5cm, 0.65m long
8. The doors are constructed by bending the galvanised sheeting over the frame which is 1cc smaller than the timber frame, and screwing it into place. The door handle and bolt are attached to the door on the inner side to open outwards. The loop for the pad bolt will be attached to the outer frame.

9. The baffles are secured by drilling holes though the outer timber frame and baffles so that the wing nuts and bolts hold them in place to ensure the compost does not spill out when checking on the pile.

10. This should be installed after all other construction is finished as easy access is needed for installation of urine diversion piping

Baffles:

- Circles are locations for drilling. Make sure you’re in the centre of the timber and that you are not drilling where an existing screw is. By having the baffles in place while drilling the holes through the timber, you will be drilling though the baffle boards as well meaning they will line up without additional measuring and drilling.

Note: by building access doors about 48 less bricks will be needed for construction.

Part 4: Evaporation bed
1. Dig a trench 1 metre away from the composting toilet with the dimensions 1m by 1m with a lip 0.1m deep and 0.25m wide all around and 0.5m deep with slopping sides. Make sure to remove any sharp objects so you don’t puncture the liner.

2. Lay one course of bricks on the edge of the trench lip making sure to place on mortar to stabilise it.

3. Drape pre cut liner into the hole and over the first course of bricks. Make sure it fits comfortably and is not stretched. Crinkling is fine as it will be filled up later.

4. Where there is overlap at the trench lip add another course of bricks so next to the first so that the plastic overlaps the first course closest to the edge and goes under the second course so it is held in place. Again lay on a bed of mortar to ensure its a strong bond.

5. Now lay another course of bricks in the opposite direction of the first course to make sure the liner will not move.

6. Fill the trench 1/3 with course sand. It does not have to be the same as what is being used in the concrete.
Part 5: Constructing the concrete capping of the chambers

1. First the squat hole ring should be made. With the bucket cut the outer rim off to give a ring about 15cm tall and same depth. This should a ring to give a ring about 3-5cm width. With a mortar mix and tie wire as the reinforcing, half fill the ring mould in a flat surface then loop tie wire around the circle a few times.
2. Allow to cure.
3. When the ring is cured the capping can be made for the toilet. This will be a 10cm thick slab in 2 pieces with moulded wash basin and urine collecting trough in the design. The design will also need to incorporate a hole for the ventilation pipe.
4. The basins should be sloped enough to ensure emptying via gravity. A piece of the 20mm piping to be use to ensure that no drilling is needed and can be removed later. Only two small pieces, 15cm at the most, should be used. Also, a piece of the ventilation pipe should also be moulded in while the slab is drying.

5. The ring has already been moulded by to ensure that it does not come away from the slab, use tie wire around it to attach it to the rebar reinforcing of the slab. This just needs to be done around the ring so it will be covered by the concrete mix.

6. During the curing process is when the moulding process will take place. Using tools and hands (wearing gloves), hand mould the basins making sure to plan ahead the placement of the rebar so it is not in the way.

7. Like before, allowed to cure for two days, keeping it damp to avoid cracking and covered as well.

8. When cured, place a mortar mix on the top of the chamber walls and lower the capping slabs on top. Make sure the exhaust holes are above the access doors.

9. Fill the gap between each slab with a mortar mix.

**Part 6: Building the stairs**

1. The stairs use about 144 bricks on the total amount. The tread will be 3 and ½ bricks deep and 2 courses high. There will be 3 steps in total to get to the top of the toilet.

2. Clear any rubble away and make sure your starting at the height of the top of the foundation.

3. Lay first course of bricks on a bed of mortar to add support and use spirit level to ensure the steps are level.

**Side Profile of stairs:**

![Side Profile of stairs]
Part 7: Installing urine separating system

1. Take 4 of the 20mm 90° fittings and where the holes where made in the concrete slab slip in and glue on with silicon sealer. This is a water proof sealer and should help to keep it in place. The join should be facing towards the internal wall. Let the glue dry. Make sure you are installing both pipelines at the same time.

2. Now take the 20mm hose and cut 4 pieces, equal length so that they stretch in a curve from the 90° fitting to the base of the internal wall. Attach another 90° bend from the urine basin tube (closest basin to the stairs) and a T join to the cleansing basic tube.

3. Connect the urine basin tube to the cleaning basin tube via the connections by an appropriately sized piece of pipe.
4. Take the PVC piping and place from the hole in the wall to the evaporation bed. Thread through another piece of piping until it’s about half way down the side of the pit.

5. Connect a 20mm join to the end of this pose

6. Take a 1m piece of the 20mm pose and using a knife or scissors, poke holes right along the entire length so drainage of the urine/water mixture occurs. Attach a stopper to the end

7. Connect this to the pipeline.

8. Test there is no leaks or blockages by pouring water though the system.

9. Cover with 10cm of course sand and hessian if widely available. It stops the course material becoming clogged.

10. Fill the pit to about half a brick height from the top. This can then be planted with a fruit tree or flowering plants.

Part 8: Installation of the toilet House

As mentioned the materials for this have not been added as it should be determined form the material that are free and available if possible. There are some aspects of the build that need to be discussed though.

