Biodigester Toilet

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Executive Summary

The poverty-stricken village of Devikulam located in India has many problems that are in severe need of being solved. Pollution-related issues such as lack of clean water, clean cooking sources and the health risks related to open defecation are all of major concern to the wellbeing of the village. Appropriate housing, local industry and community integration are also areas that are in need of improvement.

In order to fix the many issues that face the village, the group discussed a number of ideas to solve a range of the problems. Ideas include solar stills, rainwater capture, wind energy, a brick extruder and a way to compress rice hull into building blocks were investigated. The idea that was chosen however was the biodigester. It was decided that the biodigester helps relieve the greatest number of problems and would be of most benefit to the community. The problems the biodigester helps solve are as follows:

- the disease related dangers associated with open defecation,
- the dangerous use of wood fire cooking which is a major cause of health problems and even death due to smoke inhalation,
- the biodigester also provides nitrogen rich fertiliser which can be used to increase the income generated through their agricultural industry.

Biodigesters use anaerobic digestion to break down biological matter which in turn produces methane gas that can be used as a clean energy source for cooking and even lighting. Anaerobic digestion also has the added benefit of helping to destroy pathogens found in human waste far quicker than that of leaving it to compost. Within three months of waste being left in an anaerobic state it becomes safe for people to handle without serious health concerns, the waste can then be used as fertiliser.

The basic design of the biodigester consists of two main storage tanks and a toilet slab with a modular toilet design. The tanks are designed to be used in a cyclical manner, with one tank being used and the other tank being left undisturbed for a six month period to ensure the waste is safe to handle. The tanks will be large rectangular structures built mostly underground with a slight lip above ground. The tank cover will be made of heavy duty plastic and held down to keep an airtight seal with the tank.

The toilet slab is a raised concrete slab that has rectangular insets containing pipes which lead down to the storage tanks. The rectangular insets can have a modular insert placed within it depending on what the pipe leading to the tank is being used for. If the tank is being left undisturbed the
inset will have a cover in place, otherwise it will contain either a squat toilet or a mixing trough for manure.

The system is designed to be shared by multiple villagers, in order to reduce costs and get the maximum efficiency out of the system. As such the implementation and building processes need to be very specific. Holes are to be dug to the correct size, with the pipes placed in the correct manner. Afterwards the concrete is to be poured into the hole to form the tank. The plastic sheet is then placed on top of the tank. Afterwards the pipes are connected to their correct systems and the biodigester is ready to be used.

As part of the implementation process, it would be ideal to introduce the system to the higher caste villagers, so that they do not look down on the idea and in turn encourage the rest of the community to use the system.

For a system such as the one proposed, the villagers will need training on how the biodigester works, how to use it and how to maintain the system correctly. They will also need information on the health benefits and clean energy produced by the biodigesters, training on how to utilise the energy for their everyday needs.

In conclusion this design is ideal for the Devikulam community as it eliminates several of their problems and replaces it with a renewable, useful and clean energy source. The benefits outweigh the costs of the project, the gas produced saves on other cooking fuels and the fertiliser can help improve crop yields. We have met all of the learning outcomes as outlined by Engineers Without Borders. We have demonstrated the application of technical knowledge by coming up with a simple design for a complex process, as well as learnt to integrate sustainability and the specific context to the end design. Throughout the development process we have also been able to develop communication and teamwork skills, by assigning jobs and incorporating multiple ideas into the design. Finally, we have learnt to work with the complexities of working cross-culturally.
Team Reflection

Bradley Ashley

The largest Obstacle I faced in this challenge was communication with the entire group, which affected how well our report turned out, as demonstrated in the Interim Chapters Report, where much information was overlapped by different members of the group. However, having said this, our project simply would not have been possible without the help of each member of the group. Each member provided different ideas, backgrounds and knowledge which were all vital aspects to the development and growth of our project. If I had the opportunity to re-do this project I would have organised one or two more meetings a week. These meetings would have been much shorter in length and would have only been there to check each members progress on their separate chapters and workload. This would have allowed the group to have less overlap on information. The most enjoyable aspect of the challenge was meeting new people who I would not have met if I did not have the opportunity to participate in this challenge.

Farai Chikwati

The greatest challenge I faced working on the project was my lack of background information on the cultural aspects of the community to the extent that, that for some part of the challenge and regardless of what I have learnt I was left making assumptions based on my past experiences. Working as a team, however, made the challenge more manageable, none of us had to carry any burden alone. Instead we researched and shared our ideas while carefully considering social, cultural, economic and environmental constraints. Given the chance to repeat this challenge, I would make sure I got my ideas organised in time, giving me enough time to review what I had written. Most of all, I enjoyed working as a team as it helped me see some different ways of approaching problems that I had not considered before, it also helped in keeping me motivated as the challenge grew more and more difficult.
Jithin John

This EWB challenge was something of an eye opener to me. Due to the various scenarios we faced during the challenge, I was able to discover and display my innate skills and abilities. This challenge exposed me to real world problems and also taught me how to tackle them using my skills as an engineer. The largest obstacle I faced while working on the project was meeting the time constraints as well as presenting ideas which were sensible and passed the quality mark.

Working as a team helped me a lot in realising the importance of camaraderie and teamwork. By working in a team I understood how much we depend on others for various tasks and how important this relationship is. In other words you can only achieve something by sacrificing something of yours. Another thing I realised during teamwork is that not a single person is similar to another, everybody thinks and acts differently in almost every perspective. This difference in thinking helped us a lot in gathering different ideas for our project, making it more distinct and unique in its own way.

If we were given a chance to do the project again, I would probably recommend that in the future we are given something which we can sort of understand more in a realistic way rather than working on the basis of assumptions. The amount of background knowledge we were able collect is limited because most of us solely relied on online resources and data collected by someone else, not a single person involved in doing the project has a genuine understanding of what the situation at Devikulam is.

The most enjoyable part of the challenge was working in teams. This made the task easier and more manageable. There was not a single point in time where I felt really stressed because I always had my teammates to rely on.

Joshua Petrohilos

The EWB challenge has been a very enjoyable and interesting experience overall. It has been a pleasure to work on this project as part of my Engineering degree. Throughout the design process we ran into several obstacles, the most severe of which was the initial complexity of the design. Little relevant information was initially available, so we really had to knuckle down with our research, which ended up with spectacular results. Working as a team had a positive impact on the project, as jobs were able to be allocated freely, and ideas were able to be discussed and considered by the team.

The most enjoyable part of the project was making excellent friends with my fellow group members. I am truly glad to have been given the opportunity to work with such amazing people. I also enjoyed being able to apply my knowledge to an actual real life problem. If I were to do this project again, I would change absolutely nothing. It has been an enjoyable experience, and I am extremely proud of the design we have come up with.
Xan Smith

The largest obstacle faced while working on the challenge was due to the size of the project. Initially the project seemed to be a simple matter of creating a toilet and a system to capture the gas. However after discovering the health aspects involved in the handling of human waste and the complexities of biodigester design the project became more difficult than initially expected.

Working as a team has been a good experience, different people have different skills and abilities, all of which have added to the project as a whole. If the project was to be done again more initial research would be invested into uncovering the complexities that would be faced, also more planning and group organisation would be done from the very beginning of the project.

The most enjoyable part of the project has been working with a good group of people, designing something interesting, and learning new things.

