Engineers Without Borders Challenge 2011

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Team Non-QLD

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Sanitation Through Education and Compost Toilets
Executive Summary

The 2011 Engineers without Borders Challenge aims to improve various aspects of a village called Devikulam in southern India. The EWB Challenge is a way for aspiring engineers to experience first-hand the problems apparent in the world and provides the opportunity to design solutions to rectify this. The chance to actively participate in real life engineering projects allows students to develop teamwork, communication skills and knowledge about sustainability in certain future endeavours.

This report specifically targets the quality of water available and sanitation systems that could be installed as future projects. It details our approach to the problem and discusses the most sustainable solution. It provides ideas for how waste management and sanitation can be handled in the future and ways to advance the general hygiene behaviours of the village. It aims to improve the current habits within the community as a viable long term solution to eradicating disease and illness.

The report identifies the current situation in the village and recognises cultural, social, economic and environmental factors that will come into consideration while implementing the solution. To achieve sustainability the design must take into account these factors yet still provide a means to improving the wellbeing of the community. Cultural beliefs such as reuse of human waste has a substantial impact the final design, this combined with financial restrictions means that finding the most viable solution is vital.

Educating the community is a solution that will be economically viable with low initial costs and no ongoing costs. It is a long term solution that will provide benefits for the current village and for future generations. It will have a beneficial influence on the environment as waste management will reduce the microorganisms in the water and halt the apparent odour. It identifies that used in conjunction with a technical implementation the education system will see long term positive impacts on the resident’s health and welfare.

A toilet system will enable the community to physically stop the need for open defecation. This will stop the run off into the supply and will see an improvement in the quality of water in the supply. It will detail the measurements and construction requirements needed for build a toilet as well as education plans on how to properly use the system. The implementation will see a more rapid increase in the water quality and health of the community. The use of the toilets at the same time as educating Western hygiene practices will ideally provide the best result from the project.

Identifying the costs relevant to installing a new education system and how the finance will be raised is an issue that will have little impact in the design. The minimal costs affiliated with the solution means that the revenue can be raised through community funding and small donations through charity organisations. The toilet system requires more capital to be raised and government spending, donations and community help will be required to install it and allow the design to work at its optimal level.
As this design meets the requirement of being economically, socially and environmentally viable it is clear that it can be utilised to improve the quality of life of the people living in Devikulam. Making the solution accepted among the community and is the hurdle that must be overcome. If this can be achieved then the ultimate goal of a sustainable design that can reduce the pathogens in the water, prevent illness, disease and in certain cases death can be implemented and be successful.
Team Reflection

The EWB challenge this year provided our team with the chance to demonstrate and develop our abilities in a real life engineering project. It enabled us to work towards a common goal of improving the quality of life in the village Devikulam through a sustainable design. We feel that we have been able to develop the design required for the challenge in a way that proves to be accommodating to the villager’s needs.

The project brought with it several obstacles that were needed to be overcome. We felt that our biggest obstacle was one of organisation, in that we took longer than expected to decide on a design that would best fit the criteria of the challenge. As such we spent large amounts of time researching different ideas trying to discover the way we wanted to head. The isolation and cross cultural aspects of the project also provided issues as we had little to no knowledge of the region, the people and the customs and beliefs. Being able to identify a solution proved difficult without an in depth knowledge of the society in the village. To achieve sustainability we required a framework for the economy, however without a means to access financial assistance we struggled to determine how viable our design was economically. During the time of the project we encountered multiple issues however as a team we overcame each one and provided what we believe to be a viable solution to issues in Devikulam.

Working as a team on the challenge allowed us as individuals to develop our skills. We felt that we learned from each other’s strengths and improved upon our weaknesses the longer the project continued. These strengths and weaknesses allowed the allocation of tasks to be simplified down to who would achieve the best results for each section. The accessibility of other members meant that we could immediately discuss any issues that became apparent with other members of the team. Working as a team gave us the opportunity to develop our skills in communication and consistent meetings meant that these abilities were solidified.

If we had our time over again to complete the report we would aim to be clearer with our intentions from the start. We would try to focus more on sustainability with respect to material selection and possible long term impact on the environment. The team would aim to improve our organisational skills, especially in regards to having a set date to complete tasks and regular meetings. Our weekly formal meetings allowed for information transfer however more meetings would improve the efficiency of the team and provide us with more time to detail the sections of the report. Ultimately, we would aim to set and reach deadlines earlier and have a solution that we could work and research towards sooner in the project.

The EWB challenge also offered several enjoyable experiences. Working as a team allowed us to collaborate and share ideas to find the best possible solution to an ill-defined problem. The fact that the project was based on a real life situation gave us an incentive to help a less fortunate community and improve their standards of living. Being able to work within the sustainability framework allowed the team believe that any work done could actually be implemented in the future. This gave us motivation to find the ideal solution to the problem. We often found that many university projects can lack the perspective provided by a real life issue and this presented us with a chance to develop work skills that are relevant to the work force.
If presented with an opportunity to complete the project again the team would aim to improve in some areas, however certain parts were conducted and completed successfully. The weekly meetings enabled us to develop the project and writing of minutes and charts allowed the team to stay up to date on the changes in the project. As distance education students we managed our time well and made changes to our daily routine to accommodate for the team. As we had different work schedules and international time zones we required these alterations to be successful in the project. Despite different schedules the team remained constantly accessible and this enabled us to work more efficiently and towards a common goal.