- The PVC piping should be fed though the roof with 1 metre above the roofline. It should also be planted a dark colour, preferably black. This aids in good circulation as the air in the pipe heats up causing it to rise, therefore causing lower pressure in the chambers and sucking new air in. This sort of toilet needs constant air flow and this is the best way to achieve it without the use of an exhaust fan.

- The top of the PVC piping should be covered with fly wire to reduce the chance of insect infestation.
- Covers should also be made. Can be of material found locally such as scrap wood or metal pots

**Part 9: Preparing the toilet for first use**

1. Place a layer of hay on the bottom of the toilet to add enough carbon for the aerobic bacteria.
2. Place in baffles and close door if installed.
3. If opting for the ‘brick-up’ method, mix a mixture of clay and sand in an already predetermined mixture and use like mortar. Close up both access holes.
4. The toilet will have 3 buckets, one with water for cleaning inside the toilet, one with water and soap outside for hand washing. The other bucket should contain sawdust or kitchen ash to cover the faecal matter after each deposit. This is necessary in order to ensure an odourless chamber.
Roofing is shown as a simple half gable design but this is for practicalities sake. The design of your composting toilet should be adapted to your needs. This may include the addition of a washing room for instance. The materials available in the local area also dictate the construction of such a building. As long as the basic principles of the chambers are followed, the toilet is very easy to adjust to different needs. The list of materials is just for the design of the chambers which are the most important aspect. It is up to the family to decide on what they would like or could afford.

The windows shown in the diagram on the previous page are important for ventilation and also to help heat the PVC ventilation pipe. As mentioned previously, by heating the pipe is causes the air to rise, drawing more air into the chamber. It is ideal to have this facing south, or where
the sun will be in direct line of the windows but due to the ventilation pipes passing one metre above the roof line, it is mandatory.

8.0: Cost of the Composting Toilet

As mentioned numerous times already, this costing is for the composting chamber itself. The reasons for this include many unknown factors such as:

- Ideal materials for toilet house construction
- Local availability of materials
- Price of local materials
- Skilled labour available
- Location to house
- House styles

So it is easier to leave this up to the family involved and they can dictate what they would prefer. Costing would have to be done on site. The problem with costing such products is the availability of price lists for the suppliers in the region that Devikulam is located. All costings are in Australian dollars which is almost equivalent to the value of the US dollar (19th of May, 2011).

<table>
<thead>
<tr>
<th>Material</th>
<th>Number</th>
<th>Price per Unit ($AU)</th>
<th>Total ($AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard House Bricks (230x110x76)</td>
<td>480</td>
<td>0.50</td>
<td>240.00</td>
</tr>
<tr>
<td>10mm rebar (6m lengths)</td>
<td>10</td>
<td>10.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Cement (20kg Bags)</td>
<td>14</td>
<td>8.50</td>
<td>119.00</td>
</tr>
<tr>
<td>Sand (m$^3$)</td>
<td>0.3</td>
<td>49.50</td>
<td>14.85</td>
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<tr>
<td>20mm Aggregate (m$^3$)</td>
<td>0.4</td>
<td>135.00</td>
<td>54.00</td>
</tr>
<tr>
<td>Tie wire (roll)</td>
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<td>11.50</td>
<td>11.50</td>
</tr>
<tr>
<td>100mm PVC pipe (3m)</td>
<td>2</td>
<td>24.00</td>
<td>48.00</td>
</tr>
<tr>
<td>Fine sand (m$^3$)</td>
<td>0.4</td>
<td>49.50</td>
<td>19.80</td>
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<tr>
<td>Masonry Cement (20kg Bags)</td>
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<td>64.00</td>
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<tr>
<td>Material</td>
<td>Number</td>
<td>Price per Unit ($AU)</td>
<td>Total ($AU)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------</td>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>20mm irrigation piping (20m roll)</td>
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<td>10.50</td>
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<td>20mm 90° fitting</td>
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<td>6.00</td>
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<td>20mm T join</td>
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<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
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<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>20mm joiners</td>
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<tr>
<td><strong>Total:</strong></td>
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<td></td>
<td><strong>22.50</strong></td>
</tr>
</tbody>
</table>

Evaporation Bed Cost:

<table>
<thead>
<tr>
<th>Material</th>
<th>Number</th>
<th>Price per Unit ($AU)</th>
<th>Total ($AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC pond liner (m²)</td>
<td>1</td>
<td>7.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Masonry cement (20kg)</td>
<td>1</td>
<td>8.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Sand (m³)</td>
<td>0.06</td>
<td>49.50</td>
<td>3.00</td>
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<tr>
<td>Standard house bricks (230x110x76mm)</td>
<td>96</td>
<td>0.50</td>
<td>48.00</td>
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<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>66.00</strong></td>
</tr>
</tbody>
</table>

Total cost for the chambers in Australian dollars is $759.65. Although the cost does seem more than a single family can afford, the fact that the cost for this project is based on Australian products and prices, not the prices of materials in India, should be remembered. Since labour and materials are substantially more expensive here than in third world countries, this price is meaningless until actual prices for the materials can be collected. For comparison, Clavert built composting toilets in India during the period of 1999 for £90, even with exchange rates taking into account the difference between countries this is an enormous difference. A composting toilet system was also implemented in Cambodia at a cost of US$350 in 2010 (HUSK, 2011). This does not include the toilet room above the chambers as this would be dictated by the region it is in.