Adam Szumlinski

The most difficult task I faced when given a problem as large as the EWB project was that initial ideas and designing phase, such as finding suitable solutions to reach our goals whilst considering the cultural, social and real life limitations and aspects of the chosen community.

I think that working in a team really helped both the project and myself to progress, as there is a constant stream of information and ideas being put forward by other members of the team, such ideas may not have been considered on ones own and this allows the project to develop with the benefit of diverse ideas and combined knowledge.

If I were able to repeat this project and change how I approached one of the aspects of it I would first define the problem I wanted to face and then define my project around the cultural and social aspects and the available resources and scope, as we found that it is more difficult to go from an initial idea back to considering the factors and limitations and defining the scope.

The most enjoyable and beneficial part of the project was to be able to improve my team organisational skills and being able to improve my communicational and time managements skills in a comfortable environment.
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1 Introduction

1.1 Background

The community of Devikulam in the South East of India has been chosen by Engineers Without Borders for the 2011 EWB challenge. Devikulam is one of several villages in the Nakukuppam Panchayat region in the state of Tamil Nadu. The majority of the people in Devikulam are living below the poverty line, there are severe divisions between castes and the infrastructure of the village is of poor quality. (EWB Background, 2011)

The aim of the EWB challenge is to provide the community with sustainable solutions to a range of issues such as energy, water, sanitation, housing, industry development and waste management. The challenge also aims to help break down divisions between castes. (EWB Background, 2011)

The main fuels currently used for cooking in Devikulam are kerosene and firewood. (EWB Power, 2011) According to the World Health Organisation over 1.6 million deaths were attributed to smoke from biomass fuels in 2000. (Smith et al, 2004, p. 1436)

Recent sanitation tests have shown that bacterial contamination of Devikulam’s water supplies is of concern, the practice of open defecation allows human and animal waste to pollute the water during monsoon season when the rain washes effluent into the water supply. (EWB Water, 2011)

1.2 Problem Definition

Design a safe biodigester toilet to provide sanitation, gas and fertiliser while ensuring that construction is simple and inexpensive.

1.3 Problem Scope

The key aspects that must be covered by the biodigester design are as follows:

- Gas Storage
- Gas Distribution
- Toilet facilities
- Waste treatment
- Cost of implementation
- Ease of Construction
Other aspects that need to be considered are how to make use of the biogas and the human waste fertiliser. A major point that must be covered for the project to be successful is how to implement the biodigester into the community and make it acceptable to the people of Devikulam.

1.4 Criteria

The design of the biodigester must meet the following criteria:

- The cost to build the biodigesters must be minimal and affordable to the people of Devikulam.
- The biodigester should be as simple as possible and not require advanced technology to work.
- The biodigester must be safe and have a positive impact on the lives of the people of Devikulam.

1.5 Ethics

The team took the Australian Engineers Code of Ethics into account while designing the biodigester and investigating implementation options. Research was done to the best of the teams abilities to ensure that the biodigester would be safe to use, improve the wellbeing of the community and be a sustainable option that would have a positive effect on the environment for future generations.

While it is of concern that using human waste as fertiliser may not be viewed positively by the people of Devikulam it is not actually against their religious or cultural beliefs, rather it is a reservation that if overcome would enhance their lives, wellbeing and the surrounding environment.
2 Design Options

2.1 Design Ideas

2.1.1 Rainwater Collector

An initial design idea the group had was to develop a rainwater collection facility. The facility would be used to provide potable water for drinking and cooking.

Upon researching the idea of rainwater as a means of potable water, it was discovered that rain water was not as clean as expected. This is not to imply that rainwater is unclean, rather that rain is often contaminated with bacteria by the surface it lands on (Rain-Barrel, 2005). This means that the water would require boiling before being safe for human consumption or that the rainwater collection facility would require highly effective filtration, which adds additional cost to the project.

Another factor to consider was how the rainwater collection facility would be filled. The houses in Devikulam are not designed with gutters and it may not be possible or feasible to retrofit the houses with guttering.

It was decided not to use the rainwater collection facility for the above reasons and because a solar still would theoretically provide a much more effective means of fresh, drinkable water than the rainwater collection design. The solar still would not require filtration, as very little external elements will affect the water which in turn lowers the maintenance required to wash and clean those filters.

![Figure 2.1: Rainwater Collection Facility](image)

Figure 2.1: Rainwater Collection Facility
2.1.2 Solar Still

A design option investigated was the construction of a solar still water purifier, enabling the town of Devikulam a means of producing drinkable water easily and freely.

The general principle of a solar still is to use the sun's solar and heat energy to evaporate a pool of contaminated water. The evaporation process would leave behind salts, debris and other chemicals. The water that had evaporated would then collect and condense on a slanted or convex panel above and collect into a separate trough or container which is drinkable.

![Solar Still Diagram](image)

**Figure 2.2: Solar Still**

The major drawbacks with a solar still is that during optimum weather conditions a solar still can produce around six litres of clean water per square meter of surface area (SolAqua, 2008) the distilled water doesn’t reach boiling point so microorganisms and bacteria may survive the process and cause a threat to health concerns.

To overcome these drawbacks a secondary energy source would be necessary, either an electric or fuel powered heating apparatus added to speed up the distillation process and also increase the temperature of the impure water.
2.1.3 Brick Extruder

A possible idea for the EWB Challenge was to create a hand cranked brick extruder that had a replaceable die design to enable different shapes to be extruded. These shapes would include semi hollow bricks, roof tiles and piping. The basis of the design was a feeder for the clay, a screw pump that would be cranked by hand to force the clay out through the interchangeable die. The idea was discarded due to the fact that using local resources firing bricks in a kiln was not feasible due to the lack of a kiln and the energy requirements of running a kiln if one were to be built.

Unfired bricks can be eroded and damaged by water unless treated with bitumen emulsion or other water dispersant methods. Semi-fired bricks can help relieve this problem and can be produced by stacking the bricks and then firing them with the rice hulls which are a waste product of rice. This is limited to the availability of rice hulls which are seasonal, is energy intensive and still does not match the quality of fully fired bricks.

The problem of erosion and damage by water eliminates the possibility of extruding roof tiles and piping which means that the design would simply be a brick extruder. This makes the design infeasible because it would be simpler to just make mud bricks using casts as it is less complex making and maintaining the casts, costs less and uses less resources to produce.

Figure 2.3: Brick Extruder
2.1.4 Windmill

In theory the usage of wind energy as a primary energy source would have been a great fit for the Devikulam community, as it provided a renewable and clean source of energy.

When researched however, a few issues arose in terms of implementing the system, the most significant of which was the efficiency and proportional size of the system. As wind has very little density and the speed of wind can vary, a wingspan that covers a large surface area is a must. 2.5m-7.6m diameter is recommended for a stand-alone system (Wind Energy Development, 2011).

The current mean wind-speed is 5.4m/s, with a standard deviation of 1.4m/s (EWB Wind, 2011). This means that good values of energy can be produced, however, other factors must also be considered. The maximum theoretical efficiency of a wind turbine is 59%, however turbines of this efficiency do not yet exist. On average, the efficiency of a system is 35%, which is roughly one third of the energy that hits the turbines blades (Watson, 2010). Another issue with its efficiency is the obvious problem of variable wind speeds, meaning a constant level of energy generation is not possible.

If the wind speeds are variable, an obvious fix would be to instead enlarge the swept area to ensure greater energy produced. While this would work, it would seriously impact on the cost of the system and also the systems size.