As a team we complete certain facets well and left other areas to improve on. Identifying ways we could improve will allow us to develop our skills further in future projects. Ultimately we found this project to be rewarding in a team and an individual way and we all feel that our design answers the criteria set by the challenge.
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1.0 Problem Definition

1.1 Problem Scope

Devikulam is a small village in southern India surrounded by the dense Pitchandikulam forest. It has a small population that suffers from several issues ranging from poor quality of infrastructure to no real waste management plan. This is impacting the community in a large way and they require alterations to the current scheme to resolve this. The community can do little to solve the issues as the majority of people in the area live below the poverty line. Most residents have a low annual income and low levels of education and as such there is a lack of skilled workers that can provide beneficial alterations to the village.

Although there are numerous issues to be dealt with, this report focuses on the water quality and sanitation as well as waste management. Access to clean drinking water is limited in the village due to ongoing contamination and current waste management are affecting the issue. Humans and animals openly defecate which runs off into the water and taints the supply. Preventing further contamination is vital in improving the quality of their supply. Providing a toilet that can separate the urine from the faeces will make it easier to bury and eliminate it as a factor to the water quality. A lack of education in common Western hygiene practices is the essential key to rectifying this problem. Correct use of the toilet systems and preventing unnecessary damage will enable the longevity of the design. The design must also be presented as a sustainable implementation that will improve the quality of life within the village.

1.2 Technical Review

Current Situation

Sanitation is an important issue for all members of western society. We are taught from a young age to shower, wash our hands, use the toilet and other simple hygienic practices. Because we know and use these hygiene practices we live relatively healthy lives and experience bacterial infections only rarely. However this is not the case for the majority of the population of India and a small rural village located in the Southern Indian state of Tamil Nadu called Devikulam.

Devikulam village is a typical rural Indian community; almost all of its occupants are members of the two poorest castes: the scheduled class and the most backwards class. Not surprisingly almost all of these people fall below the poverty line and as such their village has only the most rudimentary infrastructure and formal hygiene practices and education are unheard of. Because of this the health of the villagers is constantly under serious threat from bacterial infections.
The most serious of these hygiene and sanitation problems is open defecation. It is not surprising that this is the case; about 665 million people in India (more than half of the population) defecate in the open because they do not have access to toilets. The faecal matter left behind when people defecate on the ground contains many harmful bacteria called coliforms. These coliforms, when ingested, can have many serious effects on human health. Shown below is a list of only a fraction of coliforms that exist and the diseases that they can cause:

<table>
<thead>
<tr>
<th>Coliform Bacteria</th>
<th>EPA list Primary Pathogen</th>
<th>Heart Disease</th>
<th>Cardiovascular Disease</th>
<th>Respiratory Disease</th>
<th>Pneumonia</th>
<th>Emphysema</th>
<th>Septicemia</th>
<th>Bacteremia</th>
<th>Blood Poison</th>
<th>Urinary tract infections</th>
<th>Digesting (fresh eating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Aerivates</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>x</td>
<td></td>
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<tr>
<td>2. <strong>Bacteroides eggerthii</strong></td>
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<td>3. <strong>Citrobacter freundii</strong></td>
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<td>4. <strong>Corynebacterium kutscheri</strong></td>
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<td>5. <strong>Corynebacterium xerosis</strong></td>
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<td>6. <strong>Coxiella burnetii</strong></td>
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<tr>
<td>7. <strong>Deinococcus radiodurans</strong></td>
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<td>8. <strong>Enterobacteria</strong></td>
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<td>9. <strong>E. coli</strong></td>
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</tbody>
</table>

Figure 1: A list of coliforms present in the bores

Perhaps the most well-known of these bacteria is E. Coli. As can be seen on the table (Figure 1), it has the most related serious illnesses and in reality it is regularly the cause fatalities.
This is why removing open defecation as a practice within communities is the main goal of most sanitation improvement programs implemented by health organisations today. The situation in Devikulam is exactly the same. The propagation of bacteria from faeces to person and person to person is the key to understanding how the bacterium spread among the people. Shown below (Figure 2) are ways in which bacteria might be transported from faecal matter to infect humans:

![Figure 2: Routes of Disease Transmission](image)

The routes which a coliform might take to infect a human are numerous although it can be seen that there are three main points at which the process can begin. These are: Transportation of bacteria by vectors like insects, on the hands of the person who produced the faeces and the contamination of water sources by the faeces.

This is the most common route of propagation of coliforms and is also the one of most concern, especially in Devikulam village. Devikulam experiences regular rainfall and a heavy monsoon season, which is responsible for washing faecal matter into their water supplies. The village rainfall statistics can be seen below (Figure 3) (values in mm):

![Figure 3: Table of Annual Rainfall in the Village](image)

These figures are indicative of a constant and periodic opportunity for the transport of bacteria and faecal matter directly into water sources. Luckily (or perhaps out of good planning) the majority of water sources in Devikulam are capped and water cannot easily enter from ground. However rainwater can still easily transport coliforms into water supplies through the soil and through cracking and weaknesses that may occur in source capping.
Recent tests performed on the village water supplies seem to indicate some form of water source contamination does occur:

<table>
<thead>
<tr>
<th>Bore</th>
<th>Coliforms (N/100mL)</th>
<th>E. Coli (N/100mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>124</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>142</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>504</td>
<td>184</td>
</tr>
<tr>
<td>Average</td>
<td>256</td>
<td>70</td>
</tr>
</tbody>
</table>

These results are not very encouraging. In fact these levels exceed the safe drinking water standard recommended by the World Health Organisation of zero coliforms/E. Coli per 100mL sample. Reports from reviews conducted on site maintain that the water is still safe for drinking and at this point poses no serious threat to the health of the villagers. However with levels already at questionable concentrations it raises serious concern as to how long this will remain the situation unless some form of intervention occurs.