### 9.0: Education

If there is no toilet close to home people are forced to live in an unhealthy lifestyle and also living in an unpleasant environment. Diseases are being spread around due to unclean water and poor sanitation; diseases include cholera, typhoid and dysentery. Sharing toilet facilities or going out in the open with hundreds of other people will make it uncomfortable particularly if you are suffering with diarrhoea. Being a girl or woman, they will be disadvantaged due to them being insecure due to social stigmas and religious beliefs, where they have to wait until it is dark, which can lead to illness or an attack. Having poor sanitation causes sickness which can
cause children to miss school or adults from working and earning income. Sickness leads to
medical expenses and the income of many are limited in rural districts and villages like Devikulam.

Having sanitation in a rural community helps the privacy and safety for the people and benefits
for the women. Sanitation improves the health of the people and men and women will go to
work healthier and earning a living. It is not sufficient to provide impoverished people with a
clean and sustainable way of treating their waste, as many have not been educated to use such
a system and this is a major stumbling block in the implementation of new toilet facilities like a
composting toilet.

The education of the people of Devikulam is an important aspect of the project if it is to
succeed. The way in which to educate the people will vary depending on their age as younger
children tend to be more receptive to change.

9.1: Education of Children

Children tend to be the easiest to educate as programs can be introduced into the school
curriculum. This is also beneficial as it can be applied to all schools and a national, or
international method of education can be developed. Below are four methods sourced from
The World Bank Organisation’s educational site, SchoolSanitation.org, regarding teaching safe
hygienic practises to children.

9.1.1: Child-to-Child Approach

The Child-to-Child six-step approach provides a convenient framework for children's active
participation in health and hygiene promotion (Child-to-Child Trust, 2009). Child-to-Child ideas
and activities represent an approach to health and hygiene education. Child-to-Child activities
should be seen as components that may be integrated with broader health and hygiene
education programs that are either at the planning stage or already in operation. The
distinguishing characteristics of Child-to-Child are the direct involvement of children in the
process of health and hygiene education and promotion and the nature of their involvement.
The most effective programs are those that involve children in decision-making rather than merely using them as communicators of adult messages. However, whenever children are involved as partners in this way, change is demanded in current structures and methodologies in health and education.

Child-to-Child ideas and activities spread and take root in many different countries and contexts. Wherever their activities take place, they stress the potential of children to promote better health and hygiene to younger children, to children of the same age, and within their families and communities.

Figure 8.1 (schoolsanitation.org, 2011)

Child-to-Child sees children as agents of change themselves, not megaphones to transmit messages from adults. The six-step approach enables both children and adults to work with Child-to-Child ideas.

The six-step approach has an important effect on the way children are taught and learn for three reasons:

- It links what children learn with what they do;
- It links what children do in class with what they do in the home;
- The activities are not taught in one lesson and then forgotten; they are learned and developed over a longer period of time.

**Steps of Child-to-Child Teaching**
1. Identifying a local health issue and understanding it well: Children and/or their teacher/facilitator identify a priority health issue. The issue chosen may relate to a stated objective of the school curriculum or syllabus, or to a health campaign taking place in the community. Once an issue is identified, the children carry out activities designed to increase their understanding of it.

2. Finding out more about the health issue: This step involves children in further information-gathering activities. Some of these activities may take place inside the school, while others might take place in the community or at home. Ideally, these activities help children to learn how to gather and document information and develop important communication skills.

3. Discussing what’s been found out and planning action: Here the children organize their findings and use them as a basis for planning action in relation to specific health or hygiene problems they have identified during step 2. The teacher/facilitator can take part in the planning process, and help children to distinguish between correct and incorrect information they might have gathered.

4. Taking action: The children undertake the activities planned at step 3. These might take place in school, community, or home, depending on the nature of the health or hygiene issue chosen. The types of activities undertaken may also depend on local customs and the nature of the relationships in the community, including between the school and the community.

5. Discussing results: The children and their teacher/facilitator evaluate the effectiveness of their activities. If unexpected problems have been encountered, it is important for these to be discussed.

6. Discussing how we can be more effective next time and sustain action: Step 6 invites children to improve upon the activities they implemented at step 4 and, if appropriate, to repeat or continue their action.

9.1.2: PHAST Adaptations

PHAST, developed by WHO, the World Health Organization, in the mid 1990s in Africa, stands for Participatory Hygiene and Sanitation Transformation (WHO, 1996). It is an innovative approach designed to promote hygiene behaviors, sanitation improvements, and community management of water and sanitation facilities using specifically developed participatory techniques. It is an adult methodology, but because its use has become so common in developing countries, it is now being adapted for use with children. The advantage of adapting
PHAST is that in many countries a group of promoters who know how to train on PHAST is already in existence. One such adaptation is CHAST, Children’s Hygiene and Sanitation Training, in Somalia. Unlike PHAST, the CHAST approach skips activities such as mapping, planning, and selecting options. Instead it uses methods such as coloring drawings, playing games, and doing hygienic activities more suitable to children.