Another such issue with wind turbine efficiency is the need to be maintained regularly. Constant movement and friction can cause large amounts of wear and tear, therefore making maintenance a necessity. The issue with this of course, is the lack of skilled labour currently in the Devikulam village, meaning repair and general checkups could be lengthy and expensive.

The cost is also a significant issue. Approximately 80% of the system’s lifetime cost can be attributed to an installation cost of $3500-$8500AU per kW for a stand-alone, local system (European Wind Energy Association, 2009). Although with time the benefits of the renewability and cleanliness of the energy will outweigh the initial investment, it costs more to get up and running than a fossil fuel system (Wind Energy Development, 2011).

This, coupled with the isolation of the Devikulam community, would make it a large monetary investment to begin using wind power.

From the above information, we can see that if Wind Turbines were implemented correctly it could be a viable and renewable source of energy. However issues such as the significant cost, efficiency, proportional size, and maintenance make Wind Energy an unsuitable resource for the Devikulam community to use effectively and consistently.
2.1.5 Rice Hull Bricks

Rice hulls are the coating of seeds or grains of a rice plant which is considered an agricultural waste. It is composed of hard materials such as silica and lignin hence making it a class A insulating material. Hence it is considered virtually fireproof and is unlikely to allow moisture to propagate fungi or mold. From this fact stemmed the idea of making bricks from rice hulls. Rice hulls are readily available at Devikulam because it is a farming community with lots of agricultural activities occurring throughout the year. There is also a housing problem to be addressed in Devikulam which made the scenario perfect for the idea to be tested.

Rice hulls are already used in building construction employing the technique of Rice-hull bagwall construction method where polypropylene bags are filled with raw rice husks and then stacked layer upon layer with barbed wires in between them to hold them together. Rice hulls were also used in conjunction with bricks and cement to give the house more insulation thereby making it virtually fireproof.

The plan was to make rice hull bricks by either compressing rice hulls and then coating it with clay to give it extra integrity by mixing rice hulls with clay or lime and then molding it in the form of a brick by firing it.

From research it is shown that rice husks are not easily combustible so don’t require flame or smolder retardants. Also, P.A Olivier has stated in his article (Oliver, 2004) that ‘Ordinarily loose rice hulls have an angle of repose of about 35 degrees. But once firmly packed into a wall cavity, their tiny tips, edges and hairs interlock to achieve a negative angle of repose. Due to this peculiar bonding of rice hulls under mild pressure, they stabilize in a very uniform manner, and no further settling is possible.’ He also reiterates in his article that fire-retardants, fungicides or chemicals need not be added to the rice hull. This is hard to achieve in real life, it requires a lot of expertise and skill. Suitable equipment which could achieve this sort of compression is still to be invented. Rice hulls are used as insulation materials in some building processes wherein it is incorporated into the walls using special building methods. Currently there are rice hull bailers available in the market but the compression rate they offer is not optimal for the process of brick making.

Another factor which needs to be taken into account is the availability of rice hulls. Rice hulls are hard to obtain throughout the year as it is a by-product of rice. Since, rice is not cultivated at Devikulam throughout the year, procurement of rice hulls from outside the village also needs to be discussed.
2.1.6 Biodigester Toilet

Biogas systems have the ability to convert ‘useless’ and harmful biological waste material such as cow dung, human waste, and food scraps including vegetable material into not only a clean and reliable source of energy, but also into a powerful, environmentally friendly fertiliser. This not only provides the society with a cheap energy source, but a cheap way to improve their agriculture as well.

The system would also be of great convenience in solving health problems as it would help improve sanitation, while, fighting multiple diseases simultaneously. The use of biogas as a clean cooking source can help reduce diseases and illness due to smoke inhalation. The system is also capable of ‘improving health conditions by reducing harmful bacteria and flies’ (Greenpower India, 2011). The findings of BSP in 1999 which suggest that biogas systems/plants kill multiple parasites namely ‘typhoid, bilharzias and tape-worms’ (Greenpower India, 2011), during the different stages of this process i.e. once the raw material has been introduced to when the fertiliser has been extracted also support this. While biogas systems are greatly advantageous, one disadvantage of working with this system in rural areas/ any area are that sometimes the flame can be invisible, making it a health hazard, however, given that the burner is designed in a way that supports complete combustion, this should not be the case. Therefore, given that the community of Devikulam accepts the team’s technology, the biodigester will be very helpful as it reduces health and sanitation issues for Devikulam.

Another great advantage of using the biodigester toilet is that apart from eliminating most diseases due to lack of sanitation and the use of biomass as well as fossil fuels, it is also capable of producing by-products namely biogas manure and biogas. This is greatly advantageous as it helps relieve and in some cases even eliminate both economic and environmental issues in Devikulam by reducing the time spent in some daily chores as well as replacing some harmful substances which are used in Devikulam on a daily basis.
2.2 Final Design Decision

Table 2.1 shows a decision matrix taking into account the decision options and how well they cover different criteria.

<table>
<thead>
<tr>
<th></th>
<th>Biodigester</th>
<th>Clay Brick Extruder</th>
<th>Rain Water Collector</th>
<th>Rice Hull Bricks</th>
<th>Solar Still</th>
<th>Windmill</th>
</tr>
</thead>
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<tr>
<td>Low Setup Cost</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>2</td>
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<td>Environmentally Friendly</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
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<tr>
<td>Consistent Productivity</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>2</td>
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<td>3</td>
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<tr>
<td>Produces Energy</td>
<td>4</td>
<td>x</td>
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<td>x</td>
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<td>16</td>
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</tr>
</tbody>
</table>

The biodigester scored the best using the metric and covers the widest range of problems so was selected as the design option to focus on.
3 Final Design

3.1 Biodigester Summary

A Biodigester is a closed system in which microorganisms break down waste products to produce biogas and a nutrient-rich fertiliser. The issues the biodigester will be able to solve are as follows:

- preventing disease caused by human waste,
- preventing health problems caused by using biomass fuels for cooking
- and providing a safe fertiliser from the slurry.

There are a number of different biodigester designs already in use, the two most common being the Chinese fixed dome and the Indian floating cover biodigester (Bates, 2007, p. 2).

Another interesting design is the salchicha “sausage” tube biodigester due to its low cost of materials and fast construction time.

‘Very long retention times for sewage have the ability to virtually destroy pathogens. The amount of time human excrement should be retained varies. In a very warm climate you may want to retain the waste for 60-90 days, however in cold climates (20 degrees C and below) 150 or more days of retention are recommended.’ (Appropedia, 2011).

Because of these retention times the decision was made not to use a “sausage” tube biodigester due to the fact that it is not possible to prevent pathogens from contaminating the existing slurry as new waste is fed into the digester.

In order to prevent contamination and provide time for the pathogens to be destroyed, the team decided on an alternating two tank solution. One tank is connected to a toilet and used for gas production while the other tank is left undisturbed for up to six months to ensure all pathogens in the waste are destroyed. Once the pathogens are destroyed the tank can be emptied and the process begins again in alternate tanks, the empty tank being connected to the toilet facilities while the other tank is sealed and left undisturbed for six months.
3.2 Biodigester Details

3.2.1 Tanks

The tank will be constructed with a concrete base and brick walls. Figure 3.1 depicts a tank that would be emptied biannually and is suitable for fifteen people and one cow, or up to twenty five people without livestock. A six monthly cycle is recommended to ensure the waste is safe, but if testing shows that the waste is safe after three or four months it may be possible to introduce smaller tank sizes with a higher frequency of alternation.