After the bores become contaminated ingestion (drinking water or eating food) becomes the easiest way for a person to contract a disease. Most people are familiar with the common bacterial infections related to ingesting coliforms i.e. diarrhoea and food poisoning. Usually (in western countries) oral entry of bacteria is eliminated by hygiene practices such as washing hands and drinking from safe water sources. Unfortunately the villagers in Devikulam do not really use or understand these simple processes and as such the transfer of pathogens from faecal and water to humans is a regular occurrence.

Currently the village does not have adequate education programs in place to remedy this. Devikulam occupants, like the majority of the rest of rural Indians, simply do not have detailed knowledge of what bacteria are and how it causes illness. As such education programs are required and the best way to deliver them is at group meetings.

Education programs will need to cover all routes of infection that may occur. So far only ingestion has been discussed as a route of infection, when in fact bacteria can infect a person in a few different ways:

![Figure 5: Routes of Infection](image-url)
As such there exists an even wider range of bacterial infection routes all of which need to be addressed in their own particular environment and path of infection.

So, sanitation in Devikulam is of great concern and it is clear that there is a need for an overhaul of existing sanitation programmes and implementation of new infrastructure that will help to decrease the risk of infection for the villagers.

Remedies

Solutions to sanitation problems of Devikulam could come in a wide variety of forms ranging from composting toilet blocks to basic signs about hygiene practices in relevant locations. A solution that could be deemed appropriate for increasing the sanitation standards within the village would one that completely addresses the issue of bacteria from faecal matter infecting humans and causing illness.

Relevant remedies to this problem can be classified under two broad forms of intervention: contain and treat the source of the bacteria and prevent bacteria this bacteria from being spread. A development plan for the village relevant to sanitation would then consist of technologies that enact either or both of these measures.

Containing the source of the bacteria

It is possible that merely designating an area far away from the village and water supplies for open defecation to occur would suitably eliminate the risk of bacterial contamination of water supplies altogether. However there is much greater potential in the design of some kind of toilet facility, most likely one that uses composting. Pre-existing designs like Eco-san toilets and pit latrines are proven to be safe and effective designs that are both cost effective and environmentally friendly.

The eco san design works on the basis of separating solid waste from liquid waste and storing them separately. The solid waste comports over a period of time and can then be used as fertiliser locally for crops. The urine is also useful as fertiliser or nutrients for fish ponds. Eco-san infrastructure includes a basic toilet block with a squatting pan inside. The pan then has separate openings for the separation of solids and liquids. Beneath the squatting pan there are containers which store the wastes, containers are then switched out when full. The eco san design is both easy to construct and environmentally friendly, it does require technical designs to be created though based on the surrounding environment to ensure that sustainability measures are adequate and a suitable manufacturing guide needs to be supplied.

Similar to the eco-san design is the pit latrine. The pit latrine consists of a toilet block above a pit with cement walls and open soil base. The toilet block is simply a raised structure with a seat inside and a hole that drops directly into the pit. Waste is then composted over time and reabsorbed by the eco system.

The use of either of these toilet systems would greatly reduce the spread of harmful bacteria, in fact one study reported that the implementation of toilets in villages suffering from sanitation issues reduced diarrhoea morbidity by 32%. Although this is a very promising figure the results can be improved even further when combined with some sort of hygiene awareness program.
Preventing the Spread of Bacteria

Surprisingly the most effective way of improving sanitation and reducing bacteria related illness is hygiene education. The same study previously quoted reported that hygiene education was the most effective form of sanitation improvement reducing diarrhoea morbidity in populations by up to 45%. That is because these education programmes are a good way of teaching people lifelong sanitary habits that target harmful bacteria at the point of transfer. Most hygiene education programmes that exist are aimed at school children and are combined into four main areas of learning: Water, Sanitation, Food and personal hygiene.

Hygiene education is also important to adults though as in communities they provide the role models for children. Hygiene education lessons at women’s groups have already proven to be effective measures against the spread of bacteria. The sanitary habits that mothers learn at these groups inevitably become practices for both themselves as well as their children.

Education of this nature need not only come in the form of lessons. Signs placed around the village and technological approaches such as computer based learning are reported to have very high success rates in other villages in India, however these programs are generally much more expensive.