PHAST consists of seven steps. The first five help to take the community group through the process of developing a plan to prevent diarrheal diseases by improving water supply, hygiene behaviors, and sanitation. The sixth and seventh steps involve monitoring (that is, checking on progress) and evaluation. The information gained from these activities is used to work out whether the plan has been successful.

CHAST follows the schedule:
Figure 8.2: CHAST schedule (schoolsanitation.org, 2011)
The highly successful Personal Hygiene and Sanitation Education (PHASE) Program started in 1998 and is an initiative jointly funded by the international development organization Plan International and the multinational corporation GlaxoSmithKline. PHASE was developed and piloted with Plan International in Nicaragua and Peru in cooperation with the ministries of education and health. It specifically focuses on children between the ages of 6 and 13.

PHASE aims to reduce diarrhoea-related diseases associated with poor hygiene and to improve children’s overall health and well-being by focusing on appropriate behaviour related to water, sanitation, and waste disposal. It takes a holistic approach to healthcare, education, community development, and water and sanitation. Education materials such as cloth books and story cards have been carefully designed in consultation with children, using images and pictures that reflect their lives. Children are empowered as agents of change and peer education is encouraged.
In Peru the PHASE Program has been developed under the responsibility and guidance of the teachers. In Nicaragua, the PHASE Program uses an innovative approach for health improvement among school children: the Child-to-Child methodology (see description above). This methodology makes it possible for children to educate and care for other children. Each child transmits what she or he learns about health and hygiene to other children at school, and these children tell others, and so on, always under the supervision of a teacher or field worker.

In addition, the methodology encourages children to participate actively in improving their own health, personal hygiene and nourishment through a series of practical activities throughout the year. These practical workshops are held in Child Circles, in which teachers and parents also occasionally participate.

**PHASE has four focus areas:**

- **Water:** Improvement of available water sources to ensure provision of safe and adequate water for school children for drinking water, hand washing, cleaning, and other uses.
- **Sanitation:** Improvement or development of school sanitation infrastructure that includes pit latrines, urinals, soak pits, and refuse pits to facilitate acceptable standards of hygiene within the school environment, taking into consideration the specific needs of girls and boys.
- **Food:** Development of a mechanism for safeguarding against contamination and possible poisoning focusing on school feeding as well as the children's families.
- **Personal Hygiene:** Development of appropriate behaviour, construction/ improvement of hand washing facilities, and promotion of protective gear such as shoes or sandals.
The model has been particularly successful in those areas where it has been fully implemented using a holistic setup that involves all main partners and institutions. In Nicaragua, the holistic setup includes several groups:

- **Children's Circles**: In addition to being the beneficiaries, the children are also active partners in spreading the message. Through the Child-to-Child methodology they are agents of change among their peers and establish links between school and home.

- **Teachers**: Because the implementation is done in close cooperation with the Ministry of Education, teachers have been trained as facilitators for hygiene education. They teach the PHASE content for 10 minutes three times a week based on the instruments that the program has prepared for that purpose. The teaching manual consists of two parts: guidelines on how to teach the subject in accordance with standards and objective-centred learning at every level, and how to expand PHASE content topics while always relating them logically to the PHASE elementary education program.

- **Field workers/child monitors**: Professionals are trained in using the PHASE methodology with a Child-to-Child approach. They organize children's circles, coverage, target groups, and activities carried out by the community. At the same time, they make people aware of the importance of fostering and promoting personal and environmental hygiene.

- **Local committees and community groups**: These are linked to PHASE with the aim of creating sustainability.

- **Health units**: Health workers are reproducing the PHASE content in health units located in zones where the project is implemented. They have also shown interest in reproducing the PHASE methodology among adults.

- **Municipalities**: These provide support and an enabling environment for PHASE. Local education authorities are including the project's methodology and thematic content in the educational programs of the different grade levels.

- **Ministry of Education**: This ministry cooperates fully in PHASE, allowing for sustainability and monitoring of the program. Provided approval of PHASE contents with respect to the standards of Nicaragua's educational plan and learning quality strategy.

- **Ministry of Health**: This ministry facilitates coordination and provides support for the training of monitors and volunteers on health topics. In a later phase it began to participate as project executor.
9.1.4: Nali Kali Method

Nali Kali is the Kannada (India) word for "joyful learning." The emphasis of the Nali Kali method is on child-centred activities (Snel et al, 2002). The main features of this method are reduced learning load and mastery at the minimum level of learning. The methodology is particularly suitable for the implementation of practical action-oriented hygiene education.

The methodology divides concept learning into four phases:

- **Exploration:** children are given an opportunity to conduct survey and outdoor activities for prescribed topics.
- **Experience:** before expanding on the theoretical part of any subject, children are given ample chance to have personal experiences.
- **Expansion:** based upon the knowledge that the child has acquired through survey and personal experiences, discussions with the peer group and teacher help in the expansion and sharing of knowledge.
- **Evaluation:** to know whether the child has gained an understanding of the subject, continuous evaluation is done through games.