Figure 3.1: Biodigester Tank
3.3 Biodigester Lid

The biodigester will have a wooden frame cemented to the top of each tank (Base Frame, figure 3.2). Another frame of the same size will then be used to seal a plastic cover in-between by bolting the two frames together around the plastic and creating an airtight seal.
3.3.1 Slab

The slab in figure 3.3 will be cast using concrete. A privacy structure will be built around the slab using locally available material, the design will vary depending on materials and the builders’ preferences so designs for the structure are not included in the scope of this project.
3.3.2 Extraction Pipes

PVC pipes in a configuration similar to figure 3.4 will be connected to the pipes going down to the biodigester tanks. They will act as air extractors using convection to suck air from inside the toilet facilities through the pipe and release them well above head height. The top of the pipes should be covered in fly mesh to prevent flies and other insects attracted by the smell from entering the pipe.

Figure 3.4: Extractor Pipe
3.3.3 Squat Toilet

The toilet design will be a simple squat toilet made of stainless steel, ceramic or possibly cast into a concrete block. The toilet will not have a u-bend so no flushing is required. To control odour the extractor pipe in figure 3.4 will be used.
3.3.4 Animal Waste Trough

The animal waste trough is used for mixing cow dung with water so that it can easily enter the biodigester. It is used by removing the squat toilet and putting the waste trough in its place.
3.3.5 Hole Cover

The cover acts to plug the hole leading to the waste storage tank while not in use. The slab allows more space within the toilet facilities to be utilised and prevents people from being injured by a hole in the ground. Using the slab to plug the hole prevents air from entering the unused tank and prevents odours from entering the toilet facilities.

Figure 3.7: Slab cover

The cover acts to plug the hole leading to the waste storage tank while not in use. The slab allows more space within the toilet facilities to be utilised and prevents people from being injured by a hole in the ground. Using the slab to plug the hole prevents air from entering the unused tank and prevents odours from entering the toilet facilities.
3.3.6 Gas Valve

A gas valve similar to the one in figure 3.8 will be used between the tanks plastic covering and the main gas storage bag. Valves will also be used between the main storage bag and smaller cooking bags. Figure 3.9 shows a detailed view of how the gas valve works.
3.3.7 Flame Trap

The flame trap is a container which can screw onto the valves. They will be filled with steel wool which will prevent flame from being drawn back into the bags and also scrub hydrogen sulphide from the biogas.

Figure 3.10: Flame Trap
3.3.8 Main bag

The main bag will be connected to the biodigester tanks using the valves shown in figure 3.8. The main bag will then be used to fill the cooking bags using the same gas valve system.

Figure 3.11: Main Bag
3.3.9 Cooking Bag

The cooking bag is made of heavy duty plastic and will have a valve and flame trap attached. Ideally it would be situated outside the house and gas piped in to the stove. The bag size will vary depending on the amount of gas needed, cooking requires 0.28-0.42m$^3$ of methane per person each day (Barnett et al, 1978, p. 63).
3.4 Detailed Description

Figure 3.13: Biodigester

The biodigester tanks have a single concrete slab base of 5.5 meters by 1.8 meters. The walls are made of brick and built around the edges of the slab to a height of 1.5 meters sharing a common dividing wall at their centre. The toilet slab figure 3.3 will be placed in front of the tanks. Just below the tanks where the holes are located, extractor pipes will be connected (figure 3.4). The extractor pipes will then have 90mm PVC pipes leading to the base of the biodigester tanks. One of the recesses in the toilet slab will be blocked with a cover while the other hole leading to the ‘in use’ tank will have the squat toilet placed in the recess.

The top of each tank will have a wooden frame cemented to it, plastic sheeting will be held between the cemented frame and another frame of the same size creating a seal, a gasket made of rubber or silicone sealant will be used to ensure an airtight seal. The center of the plastic sheeting will have a valve tap leading to the main gas storage bag.

The main gas storage bag made of heavy duty plastic sheeting will be connected to the valve on the top of the tanks via a flame trap and valve taps on the bag itself. The plastic bag will have additional valve taps to allow smaller cooking bags to be attached and filled. The cooking bags can then
be taken from the biodigester to the house for cooking and lighting. Figure 3.14 shows a biodigester with tanks below ground, a privacy structure and a pergola for shade above the tanks.

Figure 3.14: Biodigester Render
3.5 Design Documents

3.5.1 Bill of Materials

The two main materials required to build the biodigester are concrete and bricks, this will account for the bulk of the projects cost.

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount Required</th>
<th>Unit Price</th>
<th>Total Cost (₹INR) / ($AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>2m$^3$ (13 bags)</td>
<td>₹200 per 50kg bag</td>
<td>2,600 / 54</td>
</tr>
<tr>
<td>Brick</td>
<td>1600</td>
<td>₹1-4 per brick</td>
<td>2000 / 44</td>
</tr>
</tbody>
</table>

The dimensions for the tanks concrete base are 2.8m × 5.5m × 0.1m = 1.54m$^3$. The dimensions of the inlet slab is 1m × 1.6m × 0.2m = 0.32m$^3$. Total concrete is therefore 1.86m$^3$. It requires twelve bags of cement to make 2m$^3$ of concrete. One more will be required for mortar, therefore a total of thirteen bags is required.

The standard size for Indian bricks is 223mm × 107mm × 69mm. The tanks consist of two long walls and three short walls, all with a height of 1.5m. The two long walls are 5.5m which will require twenty three and a half bricks end to end. The three shorter walls are 2.66m which requires eleven bricks end to end. The height of the walls will be 1.5m which requires twenty bricks stacked. This means a total of $20 \times ((3 \times 11) + (2 \times 23.5)) = 1600$ bricks.

There is currently a financial assistance program provided by the Indian and Tamil Nadu Government called the Total Sanitation Campaign (TSC) which plans to improve the sanitation of local communities by providing assistance to build toilets for schools and individuals. (Government of Tamil Nadu, 2011)

This scheme will help reduce the cost of the biodigester system by providing materials such as PVC piping, valves, toilet fittings and contributing to the cost of the cement. If approved this will bring the cost of the project to less than $AU 90 per system.
3.5.2 Maintenance

The simple design of the tank requires very little maintenance. Each tank section is designed to hold waste for six months meaning that a biannual check would be made on the tank during the emptying process to ensure that the walls have not been compromised. If the walls have been compromised then they are able to be fixed by patching or repairing that section of the wall.

If damage occurs to the plastic covers on the tanks or the gas storage bags the odour from hydrogen sulphide in the biogas would help alert anyone to any leaks.

Damage to the plastic cover and bags may be able to be repaired depending on the amount of damage. Large tears would require a new plastic sheet to be used however small holes and tears could be easily repaired using a patch of plastic and a suitable glue.

Monitoring of the waste levels and the pH of the biodigester would need to be checked on a regular basis but could be done at the same time using a dipstick like device.

The anaerobic process in a biodigester produces an acidic environment but it should be kept fairly neutral. It is therefore necessary to add a small amount of sodium hydroxide weekly while checking every month just to make sure that the biodigester has not become too acidic or alkaline. With experience people should be able to judge just how much is needed and pH testing should not be required as frequently as during the initial implementation.