Conclusion

Clearly the most effective approach to combating the sanitation problems in Devikulam will come in the form of a dual approach: contain harmful waste material and prevent it from reaching the hands and mouths of others. So, from the options discussed here that would involve the use of some form of toilet system, preferably recycling, with an education programme that covers both the use of the toilet and various sanitary practices that people should use such as washing hands and wearing shoes in the toilet to ultimately stop bacterial infections in the village altogether. Clearly the viability of these solutions though is subject to cost analysis and cultural acceptability although studies so far have indicated that education programs and toilets are quite cheap and readily accepted by local communities that use them.
1.3 Design Requirements

To be considered a successful implementation of toilet systems and educational programs the design must accommodate the following requirements:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement in Hygiene Practices</td>
<td>The education system should introduce the basic knowledge for Western hygiene practices. Combined with the toilet systems, the village should see a reduction in open defecation which will improve the quality of the water supply in the community.</td>
</tr>
<tr>
<td>Sustainable Implementation</td>
<td>Ideally the design will see no environmental impact yet still provide a large benefit to the community. Due to low reserves of finance the design must also be economically viable.</td>
</tr>
<tr>
<td>Longevity</td>
<td>As the design will see results improve the longer it is implemented, it is essential that it has a long life expectancy. Maintaining the toilet systems and upholding the new hygiene practices will justify the operation.</td>
</tr>
<tr>
<td>Socially Accepted</td>
<td>The design must adhere to cultural and religious standards. Certain ideals among the community may prevent some implementations and any design must be accepted by the village itself.</td>
</tr>
<tr>
<td>Water Quality</td>
<td>If successful the design will result in long term reduced pathogens in the water and a far improved quality in taste. This should see a reduction in disease caused by the water.</td>
</tr>
</tbody>
</table>

*Figure 6: Design Requirements*

The solution must be socially, ethically and technically functional and remain purposeful for an extended period. It must be used extensively by the community to best utilise the system and provide the ideal results.
2.0 Design Options

Water Supply

Burnt Palm Oil Shell Filtration

This option was designed to address the water quality by removing suspended solids. This would have an obvious effect of increasing access to potable drinking water. In addressing water quality our team looked at several filtration and sterilisation systems that could treat moderate to large volumes of water. The filtration system was based on burnt oil palm shell (BOPS) and could be used as either a single or dual media filter. The BOPS is a by-product of the palm oil industry as such is expected to be readily available. As it uses a waste product as the filtration medium it is felt that it meets the sustainability criteria. The filter system could be fabricated on site and installed in the current water supply system utilising current supply infrastructure. The use of filtration as means of cleaning water is widely accepted throughout the world and therefore should not clash with the social or cultural beliefs of the residents.

UV Sterilisation

UV sterilisation of the current water supply this system was believed to be relatively low in cost with only minimal electricity requirements. The system is believed to have a low operating cost with an expected annual maintenance and globe replacement. The system however would require follow up biological analysis of the water to ensure it was functioning properly. Other issues with this system could come in the way of access to parts and professional assistance in the event of a breakdown. Also as it relies on electricity it would be rendered inoperable during blackouts. This could be rectified by the installation of solar panels which could power both the pump and the steriliser to ensure uninterrupted supply of clean water during power outages.

Rainwater Capture and Storage

Rainwater capture and storage was also explored as it would be an excellent means of providing water that should be relatively contaminant free due to natural evaporation process which generally leave impurities behind. The construction/installation of rainwater tanks would increase access to clean water. Rain water is not believed to pose any social or cultural problems and is generally accepted. However due to the extensive use of thatched roofing in the area problems may arise when attempting to direct the water from rooftops into tanks. The local rainfall data supported the notion that rainfall would prove to be a sustainable source of water throughout the year.

Sanitation

Sanitation Though Infrastructure

The two main options explored both used urine separation and are essentially dry toilet systems that do not require flushing. The system incorporates squat pans which are commonplace throughout the region which should be acceptable on cultural and social grounds.
A low cost urine separation pan style toilet with two removable pans to collect solid and liquid waste was the first option. The design aims at using local labour and materials to reduce costs, hopefully putting it with the price range the local residence. The design does not require large volumes of water for flushing or the installation of a sewage network such that the implementation of the new toilet could be relatively quick and not reliant on other infrastructure. The superstructure material of choice is untreated bamboo, with a suspended cement slab floor and supporting wall constructed out of either concrete or mud blocks. The use of untreated bamboo is believed to have a lifespan of between 1-3 years [60]. As the bamboo is untreated the material has no significant environmental impact and can be burned or simply left to compost naturally. In the three year period before renewal the growth rates of bamboo should be such that the supply of material will be sustainable.

The second system for sanitation was a dual faecal vault urine separation toilet system. One major advantage of this system is that it composts the solid waste on site and has a relatively long period between services. The composted material may also be sold as a soil conditioner therefore providing addition income to the villagers. The structures are generally of burnt brick and concrete design and as such should have a relatively long life. The initial cost of the can be somewhat restrictive however estimated to be approximately 450 Euros per unit [63].

**Education**

Our team also chose to explore the option of hygiene and sanitation through education. It was believed that education would play a crucial role in the success of implementation of new practices. A community based education system aimed at both children and adults with the goal to deter the practice of open defecation and promote good hand hygiene. This was seen as a key step in reducing the transfer of disease. As the education program has relatively low set up and operational costs it is believed to be economically viable. The system if implemented effectively should have little to no impact of the environment and with a reduction in open defecation there should be a reduced risk of the water supply becoming contaminated due to heavy rain.