9.2 Education of Adults

Due to children being more impressionable compared to adults and elders, it is easier to educate them in the proper methods of self hygiene and sanitation. When it comes to changing the habits of the older family members it becomes difficult and sometimes troubling when you have to change the way in which they have disposed of their waste as they know no better solution. Therefore the method of teaching must be changed to accomplish the same goal to a different audience.

The children can aid in the education by sharing what they have learnt at school which in turn will pass to the other members of the community. This is a common practise of education programs talked about earlier. This may not be sufficient in the long term as a multi-angle approach is a sure fire way of achieving a large increase in composting toilet use.
Bringing together to women of a village and encouraging open discussion and questioning on the importance of toilets is an important part of the nationwide project in India known as Sanitation, Hygiene Education and Water Supply in Bangladesh.

This program was initiated by UNICEF’s American division and the Bangladesh government in 2007 with funding by the United Kingdom’s Department for International Development (Huq, 2009). Generating interest, not propagating frightening thoughts, is a way in which to get a community to accept a new technology. Detailed education and how it can improve their way of life in a manner they may not have considered can have a dramatic effect in the uptake of toilets in communities where they don’t readily exist.

The major problem that will have to be dealt with is how to promote the learning and coping of the elder generation to adjust their lifestyle. It is harder to educate elderly people than the younger ones due to them not being able to adapt to new technology/designs.

Adults seek to learn through experience in order to cope with life changing experiences and may have some sort of stress that causes them to adapt to the new habit. The older generation tend to be less interested and getting them to engage in the education through different events and gatherings can help.

As the community is considered small, organizing a meeting for the whole community is a possibility. In doing so, we can educate them by:

- Teaching of nutrition information at a meal site
- Have a movie night for the community, halfway have people announce the pros and cons of having a toilet
- Group activities such as games that includes small prizes to create bonds between each community member (Group activity must be fun and interesting or else people will not want to participate).
- Show slideshows about disease and side effects
- To educate hand washing after use of toilets
- Demonstration of how to clean a toilet
- Inform them to not flush random things down (E.g. Feminine hygiene product)

We want the older people to adapt to the new lifestyle by making it very comfortable for them and also turning it into a daily habit. We can do this by making the toilet look very clean and
welcoming with a floor mat, magazines or decorations. Having windows in the design will also make it feel less like a cave with the addition of a natural light source but also secluded enough that they feel they can go about their business.

In the toilets signs can also be a reminder to the young kids and elderly on how to use the toilet properly as well as making the toilet a bit brighter by having a sign as a sort of decoration. It will also allow the people to be proud in what they have learnt and hopefully spread the word of how beneficial it can be to dispose of faecal matter in a safe and sustainable way.

Education of using and maintaining the toilet will be very important and should be taught and demonstrated. As a community, if everyone is happy then everyone will support each other to learn. We want to raise the issue that having poor sanitation causes disease and premature deaths. By showing the villagers the benefits of adopting a clean, safe method of disposing of waste compared to their current practise in combination with other activities and child education, hopefully a successful outcome can be obtained leading to a better way of life for the people of Devikulam.

9.3: Implementation

When introducing a new method of sanitation to the people of Devikulam, it is not wise to jump head first without testing the effectiveness of the system and its uptake. In order to assure that the funds going towards the building of the composting toilets don’t go to waste, the introduction of the toilets should not be the main priority. Education is paramount if this is to succeed. Once the programs have started the construction and spread of the systems should not be rushed so that the people don’t feel it is forced in them and become indifferent to the change taking place. The toilet systems should be built a few at a time to the families with children and the involvement of the people in community sessions. Once some are initially up and running, this will test the effectiveness and ease of use for the villagers. Once the word spreads about the benefits of the systems and the education programs take full effect, the process of building the remainder of the toilets can commence. This will be a slow process initially, but if the education program and support of the local people ensure that the people of Devikulam are willing to build a toilet for themselves, it will be successful.

In a country like India where some areas don’t have sanitary waste management systems, it can be expected that the acceptance of a new method will not be 100%. This is a fact that will have
to be acknowledged. The higher the percentage of villagers installing and using the systems is a goal of the project but if it improves the life of one family, it would have been a success. Any more and it would be a bonus.

10.0: Funding

The people of Devikulam survive on an average of US$2.00 a day (EWB, 2011) so the cost to implement a composting toilet system may still be out of reach for some of the residents. There are options that are worth considering to allow them to improve their way of life.

10.1: Charities and Organisations

Charities such as UNICEF, The World Bank and many more have spent many years, if not decades, trying to improve the lives of people living in impoverished surroundings. Some of the charities and organisations that are linked to the implementation of sanitary systems and the accompanying education are listed below.

10.1.1: UNICEF

UNICEF is one of the largest development agencies dedicated to working exclusively with children. UNICEF works closely with children, women and communities as well as governments, other UN agencies, faith-based groups, non-government organisations and the private sector on behalf of all children without regard to race, creed or religion.

Through contact with UNICEF the lives of millions of children have been saved or changed for the better. But the challenge is ongoing - millions of children still need our help.

UNICEF concentrates on the well being of children. UNICEF's mission is to make sure that the rights of children all over the world are protected and that people under the age of 18 are given special care and protection.