<table>
<thead>
<tr>
<th>Task</th>
<th>Procedure</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking tank integrity</td>
<td>Look for damaged bricks and mortar after emptying tank of fertiliser</td>
<td>6 months</td>
</tr>
<tr>
<td>Checking lid plastic</td>
<td>Visual inspection for sun damage, holes and tears</td>
<td>Monthly</td>
</tr>
<tr>
<td>Checking lid frame</td>
<td>Visual inspection for warping, rotting or deterioration of the wood.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Monitoring pH</td>
<td>Take a sample from the biodigester using dipstick.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Monitoring waste level</td>
<td>Visual inspection or using dipstick.</td>
<td>Monthly, weekly as it nears capacity.</td>
</tr>
</tbody>
</table>
3.5.3 Safety

The biodigester is designed to improve the health of the community by storing human waste which contains pathogens away from where it can affect people. Acting as a storage container for waste which is dangerous to humans obviously represents a risk to people's safety if the system is used improperly.

The biodigester is designed in such a way that if used correctly it should destroy pathogens in the waste before being handled by humans meaning it is not a risk to their health. (Feachem et al, 1980, p.115) Shows that while not as effective as thermophilic composting, anaerobic digestion destroys pathogens faster and far more effectively than composting toilets. In order to destroy all pathogens in the waste the tanks are to be emptied after six months if not having any new waste added, if this procedure is followed then handling and use of the fertiliser on crops should be perfectly safe.

Gas storage and handling is another area of concern. Methane is not toxic or corrosive to most metals and plastics however over time it will corrode silicone (AIR LIQUIDE, 2009). The proposed storage bags are made of plastic and will not corrode with prolonged exposure to methane.

Methane is non-toxic and does not pose any health related problems if inhaled, the gas becomes ignitable when concentration becomes greater than 5-15 percent.

If a leak in the tank were to occur, the gas would dissipate into the air before the concentration reaches this critical level, causing no health problems or fire risks.

Methane is an asphyxiant which means that in high concentration levels it will displace the oxygen, causing possible suffocation, this property had to be considered in the design (ISOC Technology, 2010).

The solution is to store all the gas produced from the biodigester in a large outdoor bag, if this bag was to leak the methane would disperse into the atmosphere without reaching dangerous concentration levels. Smaller cooking bags designed to hold enough gas for cooking meals each day would be stored just outside the house and piped in, if a leak occurred in the pipeline the hydrogen sulphide in the biogas would be smelt and inform the users of a leak. Even if the user was unaware of the leak the volume of the cooking bags in relation to the size of a house would not be great enough to cause asphyxiation.

Biogas is composed of;
40-70% Methane
30-60% Carbon dioxide
1% Hydrogen
0.5% Nitrogen
0.1% Carbon Monoxide
0.1% Oxygen
0.1% Hydrogen Sulphide

Carbon dioxide, hydrogen, nitrogen and oxygen are naturally present in the air and pose no concern to human safety, however higher concentrations of carbon dioxide would create difficulty when trying to burn the gas. Hydrogen sulfide is a corrosive gas and will react with metals. This raises the concern of damage to cooking devices through corrosion. The corrosion problem is solved by using a flame trap which doubles as a gas scrubber by passing the gas through steel wool which will react with the gas before it reaches the stove. Because the steel wool will corrode it is important to monitor and replace it regularly.

Fire safety is addressed by implementing a flame trap between the outlets from gas storage bags. The flame trap will be a simple cylindrical tube filled with steel wool, the spacing of the steel wool fibres allows gas to pass through but if flames try to pass through the fire will be smothered and extinguished. An illustration of the flame trap design is shown in figure 3.10
4 Applications of byproducts

The primary purpose of the biodigester is to help solve health and sanitation problems within Devikulam. The biodigester also produces biogas which can be used for cooking and lighting, it also produces a nutrient rich fertiliser which can be used on crops.

In order for these byproducts to be utilised, appropriate technology must be introduced.

4.1 Fertiliser

The biodigester toilet converts dangerous waste into safe, nutrient rich fertiliser which can help improve economical and environmental problems within Devikulam. Anaerobic digestion produces far better fertiliser than aerobic composting of waste products because it is able to retain almost all of its nitrogen content while aerobic composting will lose up to fifty percent of its nitrogen content over a period of 30 days (Lichtman, 1983, pp.42-43)

Assuming the education schemes proposed help to gain acceptance in the use of the biodigester waste as a fertiliser the increased yields and savings from not using chemical fertilisers is going to be beneficial to the Devikulam community increasing the wealth of the farmers and Devikulam as a whole.

4.2 Gas

An intended byproduct of the biodigester toilets is biogas. Biogas mostly consists of methane and can be used for cooking and lighting using the correct technologies.

By using biogas as a cooking technology it can greatly reduce the incidence of health related problems due cooking with biomass products such as wood. Cooking indoors with wood is linked to eye infections and respiratory problems due to smoke inhalation (Greenpower India, 2011). The use of biogas for cooking can also help the households of Devikulam economically by reducing their reliance on kerosene and reduces the work involved with collecting firewood (EWB Power, 2011). The use of biogas as a lighting source can also reduce reliance on the electrical grid.

The use of biogas also has a positive effect on the environment by using a renewable resource rather than fossil fuels or firewood which adds to deforestation.
4.2.1 Cooking Technologies

Simply burning biogas without proper cooking technology can result in incomplete combustion, producing carbon monoxide which is dangerous to peoples health. This danger can be overcome by providing a good air to biogas mixture before the biogas is burnt. A simple method of achieving this is to use an ‘injector’ as seen in figure 4.1. Another important role of the injector is that it will prevent flame from entering the gas supply line (Fulford, 1996, p.2).

![Injector Diagram](Fulford, 1996, p.6)

Biogas stoves are readily available in India and pricing for a single burner is approximately ₹1000 (Rupak, 2011). Stoves can also be made out of clay as long as a good injector system can be implemented an example is shown in figure 4.2.
4.2.2 Lamps

Biogas lamps would help by providing a backup lighting source which would be helpful within Devikulam due to the frequent power outages EWB Power (2011). The lamps would also have economic benefits for people within the community by reducing their electricity bills.

Biogas lamps work on a similar principle to cookers as can be seen in figure 4.3, but they are more complex than stoves so would need to be purchased as manufacture is too difficult. Biogas lamps are available in India and an indoor lamp would cost approximately ₹1000 Rupak (2011).
Figure 4.3: Biogas lamp
(Gesellschaft für Technische Zusammenarbeit, 2010, p.22)
5 Materials and Implementation

5.1 Materials Selection

Several materials were considered for each of the major components of the biodigester system. These systems included:

- The tank,
- the lid and
- the housing shelter.

The criteria for the materials selected were

- Cost
- Structural integrity and durability
- Sustainability
- Availability of resources
- Ease of construction

The tank

Two broad construction options for the tank are prefabricated or on site construction.

If the tank was prefabricated it would need to be made of either fibreglass, plastic or concrete slabs, these options require professional services, would be costly and would incur considerable transportation costs. For these reasons prefabricated systems were deemed infeasible.

The tanks need to be structurally sound and capable of holding large volumes of waste matter. Most metal products would be susceptible to corrosion and are expensive. Other common materials such as cement, concrete or bricks were the better suited to the task so a decision was made between them.

To choose between these materials the costing matrix in table 5.1 was used.
Table 5.1: Costing Matrix

<table>
<thead>
<tr>
<th>Material Required</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement 130 bags of concrete</td>
<td>₹ 26000</td>
</tr>
<tr>
<td>Concrete 26 bags of concrete plus sand and gravel</td>
<td>₹ 7000</td>
</tr>
<tr>
<td>Brick 10 bags of concrete for the base and mortar plus 1600 bricks</td>
<td>₹ 5200</td>
</tr>
</tbody>
</table>

The matrix shows that bricks and mortar are the cheapest option, it is also simpler to build using the bricks than to lower large concrete slabs into place or build vertical walls using formwork.