**Aquaponics**

Aquaponics is a hybrid system of aquaculture and hydroponics. As urine can be used in aquaculture to promote fish growth it could be used a viable solution. The system utilises a fish pond and a number of planter beds, water from the pond containing is then used it irrigate the plants. As the water passes through the soil excess nutrients are removed by the plants and the remaining water is collected and recycled through the pond. The system has several key benefits as nutrient comes from the pond water the need for fertilisers is minimal reducing the costs of food production. There would be an increase in fresh fish and vegetables. The system suggests long term sustainability as the fertilisers come from waste products as opposed to other sources of minerals which may involve mining or other environmentally damaging practices. The system reduces demand on water supplies for both the irrigation and aquaculture although some make up water is required due to transpiration and evaporation. The initial cost of the system could prove to be prohibitive due to the extreme low income.
Future developments

The current system could readily be used in conjunction with a bio-digestion plant. This would allow for the solid waste from the communities toilets to be converted into bio gas and ultimately energy and food. The collection of urine could also prove beneficial possible creating a source of income for families. Another option is urine collection as it could be in used in Aquaponics, as studies have indicated urine may promote fish growth in aquaculture [63]. The ultimate goal for the future is that the waste products both solid and liquid can find viable uses as this would help to promote the use of the toilets and stop the practice of open defecation. Secondly if the wastes had monetary value it would provide additional income helping to raise the current living standards.

The current design of the toilet requires significant amounts of cement. With further development it could be possible to construct much of the lower section of the toilet with mud blocks. This would significantly reduce the requirement for cement, therefore greatly lower the cost. As we had no access to the local soils it was not possible to assess the suitability of mud brick in the construction. However mud bricks are a widely accepted building material throughout India and it is assumed that there would be some level of local knowledge. Mud is considered an exceptionally sustainable material as it is readily reusable and requires only a fraction of the energy required to make cement or fired bricks [67].

2.1 Option Selection

The following table (Figure 7) shows some of the concepts explored by the group when addressing the problem in the Devikulam set forward in the EWB challenge and how they measured up against the constraints that we placed on the validity of each design.
<table>
<thead>
<tr>
<th>Concept</th>
<th>How cost effective is the implementation and ongoing cost</th>
<th>Is the design eco friendly</th>
<th>Time frame for implementation and ability to see a change.</th>
<th>Will the design meet the needs of EWB challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the roof surface area to capture drinking water that is safe for the community to drink</td>
<td>This would be very expensive to implement as roofs would need to have gutters installed and also tanks built to hold the water</td>
<td>The design would be eco-friendly</td>
<td>The time frame for this project would depend on local sources for guttering and also the ability for locals to install or would the product and labour need to be sourced from elsewhere</td>
<td>This would meet the need for quality drinking water but cost and also availability of resources may lead to further complications</td>
</tr>
<tr>
<td>UV steriliser that is attached to a tank to provide drinkable water.</td>
<td>The UV unit itself is not very expensive but creating tanks is expensive and also who is going to pay for the running cost of the unit.</td>
<td>The unit is eco-friendly but does have some power consumption which will strain the already minimal power supply to the village</td>
<td>The UV steriliser could be implemented straight away but the tanks for holding the water would take time and materials to build.</td>
<td>Although this would provide suitable drinking water it would not address problems such as power use and also further containments in the current water supply</td>
</tr>
<tr>
<td>System</td>
<td>Cost of raw materials</td>
<td>Eco-friendliness</td>
<td>Availability of raw materials</td>
<td>Potential Impact</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------</td>
<td>------------------</td>
<td>-------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>BOPS filter (rapid filtration system made from Burnt Oil Palm Shell)</td>
<td>Minimal once established in the local community. The cost of a pumping system including pipe, pump and electricity is a major drawback.</td>
<td>The unit is eco-friendly and the processed materials could be used to create power for the community with green biomass energy.</td>
<td>The materials would have to be sourced from other regions until the village could be self-sufficient on the raw materials</td>
<td>This could create a viable agriculture venture from the village and possible biomass energy but the initial cost of raw materials and also lack of addressing other problems means that it will not work for the community</td>
</tr>
<tr>
<td>Aquaponics</td>
<td>There would be a moderate cost to implement this system. However the system will reduce cost in the community as it provides the nutrients to grow food by processing human waste.</td>
<td>Very eco-friendly with some useful by-products such as food from plants and meat fish. It also reduces the impact on the local water supply.</td>
<td>Instant implementation of the system but would take a while to see any benefits such as food or a return on the initial investment.</td>
<td>Current customs in the village would have to be overcome as the villages do not like to use human waste to grow anything that they will eat. The system only uses the urine and further measures will have to be put in place to remove defecate from the environment.</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>There is already an education framework in place for the children and with the addition of some basic signs and meetings for the older generation this would be a very cost effective venture</td>
<td>Very eco-friendly – only concern would be that the soaps used by the community would have to be eco-friendly soap to ensure a healthy environment</td>
<td>As there is already an education program in place for the children there would be no time delay on implementing the education for them. Signs and meetings for the older members of the community could be organised in a very short period</td>
<td>By educating the community to stop defecating in the streets and also keeping germ transfer minimal it will stop the increase of germs into the water supply</td>
</tr>
<tr>
<td>Simple toilet from local materials</td>
<td>As most the materials are local it will be a very cost effective approach to giving each house in the community a facility to use and to take ownership of and stop them defecating in the streets</td>
<td>Very eco friendly</td>
<td>The toilet system can be implemented immediately and can be built by the members of the community with the simple plan that will be provided.</td>
<td>The toilet system will assist in keeping the faeces off the streets and will help to stop the germs ending up in the local water supply.</td>
</tr>
</tbody>
</table>