One of UNICEF's priority areas is the Child Survival and Development. This area is concerned with providing essential health, nutrition, and water and sanitation programs to ensure children's basic right to grow up in good health. It is a priority for UNICEF to give children a
better, healthier life and by all means, a good sanitation system is one of the ways in which to save the children and the community.

10.1.2: Red Cross

Red Cross is always there for people in need, providing relief in times of crisis and care for the most vulnerable around the world. Red Cross’s Movements mission is to prevent or reduce human suffering, wherever it is found by the Fundamental Principles of humanity, neutrality and independence in this mission.

The International Red Cross and Red Crescent Movement, born of a desire to bring assistance without discrimination to the wounded on the battlefield, endeavours, in its international and national capacity, to prevent and alleviate human suffering wherever it may be found. Its purpose is to protect life and health and ensure respect for the human being. It promotes mutual understanding, friendship, co-operation and lasting peace amongst all people.

Water and Sanitation is one of many priorities of Red Cross to the world. Australian Red Cross works closely with communities, authorities and local Red Cross partners to improve access to water and sanitation in Asia Pacific communities. Water and sanitation programs are part of an integrated community health approach and it’s their mission to give priority to the most urgent cases of distress.

10.1.3: World Vision Australia

World Vision works around the world and in Australia - to transform the lives of disadvantaged and at-risk children and communities. World Vision is committed to the alleviation of suffering, and an end to poverty everywhere.

Water, Sanitation and hygiene have been identified as the key ingredients in the fight against poverty. This includes all aspects of environmental cleanliness from safe excreta disposal to solid waste management.
Over 150 countries, including Australia, have pledged to help end global poverty by signing the Millennium Declaration, thereby committing to improving the quality of life for people living in abject poverty. World Vision Australia works that if they are to make any headway in the fight against poverty, water, sanitation and hygiene need to be first and foremost improved.

World Vision Australia transformational development work is community-based, sustainable and focused on the wellbeing of children which consists of a holistic and long-term approach to improving the lives of the poor.

10.1.4: The World Bank

The World Bank is an organisation made up of the “International Bank for Reconstruction and Development” and the “International Development Association”. It is a vital source of financial and technical assistance to developing countries around the world. Their mission is to “fight poverty with passion and professionalism for lasting results and to help people help themselves and their environment by providing resources, sharing knowledge, building capacity and forging partnerships in the public and private sectors” (The World Bank, 2010).

The World Bank focuses on the achievement of the Millennium Development Goals that call for the elimination of poverty along with the sustained development in impoverished countries around the world. They accomplish this by working with their partners to alleviate poverty in developing countries and “address the global challenges in ways that advance an inclusive and sustainable globalisation”.

In 2010 The World Bank spent $46.9 Billion on 303 projects in developing countries worldwide taking advantage of their financial and technical expertise to achieve this impressive amount. They are currently involved in 1800 projects in many sectors such as providing microcredit in Bosnia, education of girls in Bangladesh to helping rebuild East Timor upon gaining independence.

10.2: Government Initiatives

India has established a national program that is designed to give total sanitation coverage in India by 2012. This program is called the Total Sanitation Campaign or TSC for short. The program is operational in 578 out of 600 districts nationwide with outlay being approximately 3.35 billion dollars. This is split into a central and state share as well as community contributions. Since its inception the TSC has revolutionised the sanitation sector across the
country. In 1981 sanitation coverage was 1% compared to 48% in 2007 (UNICEF India, 2008). Due to this being part of the government’s five year plan, it is an important program and is getting the funding needed to improve fresh water supply and bring sanitation systems to districts where they did not exist previously.

The Programme was launched in 1986 with the objectives of improving the quality of life of rural people and providing privacy and dignity to women. The concept of sanitation was expanded in 1993 to include personal hygiene, home sanitation, sage water and disposal of garbage, human excreta and wastewater (India.gov.in, 2011).

The components of the programme include construction of individual sanitary toilets for household below poverty-line (BPL), conversion of dry latrines to water-pour flush toilets, construction of village sanitary complexes for women, setting up of sanitary marts and production centres, intensive campaign for creating awareness and health education, etc.

There are therefore many options in which to gain funding, either as loans or aid to help make suitable sanitation a future for the people of Devikulam.

11.0: Impact

The impact of a new sanitary on the people of Devikulam will affect many aspects of their lives which makes it exciting yet quite problematic as well. Since there are unknown factors, predicting how the people would accept such a technology is out of reach. There are different aspects in which it can positively affect the way of life for the villagers and hopefully fulfil their goal of becoming sustainable through the implementation of new technologies either simple or complex.

11.1: Creative Use of Compost

The end product of the composting toilet is exactly that, compost. Compost is ideal for helping develop the soil structure by introducing humus, decomposed organic matter. This aids the soil but increasing microbial growth as well as water retention. It also supplies a source of fertiliser which will not cause issues in waterways like synthetic fertiliser. It also doesn’t need to be purchased which is a primary benefit to farming communities. The main hurdle is overcoming the idea of using composted human waste and organic matter as a source of fertiliser. In china
and Vietnam this is common practise but due to social stigmas and religions in India, this may be harder to implement.