The Lid
There are several types of lids suitable for a biodigester system. The most common domestic biodigesters use a fixed dome or a floating cover design. The dome lid option is complex to build and is difficult to ensure there are no leaks in the design. The floating drum option is simpler and allows greater control over the gas pressure within the system but the moving parts do introduce a possible vector for failure.

A simplistic solution was to create a solid flat lid which would directly feed into a gas storage bag. Perspex, glass or a durable plastic would each be a suitable option for creating the lid section. While perspex would be very durable it would be very costly to purchase pieces large enough to cover the biodigester. Plastic was chosen because it is easily obtained and if damage does occur it is cheap and easy to repair or replace.

The shelter
The design of the shelter is left up to the local community to decide. There are no specific constraints concerning the construction of the privacy shelter and biodigester shelter. The shelter itself can be built from a range of locally sourced materials such as bamboo, straw mat sheeting or wood, in any manner preferred by the community.

5.1.1 Materials Locally Available
Materials that are required to build the biodigester can be sourced from areas surrounding Devikulam. This allows the people of Devikulam to become involved in the project and greatly reduces the cost of transporting such materials into Devikulam. Some materials locally available are clay, pebbles and small rocks that are spread throughout the town. Removing vast amounts of material from the local environment will affect the local
ecosystem so it is important to limit the amount of damage to the environment by placing constraints on the amount of material removed per biodigester.

The locally available materials will be used as an aggregate when concrete slabs are mixed. Local materials will also be used for the building of the privacy structure surrounding the toilet.

5.1.2 Materials to be Imported

Many materials need to be imported to Devikulam for the Biodigester. Cement, bricks, plastic, PVC pipes and smaller items such as ball valves and tubing all need to be imported as they are not able to be manufactured locally. All of the items required for the biodigester are fairly common and would not be difficult to source.

5.2 Implementation Plan

It is intended that the biodigesters are first introduced to the local schools where they can be used by students. The students would also be taught the basics regarding the health and science behind the biodigester, breaking down misconceptions and prejudice this is covered in greater detail within the education chapter.

After the introduction to schools it is intended to introduce a number of public toilets around the village and then to households within the community.

5.3 Tank Calculations

The biodigester consists of a single tank divided into two sections, a toilet for human waste, a mixer for cow dung and organic waste and a gas storage system. Due to the immense amount of waste to be stored over such a long period of time, the tanks would need to be quite large.

Humans produce approximately two litres of waste per day taking into account water used for cleaning and farm animals such as cows can produce up to 20 litres of waste each day after mixing to a 1:1 ratio with water (Polprasert, 2007, p.22).

The system is designed to store enough waste from 25 humans over a six month period which would be the same as 15 humans and one cow. This means that the tank must hold approximately 9000 litres. To optimize the volume of the tank to the amount of building material required the inside of the tanks needed to be approximately $2.6 \times 2.6m$ for the base with a height of 1.4m, calculations to reach these values can be seen in figure 5.1.
Figure 5.1: Tank Size Calculations

Adding ten centimeters to all sides for wall thickness and having the system share a common wall to save on material gives a base size of 5.58 m and a height of 1.5 m.

5.4 Construction Process

There are many important processes involved in the construction of the biodigester, the basics can be broken into the following steps:

1. Resources must be sourced including cement, mixers, bricks, PVC piping and plastic.

2. A pit must be dug.

3. A concrete slab must be laid for the tank and the toilet inlet.

4. Walls of the biodigester must be built and PVC piping laid.

5. Plastic Lid and gas storage bags must be produced.

The biodigester tank is mostly underground this means the first thing that must be done is a hole large enough to accommodate the digester needs to be dug. Concrete must then be mixed and poured to form the tanks base which can be done by following the steps below.
5.4.1 Concrete mixing and pouring

1. Ensure all equipment required to lay the concrete is at hand.

2. Formwork must be built with sides $2.8 \times 5.5\text{m}$ and place on level ground within the pit. The formwork can be made of wood and braced into the earth using stakes. (CCAA, 2004, p.18,p.53)

3. The concrete must be prepared by mixing cement with aggregates, ensuring the right consistency, too much water will weaken the concrete. (CCAA, 2004, pp.15-17)

4. Pouring the concrete should be done slowly to ensure no air pockets are formed within the slab, an agitator can be used to help with this process. (CCAA, 2004, p.23)

5. A screed or flat piece of wood can be used to level and smooth the surface of the slab. (CCAA, 2004, p.26)

6. The concrete needs to be wetted continuously whilst drying, otherwise cracks are likely to form. (CCAA, 2004, p.29)

The process of making the toilet slab figure 3.3, is similar to laying the base to the tanks but uses a more complex formwork to build so once the formwork is made it should be kept for future biodigester builds but the pouring of the concrete is the same. After the slab has had time to set the walls of the biodigester can be built. Each section of the biodigester tank will have an inlet pipe, this pipe needs to be built into the wall during construction. The walls are made of brick so this is done achieved by cutting the bricks into sections and ‘wrapping’ them around the pipe sealing the pipe into the wall using mortar. Laying of the bricks is covered in the following steps.

5.4.2 Brick Laying

1. Ensure all equipment for laying bricks is at hand.

2. Lay a line of mortar on the concrete slab where the bricks will be laid.

3. Place mortar onto one side of the brick to allow another brick to be placed directly next to it as shown in figure 5.2.

4. Place the brick firmly on the slab where the line of mortar is, ensuring the brick is level and remove the excess mortar that is squeezed out.

5. Once a row has been completed the process from step two is repeated, building on the row of bricks just laid. Ensure the bricks on each row are offset by half a brick relative to the row below. This process is called ‘staggering’ and helps keep the wall strong.
5.4.3 Biodigester Lid

After the bricks have been laid a wooden frame will be cemented to each of the tanks that make up the biodigester these wooden frames will act as bases to airtight lids.

The airtight lid on each biodigester will consist of two wooden frames which sandwich a sheet of plastic between them. The top wooden frame will be screwed tightly into the cemented frame to ensure an airtight seal.

In the center of the plastic sheet a small hole will be cut and a simple plastic ball valve will be sealed into place by tightening the threaded nut and rubber washers as seen in figure 3.8.

5.4.4 Gas Storage Bags

The gas bags can be produced using standard HDPE plastic drop sheeting and a soldering iron a prototype example can be seen in figure 5.3. In making the bag it is very important to have a well ventilated area to work and it is preferable to wear respirators as the fumes given off by the plastic are toxic.

To make the bags a sheet of plastic of the correct size needs to be cut, the plastic can then be folded over on itself and the edges sealed together using the soldering iron. This is done almost like slowly ruling a straight line with a pencil, as the soldering iron is drawn down the length of the plastic it melts together forming an airtight seal. Valves also need to be put into the bags, this is done simply by cutting a small hole into the bag, placing the
ball valve, rubber washers and nut through the hole and then tightening the rubber washers with the nut until an airtight seal is produced.