**Figure 7: Concept Evaluation**

From the table above you can see why the group has taken the approach of a double headed solution where the simple toilet provides the facility to keep the faeces off the streets but the education system will explain to the community what they must do so. The other concepts considered have been excluded due to costing or other reasons leaving the team with what we believe to be the ultimate solution for the community and the combination of education and the toilet system will undoubtedly increase the standard of living in the community.
3.0 Design Description

The solution proposed aims to improve the quality of life in the village of Devikulam by improving the quality of drinking water through education and waste management. The constitution of the World Health Organisation (WHO) defines health as “a state of complete physical, mental and social well-being.” [5, page 8] Our project aims to improve the health of the villagers by first guaranteeing their physical wellbeing. The WHO also states that “meeting health based targets should be viewed in the context of broader public health policy” and that it should include initiatives “to improve sanitation, waste disposal, personal hygiene and public education.” [1, page 36] Our system is designed to address each of these initiatives. We believe that as drinking water quality improves and waste disposal and hygiene education takes affect the mental and social health of the village will also.

The well water has a coliform count above recommended levels [13]. The contamination is thought to come from the rain water after contact with unburied faecal matter. If the local people could be taught the dangers associated with exposed human waste and its link to sickness they could be encouraged to use public toilets or dispose of their waste in a more sanitary way. If the safety and quality of the drinking water could be improved the water related sickness will decrease.

Our team has performed research into the cultural, environmental and economic conditions prevalent in the region and have developed a low cost system to create an improved standard of living through sanitation and education. It is hoped that our ability to research the issues faced by the people of Devikulam will produce a sustainable improvement to the community.

The project consists of two parts, an educational component and an engineering solution. It is our belief that the two lower cost components will when used in conjunction have an increased effect. Education on its own will create improvements but when combined with a tangible avenue for application it will have improved chances of success.

The engineering component proposed is a simple toilet structure suitably placed in the village. The construction of the toilet will be such that the waste will be contained and prevented from coming into contact with the village water supplies. The toilet must also have features that enable users to uphold the local customs and traditions regarding privacy and ceremonial cleanliness. The toilet will require periodic servicing to remove and dispose of waste. Some education and training will be required for this task. The design of the toilet will be refined to the point that it can be constructed from local materials by local villagers with a minimum of imported parts.

The educational component of the project will be designed to teach villagers of the benefits of washing their hands before eating, using soap and the importance of disposing of human waste safely. Education tools will be specifically targeted to the three main groups in the village, the children, the women and the men. The children will be taught good hygiene behaviour through the local women’s group and encouraged to continue through a basic reward system where soap forms the reward. The women will be taught about the link between contamination and sick children. The men will be taught not to defecate in public through the use of signs placed within the village.
A WHO document [15, page 23] had this to say about our target audience. “A comparison of the Indian state of Kerala with the rest of India shows how a combination of technical and social interventions is necessary. Women in Kerala are better nourished and better educated than the average in India. It is a reasonable speculation that the better survival and lesser stunting of their children is a direct result of maternal education and better nutrition for mothers and children.” Our design will follow this pattern in an effort to improve the quality of life in Devikulam.

3.1 Summary of the Design

Part 1: Toilet block

The physical component of our proposal consists of a toilet or toilet blocks placed in the village of Devikulam to prevent human waste from contaminating the local water supply. We have designed both parts of this system with sustainability in mind. The physical system must be effective in its function but low cost in its implementation, the toilet must also fall within the acceptable social standards of the community. The physical components of the education system are selected to be simple and low cost but effective. They must also be sensitive to local beliefs and customs.

The toilet design must adhere to the following criteria as determined by Team Non Qld.

− Human waste is contained.
− Sanitation is maintained to a high standard.
− Privacy and local customs protected.
− Low cost.
− Easily constructed.
− Safe.

Some education and training must be provided to enable the construction and maintenance of the toilet. Details of this will not be provided as part of this document.

The toilet block forms the engineering part of the solution, its success as a solution is dependent on its maintenance and correct use. The need to use the toilet will be promoted in the second part of our proposal.

Part 2: Education

The complimentary component in our proposal is education. The system we have chosen will focus strongly on the need for hand washing and use of toilets. This will be achieved by educating the villagers about the dangers of contaminated water and other disease vectors. It is hoped that the children can be taught using a simple reward system via the women’s group. Actual soap will form the reward thus encouraging continued good practice. The women will be taught about the link between hygiene and family sickness through the use of simple educational materials. The men will be taught through the use of signs placed throughout the village particularly near the water sources. The signs will be designed in such a way that cultural sensitivities are not challenged.
3.2 Detailed Description

3.2.1 Toilet System

The urine diversion dehydration composting toilet design in its entirety is made up of two separate and complimentary constructions. The first is the hardware that will separate the faeces and the urine, store it, and compost it. The second part is the building that will house the hardware and most effectively allow the UDDCT processes to occur.