As mentioned previously, due to the low composting temperatures round worm eggs may survive the process and still exist. This does rule out the use of the compost on root crops but makes it ideal for orchards or plants used as a resource such as palms for their leaves used as thatching. If the compost was to be further composted in a heap via higher temperature thermophilic composting it would allow it to be used on vegetable patches without any problems. At the very least if the villagers don’t want to use the compost it can be discarded in a hole in a field safely without issues.

11.2: Contextual Implications

11.2.1: Social Impact

In planning the implementation of the idea of composting toilets in each household, the culture and religion of the people must be respected. The impact of introducing such a project should be looked at carefully in terms of how the local population will react. The main religion practiced in the Devikulam community is Hindu. Composting toilets in each household will benefit the way of life as it will reduce the common practice of open defecation. With the education scheme that will be aimed at the community, especially the children, they should respond positively to the implementation of composting toilets in their household as long as the appropriate support is provided.

The lack of suitable waste management solutions in the Devikulam Township lead to open defecation which can lead to widespread outbreaks such as diarrhoea or other faecal born diseases. By installing composting toilets the short term will see a decrease in common faecal born disease and in the long term improve the overall health of the village. This is due to the control of pathogens through the composting process instead of raw waste being in direct contact with the villagers.

For women in India without access to toilets lead to unhealthy defecation practices where they would only defecate at night so it was not to cause shame to them. By supplying this much needed necessity, a diminishment of a woman’s shame can take affect giving the women a greater sense of dignity.
<table>
<thead>
<tr>
<th>Short term</th>
<th>Long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Community involvement where education implementations for children bring community together in discussing composting toilets</td>
<td>- Gain of women’s dignity</td>
</tr>
<tr>
<td>- Open defecation practices reduced</td>
<td>- Improvement in health of village</td>
</tr>
<tr>
<td>- Faecal born disease outbreaks decrease</td>
<td>- Less outbreaks of faecal born diseases</td>
</tr>
</tbody>
</table>

**11.2.2: Economic Impact**

The economic benefits of composting toilets can be recognised over long term savings. Initially the outlay will be high but due to the toilets to needing any water and the process is a natural process and not forced, the families would save money on water. The decrease in the spread of bacteria and diseases would also benefit them in the long term as sickness will decrease meaning less money is spent of medicines and healthcare. This is a point that would be made during the education of the people to show the method is sustainable and not costly.

The initial cost of the units will be the highest cost but this can be countered from funding from several organisations. Depending on the funding received, it may include the addition of microcredit, it will ease the pressure of cost for the villagers. The task of installing the units will require some level of skill and labour so therefore, short term employment will be created for some of the people in the village over the course of the project. It can also be an opportunity to help introduce some of the people to a new method of employment by training them up as a bricklayer or general labourer.

Residents may take the natural compost for individual use to aid in their farms to increase soil fertility and yield. They may also choose to trade this organically rich fertiliser to neighbouring farmers and agriculturists to generate extra income.
### Short term

- Initial cost of unit is of high cost which may bring financial hardship
- Creation of short term employment in installation of units

### Long term

- Use natural fertiliser for individual use leading to greater financial self sufficiency
- May sell natural fertiliser once enough is collected to generate extra income

### 11.2.3: Environmental Impact

Composting toilets are environmentally friendly and sustainable. The toilet systems design is unique due to the fact that there is no need for water in its operation. This is important because water is a precious commodity in the Devikulam community. The people rely on seasonal rainfall that may not arrive as well as bore water to supply the town water tank. If composting toilets were built for every household, water supply to the toilets would not need to be considered. This would mean the conservation of this precious resource is well as less outlay for the community.

The natural compost can be used as well to help the growth of crops instead of the use of synthetic fertilizers. It will help improve the soil structure not just supply nutrients. It will also not pollute the waterways encouraging algal blooms like synthetic fertilizers can do when applied in large quantities. It is also free and helps to close the nutrient cycle by returning the primary elements needed for healthy plant growth, these being nitrogen phosphorous and potassium, to the ground to continue to cycle once again.

<table>
<thead>
<tr>
<th>Short term</th>
<th>Long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Enhanced hygienic practices</td>
<td>- Environmentally sustainable solution</td>
</tr>
<tr>
<td>- Fertiliser can used to help growth</td>
<td></td>
</tr>
</tbody>
</table>
of plants and crops
- No runoff polluting waterways and soil

- Money saved by using compost not synthetic fertilizers

11.3: Risk Assessment

The risks associated with a composting toilet have been considered in order to isolate and identify possible sources of issues that may occur after the installation is complete. Assessments will vary slightly between each installation so the residents should be made aware of all possible issues that may arise from the toilet itself. See Appendix A for the risk assessment table.

The main risk associated with a composting toilet is handling the compost before the end of the recommended retention time has passed. Since human faeces have a higher pathogen level than animal faeces this poses a serious health issue. Some diseases can make you quite ill while others can cause death. Even common problems like diarrhoea can cause death in extreme cases. The chance of this is minimal once the toilets have been installed if the villagers are educated properly about the inherent risks of handling human waste. Even after a few weeks in the composting chamber the composting process has already began and pathogens has already died due to the process.