Figure 5.3: Prototype Bag
6 Education

6.1 Education Schemes

6.1.1 Information, Education and Communication Schemes

Based on the data provided by Engineers without borders (EWB Design Brief, 2011) it has been ascertained that the villagers average level of education is not of a high level. According to the latest statistics from the Government of India (Census India, 2001) nearly fifty percent of Indians living in rural villages are illiterate. This shows that the average level of education in villages is not that high. The latest statistics from Tamil Nadu Government shows that the literacy rate in Villupuram District, which includes the village of Devikulam, is around sixty five percent. The latest census data procured by the Indian Government in 2001 (National literacy mission, 2001) states that the Scheduled Caste(SC) and Scheduled Tribes(ST) literacy rates are fifty five percent and forty seven percent respectively. United Nations statistics shows that the literacy rate in India is approximately sixty four percent (United Nations Statistics Division, 2010).

Because of the low literacy rate within the village it has been decided to use an education scheme focusing on pictures, videos and spoken documentaries so that all villagers can understand the processes which take place in the functioning of the biodigester.

The most important barrier that needs to be overcome in the implementation phase of the project is to educate the villagers regarding the benefits of the biodigester and to allay to their fears and misconceptions. Since most of the villagers are from a backward caste, they might find the idea of cooking using the gas produced from their own a waste hard to accept. The concept of eating food cooked using energy produced from ‘poo’ or ‘human waste’ is likely to be viewed negatively in a village community such as theirs, in order to overcome this barrier the aforementioned education techniques can be adopted emphasising the cleanliness and the benefits related to using biogas.

Plan for introducing the biodigester

- Introduce the biodigester into the Devikulam Primary School and Nadukupam High School. This provides sanitation facilities for students and allows for teaching the principles of how biodigesters work, basic functionality and procedures for byproduct use. The teaching can be done using demonstrations, seminars and slideshows.

Table 6.1 shows that school toilets are completely funded by the central and state governments. If the aforementioned scheme can be incorporated into the implementation of the biodigesters they can be
constructed very cheaply at both of the schools with help from the community and the village councils.

- In the next stage, the plan is to implement the system in the colony by producing a system shared by two to three families. The respective families will be educated about how the digester works and how to maintain it.

- The final stage, if the above proposals are successful, will be to make the system available to all villagers upon request. This will enhance the credibility of the biodigester among villagers.

The biodigester is designed to be used by two to three families in order to foster a sense of understanding and sharing among the community which might in turn help ease the tension which between the various castes.

Another barrier in educating the villagers is the language barrier. This can be overcome by making use of educated volunteers from the local area who can act as a bridge between the community and the project, linking them with all the details and benefits associated with the biodigester.

The already existing school can be used to propagate the benefits of the project. Students are the best way to reach into a community such as Devikulam because they can disseminate what they learned at school into their families and the community very easily. Educating children at school about the benefits of using such a system and asking for their support in the implementation of the project will help a great deal in making the project successful.

A plan has been devised to tackle the process of educating the community about different aspects of the biodigester project by dividing the process into four main parts and then focusing on the target groups within specific demographics, tailoring the education to their specific needs and teaching in ways suitable to those groups. This system is designed to put more focus on community groups and make people feel more involved in the process.

The main target groups chosen for the different educational strategies are:

- Children, focusing on safety.
- Farmers, in relation to their association with fertiliser.
- Women, as the cooks and backbone of the family.
- The community as a whole.

Sanitation concerns the whole community hence it is addressed as a community issue. Thus it is important to focus on individual groups regarding issues specific to them. The use of biogas is targeted towards womens groups because they do most of the cooking in rural India. The womens groups will be educated first on the use of gas and this will in turn educate the family
and community as a whole. Fertiliser is a farming matter hence farmers and the labourers need to be educated first in the use of human waste as a fertiliser and how it is safe because they handle it most. Later the whole community will be educated on the aspect of fertiliser. Safety is a major concern and should be tackled in a careful manner. For this we recommend the help of children as they are the future of the community and can help introduce safety values into the family. All this is better explained in figure 6.1.

![Diagram](https://example.com/diagram.png)

**Figure 6.1: Education Schemes**

The plan is to introduce the biodigester into the community coupled with the Central and State Governments Latrine Scheme which is known as the Total Sanitation Campaign (TCS). Based on the information made available by the Tamil Nadu Government (Government of Tamil Nadu, 2011) it is understood that the scheme covers Individual household toilets (IHHL), school toilets, sanitary complexes and rural sanitary marts. Under this scheme the beneficiary contribution varies depending upon the scenario see table 6.1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Government of India Contribution %</th>
<th>Government of Tamil Nadu Contribution %</th>
<th>Beneficiary contribution %</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHHL</td>
<td>60</td>
<td>28</td>
<td>12</td>
</tr>
<tr>
<td>School Toilet</td>
<td>70</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Anganwadi Toilet¹</td>
<td>70</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Sanitary Complex</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

¹Childcare Centers
This contribution scheme will enable households to install the systems at a minimal cost and will also help instill confidence in the project. When the community hears that the program is endorsed by the government they will be more accepting towards the project. Rather than viewing it as a social taboo they will see it more of as a blessing.
Help from some of the Indian Government research bodies such as the Ministry of Science and Technology, the Council of Scientific and Industrial Research and the Institute of Bio-resources and Sustainable Development can be sought to conduct tests on the biodigester so that it is deemed safe. Their studies and reports on the biodigester will improve the communities view of the project.

6.1.2 Sanitation

Sanitation is an important concern in the working of a biodigester and one which needs the greatest attention. Working in a community where there is a low literacy level and poor understanding of basic sanitation. It is of utmost importance to devise a study plan which can penetrate the hearts and minds of the common people, helping them to understand the necessity of safe sanitation procedures and practices.

Based on the statistical data provided by EWB nearly 50 households have no access to a latrine and are unaware of safe sanitation practices. This is a major concern which can be addressed by introducing our biodigester into the community and thereby teaching the community as a whole about the safe disposal of their waste and to also demonstrate the benefit it can produce by generating energy and fertiliser.

To bring the community together it is important to enlist the help of the Devikulam village panchayat(council) which takes care of the administration matters. The Panchayat comprises of elected representatives from the village of Devikulam. If the matter of sanitation could be raised and discussed in their Grama Sabha meetings (a gathering of the entire village to discuss important matters concerning the village) it would provide backing to the sanitation campaign. The villagers will be more ready to listen to someone they know and respect than an outsider. This will instill confidence in the minds of the villagers when they come to know that the initiative is being supported by their village panchayat.

The panchayat can also help subsidise the cost of the unit by using the government latrine scheme, making the biodigesters more affordable to the villagers. During the initial stages of implementation, it is best to build a number of community toilets incorporating the biodigester technology into the densely populated areas of the village.

The panchayat could enlist the support of the local primary school and the high school from the neighbouring village Nadukuppam. By building some biodigester toilets in both these locations they could incorporate its working into the school curriculum and teach the children about its various benefits. The gas produced from the unit can be used for cooking in the school and the fertiliser can be used in the school’s organic farm.

Help from various Non-government organisations (NGO’s) will be sought at this stage in order to educate the villagers on the benefits of using the
biodigester and how it will improve their current lifestyles. Since, NGO’s comprise of people from the locality or from the State of Tamil Nadu, they might have a better idea of how to convince villagers to best make use of the system.

Various plans to educate the villagers on matters of sanitation are:

- Interactive teaching curriculum for the school detailing how the biodigester works, the benefits of using the biogas over biomass and how the fertiliser produced is safe and clean.
- Dramas performed by students from the local schools.
- House visits by NGO members to educate the villagers in the aspect of sanitation.
- Help and advice from doctors attending the Rural Health Camps.
- Education via posters, local TV presentations and debates held during Grama Sabhas.