Part 1: UDDCT Pan and Collection

The hardware that we have used for the UD system is a solution known as a urine diversion pan. The urine diversion pan consists of two sections: A hole through which faeces can drop into a container and a basin for diverting urine and anal wash water into a separate container. In this way the solids are harvested separately and can be composted while the urine is likewise collected and can be used as liquid fertiliser. In this design the urine and anal wash sections have been combined to reduce its overall size, increase flexural strength, save on materials costs, and integrate liquid waste collection containers. Most other designs have a separate anal wash basin however this is unnecessary as both liquid wastes are collected and put to use as liquid nutrients anyway.

The urine/wash basin is 25 cm long by 20cm wide with a slope of about 22° allowing for plenty of capture area and downward wash force. The faecal matter hole is then 20cm in diameter, ample space for all waste to fall through. Surrounding both the faecal waste drop hole and the urine basin is a 7cm wide, 3cm thick rim which will support the pan when it is sitting in the floor of the building. This is wide and thick enough to ensure that people accidentally standing on the pan will not cause it to break or crack and fall through the floor causing injury.

This makes the load bearing capacity of the pan important. It is moulded out of a strong concrete mixture – 1:2:3 (cement: sand: aggregate (<6mm)) with a fairly high flexural strength. The maximum weight the pan can support is estimated at about 160kg, as shown here:

\[
Weight_{max} = \frac{a2bd^2}{3Lg} = \frac{5Nm^2 \times 2 \times 340mm \times (30mm)^2}{3 \times 650mm \times 9.8ms^{-1}} = 160 kg
\]

To increase this capacity bamboo sections are built into the pan, these shoots have a very high flexural strength of their own and as such can increase the load bearing capacity of the pan by up to twofold. It is important to note that the pan has not been designed to be stood on while in use or not. If this does occur however it can be seen that it will easily accommodate the weight of almost any human.
The construction of the pan is very easy. Concrete is laid around a cylindrical pot (solid waste) and a dried cement urine bowl cast within a wooden perimeter to and allowed to cure. This casting can be done by villagers themselves with a small amount of training at a cost of about $1 AUD for the cement, it is also possible however for a local mason to create the pans for a cost of around $14 AUD. This could be a better alternative if pans made by villagers and volunteers are of low quality and the expertise of a mason is required to create a durable product, for a longer lifetime and strength it may be worth the cost. The most expensive part of the project however is not the UD pan but the building of the toilet block itself.

**Part 2: Toilet Block**

The description of the toilet block from the ground up is as follows: A concrete slab forms the foundation of the building. In this slab four upright supports are embedded and stairs and 2 short L shaped walls are built on top of it. Supported by these walls is the floor of the inside of the toilet block, which is a concrete slab, and in the centre of this slab the UD pan is located. Around this floor walls and a door are built onto the supports and above this sits a standard angled roof.

This is the basic toilet block design, a steady structure with concrete foundations and simple privacy and protection features such as walls, a door and a roof. However despite its modest appearance the building has several unique features to its design that make it environmentally sustainable and complementary to the UDDCT operating principles.

The basic dimensions of the building are 2.65m (H)*0.9m (W)*1.5m (L). Four thick bamboo trees are buried in the ground at a depth of 1 metre and cast in a bed of cement, these poles act as the supporting frame for walls and roof. The concrete mix used for the foundation is 1:3:5 (cement: sand: gravel) and is strong enough to support a raised load of 1.2 tonnes and a load of about 5 tonnes on the ground before cracking. On this slab two L shaped walls are constructed which support the toilet room (the significance of this shape will be explained).

From the floor to the ceiling inside the toilet building is 180cm, full standing room for most people, plus an extra 15cm of open roof space (full standing room for even taller people). The room is 90cm across, enough space for the user to crouch down over the pan (which is in the centre of the room) with their knees out and not come into contact with the wall. This also allows the user to move forward while in the crouched position to make use of the wash basin.

The floor of the room is a 10cm thick concrete slab of mix 1:2.5:3, a strong ratio with a high flexural strength. The thickness of the floor slab can be increased if desired, however, it can be shown that the floor is capable of supporting a weight of up to 1.63 tonnes:

\[
Weight_{\text{max}} = \frac{a2bd^2}{3Lg} = \frac{4Nmm^2 \cdot 2 \cdot 900mm \cdot (100mm)^2}{3 \cdot 1500mm \cdot 9.8ms^{-1}} = 1.63\text{ tonnes}
\]
Even if the flexural strength of the slab were halved due to poor manufacturing the floor would still be able to support a weight of up to 800 kg. To be certain however the cement slab is also reinforced with lengths of bamboo effectively doubling its load bearing capacity. In the centre of the floor slab is a rectangular cut out in which the UD pan will sit. This does introduce a point of weakness however the design of the supporting walls has been made to combat this. One side wall extends past the other by about 20 cm shifting the weight of the floor off of this cut out in the centre and onto a solid part of the slab.