So composting toilets are a relatively safe method of treating human waste using a natural process and has very few risks that would adversely affect the village people.

12.0: Conclusion

In India, where a third of the population live below the poverty line, the basic necessities most western societies take for granted are not available. Sanitation is one such area that is greatly lacking in these impoverished areas of India. Devikulam, a small village in the state of Tamil Nadu is one such location that lacks an adequate way to treat and dispose of human waste. Due to factors like income, climate and infrastructure, the design must be able to please the local population while still following a list of strict criteria.
To decide on what method of waste management to implement for the village, research was done on many different designs from systems that are common in western society to more sustainable designs. Through a process of elimination, the options were narrowed down to two possible choices - biodigestion and composting. Using some basic mathematics it was found that the feed needed per day for a biodigester was not available to every family, so the composting toilet became the best solution for the problem.

The more research that was done on composting, the more it became evident that it was the right choice for the people of Devikulam. Although biodigestion offered a source of renewable energy in the form of biogas, it was far too complicated to engineer it into everyday life compared to a composting toilet system. The compost obtained after the end of the process can also be used as an environmentally friendly fertiliser, so it still had much to offer the people in the village.

The final design was based on a simple mouldering toilet with a more advanced urine separation system to reduce the chance of odours forming in the composting chambers. The final design was relatively simple and applicable to many regions around the world. Although the plan didn’t include the toilet house, this is something is dependent on the building restrictions of customs of the area and was left out. It offered the people a safe and clean way to dispose of their human waste even if the initial cost can be high but considering the lifetime of these buildings depends on the skills of the labourers, it is money well invested in the health of the people.

Although the system itself is simple to use and easy to construct, the education of the people is always the deciding factor in determining whether the people will accept to change their ways and embrace a new way of hygienic sanitation. Different methods have been suggested and since the development of the sanitation sector has been on the rise since the mid 1980’s, there have been plenty of time to perfect teaching methods. It has been accepted that a 100% success rate is unachievable but that is to be expected.

The impact of a new sanitary system has been shown to improve the lives of the people who build and use them, with short and long term effects being discussed. It shows that there will be visible effects immediately once the systems are installed and lengthy education programs are put in place, and will not only improve health but can improve the agriculture and horticulture industry if the stigma of using human waste is overcome.
The recycling of any waste is an important aspect of modern life where the world’s population is increasing as resources are decreasing. The quantity of resources on this earth is finite as well as their quality. One such example of this is water. By providing a solution to sanitation which is closely related to health and water purity, it helps to provide a sustainable way in which to keep drinking water clean and treat waste so it is safe to handle by the people and also producing a product that can directly aid in food production. By understanding the needs of the people and researching for methods to solve their problems it was illustrated how many other countries are in the same predicament. Places in these countries have come to realise the importance of hygienic sanitation and have showed how effective composting toilets can be to solve this issue. It is a suitable solution, and the right choice for the people of Devikulam to ensure that they can have access to water that isn’t contaminated by faecal matter from unsatisfactory sanitary practices.

13.0: Recommendations

Since this is a purely theoretical project it is recommended that:

- Pricing for local materials is undertaken for construction of composting chambers
- That the material be determined for the toilet house so costing can be done
- Research and enquiries to charities and local government be undertaken to see what sort of funding may be available for the construction of the toilets
- Competent people are available to help build and supervise construction
- That the appropriate teaching method is chosen to ensure the greatest success rate in the uptake of hygienic sanitation practises
- Gauging the public’s opinion on using the compost on orchard trees
14.0: References:

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15.0: Appendix

Appendix A

Risk Assessment Matrix: Determining the Level of Risk

Table A: Likelihood

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost certain to occur in most circumstances</td>
<td>Likely to occur frequently</td>
<td>Possible and likely to occur at some time</td>
<td>Unlikely to occur</td>
<td>May occur but only in rare and exceptional circumstances</td>
<td></td>
</tr>
</tbody>
</table>

Table B: Consequences

<table>
<thead>
<tr>
<th>Consequences</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>
Most risks for a compost toilet are located in the bottom left corner. The possibility of death from handling raw faecal matter once toilet system is in operation is a rare possibility.

Table D: Risk Assessment Results

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>L</th>
<th>M</th>
<th>H</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low – Take reasonable steps to mitigate and monitor the risk. Institute permanent controls in the long term. Permanent controls may be administrative in nature if the hazard has low frequency, rare likelihood and insignificant consequence.</td>
<td>Medium – Take reasonable steps to mitigate the risk. Until elimination, substitution or engineering controls can be implemented, institute administrative or personal protective equipment controls. These “lower level” controls must not be considered permanent solutions. The time for which they are established must be based on risk. At the end of the time, if the risk has not been addressed by elimination, substitution or engineering controls a further risk assessment must be undertaken.</td>
<td>High – Act immediately to mitigate the risk. Eliminate, substitute, or implement engineering control measures. If these controls are not immediately accessible, set a timeframe for their implementation and establish interim risk reduction strategies for the period of the set timeframe.</td>
<td>Extreme – act immediately to mitigate the risk. Either eliminate, substitute or implement engineering control measures</td>
</tr>
</tbody>
</table>