6.1.3 Gas Power

One of the main benefits of the biodigester other than disposing of the human waste is producing methane gas which in turn can be used as a fuel source. This novel idea might take some time to digest into the hearts and minds of the villagers. The villagers might find the idea of using gas produced from human waste offending to their traditional and cultural practices. To tackle this scenario, a suitable and understandable educational approach needs to be taken. A recent study by C. G Wankhede (2010, Pg 4.) has stated that lower literacy and high dropout rates among the lower castes in turn has a self propogating affect on their poverty and underdevelopment. The statistics provided by the EWB(2011) website also underlines this fact which is elaborated in figure 6.2
Figure 6.2: Community Caste Distribution

(Wankhede, 2010, p.4) states in his article that ‘Scheduled Castes and Scheduled Tribes are considered the most backward sections of Indian society in terms of educational development’ which he reiterates again using a second table 6.2. This information is relevant when we consider the fact that most of the villagers are from either Most Backward Castes or Scheduled Castes.

Table 6.2: Population and literacy in India according to the 2001 census

<table>
<thead>
<tr>
<th></th>
<th>Total (in millions)</th>
<th>Scheduled castes (in thousands)</th>
<th>Scheduled tribes (in thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Total</td>
</tr>
<tr>
<td>Primary (1-5)</td>
<td>69.7</td>
<td>61.1</td>
<td>130.8</td>
</tr>
<tr>
<td>Middle (6-8)</td>
<td>28.5</td>
<td>22.7</td>
<td>51.2</td>
</tr>
<tr>
<td>Senior (9-12)</td>
<td>21.7</td>
<td>15.4</td>
<td>37.1</td>
</tr>
</tbody>
</table>

(Wankhede, 2010, p.5)

Womens’ self help groups from the region can be enlisted to help educate women on the different aspects of cooking using methane gas. Small seminars and workshops can be held within their normal meeting hours to demonstrate how to effectively and efficiently use this energy source (Government of Tamil Nadu, 2011). They can also be taught how the biodigester works so that they too can help with maintaining the biodigester unit, thereby reducing possible hassles caused by poor maintenance.

It would also be advantageous if the gas bag manufacturing technique is
taught to the women during the self help groups so that they have a new income source and job opportunity by selling these bags to families in the community, this reduces the dependence of the community on outsiders for maintaining the biodigester. This way they might also find the idea of a biodigester more appealing since they get the feeling that they are involved in its construction and implementation.

The main aspects to be taught about using the gas produced from the biodigester are:

- The functioning of the gas traps,
- how to deal with a leak in the gas bags,
- transferring the gas from the main bag to the cooking bags and
- safe and effective use of methane gas.

6.1.4 Fertiliser

A major benefit derived from the biodigester is that the contained waste matter is very rich in nutrients. As long as pathogens in the waste are destroyed it can be used as fertiliser in the fields. The village already has a forestation project as well as many medicinal herbs growing around it. This can be used to improve their growth, the villagers can also use it in their fields to grow organic produce reducing their reliance on chemical fertilisers. These facts need to be incorporated into the proposed educational system to educate the community about the biodigester.

With the help and cooperation of the several farming groups present in the area, the safe handling procedures pertaining to the fertilisers can be taught quite easily. Since, human waste still contains harmful pathogens in the initial stages of decomposition, these farmers need to be well educated on matters such as:

- The frequency of removing the fertiliser from the pit,
- how long the slurry needs to remain in the pit in order to eliminate the pathogens completely,
- fertiliser safe handling procedures,
- how to clean the pit,
- operation and maintenance of the unit without any hassles.

To instil confidence in the minds of the farmers regarding the use of the fertilisers, it is proposed that a number of farms are adopted during the initial stages of the project where fertiliser from the biodigesters will be used to nourish the crops on these organic test farms. Eventually they will realise
the benefit of organic farming due to not having to purchase chemical fertiliser and being able to sell organic produce at higher prices. Indian farmers already use animal waste such as cow dung as fertiliser on their fields however the waste from the biodigester is much higher in nutrients because urea is a component of the waste, after the anaerobic digestion the byproduct has a much higher nitrogen content. The fertiliser is also stored in one place unlike the cow manure, this will dramatically reduce the workload and in addition will increase productivity.

The introduction of these adopted farms will hopefully encourage more farmers to endorse the technique of organic farming which will boost the image of biodigesters in the community.

Tests for pathogens or harmful substances could be conducted on samples from the biodigester at the Indian council of Medical Research, which is deemed to be the apex medical research body in India. These tests and reports will help to increase confidence among the villagers regarding the biodigester.

6.2 Safety Issues

The most important concern involved with using biodigesters is the safety factor, carelessness might lead to a disaster which is why educating the villagers on safely operating the biodigester is an important part of this project. A set of explanatory slides showing the effects of improper operations will be aired and explained to the villagers with the help of volunteers such as teachers from the local school, doctors from the primary health center and NGO volunteers. Another way of getting into the minds of the villagers is by means of documentaries and short dramas depicting stories of mishaps which might occur due to poor operation of the digester and the gas system. The statistics provided by EWB survey (EWB Survey, 2011) shows that more than 50 percent of the families in the village own a television which indicates that televising these skits or dramas on the community broadcast channel may be a good way to reach the villagers.

The graph in figure 6.3 shows the percentage of households with televisions.
A number of women’s self help groups present in the village can be utilised to educate women about the safety aspects of the system. Women will be educated on how to safely operate the biodigester system during the self help group meetings which are held regularly. This will be done with the help of local volunteers such as teachers from the local and neighbouring schools as well as other local volunteers. The various measures to be adopted for enhancing the safety aspects are:

- Setting up a village biodigester safety committee comprising the elders from the society to monitor and administer the safety aspects related to the biodigester. (getting more people from the village involved)

- School based activities such as poster contests, debates and interactive curriculum based on biodigesters at school. (health and hygiene as a subject).

- Fortnightly meetings among family clusters to evaluate the problems they are facing and discuss ways to tackle them.
7 Evaluation

7.1 Team Evaluation of Biodigester

The biodigester covers the objectives laid out by the team at the outset of the project. It is capable of storing and distributing gas, it provides toilet facilities, acts as a waste treatment facility and is relatively cheap and simple to construct.

By taking into account the sanitation scheme the cost of building the biodigesters is reduced to such an extent that they are an affordable proposal. They are very simple to run and maintain and the benefits provided by the biodigester will have a positive impact on the people of Devikulam. An education scheme was covered which is intended to promote the use of biodigester toilets and help community embrace the idea of using human waste as a positive resource rather than a negative waste product.

7.2 Feasibility of Biodigester

The feasibility of the design is promising in regards to its capabilities however it is not something that could be immediately implemented into communities. Because of the problems associated with using human waste on crops when pathogens like E.coli have not been completely destroyed are dangerous it is not something that should be tried without being absolutely sure it is safe.

Another aspect that would need to be tested is gas production from a high percentage human waste, low liquid content biodigester. Research has mainly focused on biodigesters using mostly animal waste and high water content so it would be important to test if enough gas is produced from a design such as that in this report.

The final aspect which while covered in the report is still an overlying problem with the design. The people may simply not be able to get over their reservations regarding the use of human waste byproducts for cooking and on food crops.
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