These walls extend a height of 75 cm above the foundation. This particular height is used to accommodate for the dimensions of waste capture containers placed inside the walls below the pan in the floor of the building. The solid waste container modelled for use with this building is a 55L bin with a height of 54.5 cm and a diameter of 46.4 cm, large enough to give a small family about one month’s use before it needs emptying. This particular container does not need to be used, anything that does not exceed 75 cm in height and about 60 cm in diameter is fine for use. The container used for urine and wash has been modelled at about 10L. This is mainly because the extended wall that shifts the centre of weight of the floor is on the urine container side leaving an opening of only about 40 cm. Also urine does not need to compost and so can be emptied more frequently. If left for too long (about a week) urine can begin to smell quite strongly because of the large amount of ammonia it contains.

Removal of bad smells in the container chamber is another part of the building designs. The cement floor is held up by two L shaped walls connected to the steps and the rear. In between these walls though is an open space and this creates a path through which air can flow underneath the building which can carry away odours. Wind and sun are an important part of the composting process that the UDDT uses so this wind tunnel design also speeds up the process tremendously. The L shape of the walls also makes for a cheaper design with fewer materials required.

One of the walls is connected with the stairs of the building. There are four steps with a gradient of about 93.75% which is just above the minimum requirement for residential steps in Australia (90%). This slope is a natural result of the height of the floor though, requiring step rises of 18.75 cm and runs of 20 cm.

The rest of the building is built almost entirely out of biological materials. The walls are made out of bamboo which grows abundantly in Tamil Nadu. They are built in sheets using traditional method and then tied onto the bamboo foundation supports using thin strips of bamboo as rope. Dried bamboo is used and expected to have a lifetime of around about 3 years, since the walls are so easy to put up this periodic maintenance will be very easy to do. Atop the walls is the A-frame roof which is made out of thatching, locally collected also. Alternatively halved bamboo sections are used.

This is the toilet block in its entirety. The building has been designed to be both long lasting and sustainable. The base, supporting walls, steps and floor slab are all made from strong concrete mixtures and in reality are the only parts of the building required for it to operate as a UDDC toilet. Given concrete has a lifetime of decades the design will remain functional for potentially generations.
The rest of the building is there for user privacy and protection against the elements. These components; the walls, the door and the roof are all made out of either bamboo or thatching meaning that when they need to be replaced they can be put back into the ecosystem to decompose and new materials from that same ecosystem can be used to replace them. This cradle to cradle materials design means that the toilet systems can work in harmony with the environment and the villagers that live within it.

3.2.2 Education

**Education of the Women**

The older females of the group will be educated on the importance of keeping the germs away from their children and loved ones and an emphasis will be placed on the link between the germs that defecate contains to illnesses that in the past have spread throughout the village. By educating the women of the community they will ensure that their children and partners practice germ from behaviour at home as they have a lot of sway in the running of the house and are the main care givers of the children as their fathers are working. This will reinforce the education system for the children and the men of the village.

**Education of the Children**

Implementation of discovery based unit of education in the current schooling system will take the children on a guided discovery on what are germs?, how they are transferred? and how best to minimise germs and related illness from germs?. The discovery based unit will be interactive and will engage student’s interest in the topic and also give them an opportunity to learn through visual, auditory and kinaesthetic modes of learning. Each lesson will built upon the previous lesson with a constructivist approach where “people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences.”

Concepts such as extrinsic motivation in for form of prizes to encourage the use of the facilities will be included in the unit of work and will assist in the instruction of how to use the toilet that is in place in the schooling facility and also the proper technique for washing hands. Detailed examples of lessons are available in appendix 1.

**Education of the males**

The male of the community are the workers and to ensure constant reminders to them about the importance of keeping defecate off the ground and possibly fatal germs out of the water supply signs have been created that will be posted. These sings will include things such as washing your hands that will be places in common used places such as water taps. These signs can be found in appendixes 2, 3, 4, 5.
4.0 Design Supporting Documents

Ecosan Pan – Side Projection

Ecosan Pan – Top Projection
4.1 Manufacturing Plan

Toilet System

The individual processes used to make the urine diversion pan and the toilet block are fairly simple but the method as a whole is quite a long and detailed procedure. To avoid errors being made during the construction process it is recommended that this manual be read in its entirety before beginning. Some of construction steps outlined here have previously been covered in the detailed design description and relative values for strengths of materials or sections may be located there. As with the design phase of the toilet the construction also occurs in two parts, the urine diversion pan construction and the toilet block construction.

Part 1: Urine Diversion Pan

Materials/Items

- Portland Cement (about 2.0kg)
- Sand (fine – medium grade, about 4.0kg)
- Aggregate (small - <7mm, about 4.5kg)
- Bamboo (<1.0cm Diameter)
- High Gloss Paint (2.00 Litres needed)
- Pot (kitchenware, 20.0cm Diameter)
- PVC Pipe (2.6cm Diameter)
- Pieces of Wood (for framework, no less than 3.00cm wide)
- Sheet of wood or flat solid ground on which the pan can be constructed.

*The weights quoted here will not be the exact quantities required. The densities of the materials used to calculate these values will be different to those used on the day. Also more concrete mix is required than the volume of the UD pan, as some will be lost in the mixing procedure. Widths and dimensions quoted need not be exact, as long as the deviation is no less than the margin of error of the value the final construct will be acceptable.

Method

1. Mix a weak batch of concrete (1:4:5) and use it to form a mould of the shape of the inside of the urine basin (refer to dimensions on technical drawings for inner bowl dimensions and volume). This can be done by digging the shape out in solid ground and pouring the cement into this shape. Make sure that a small section of the 2.63cm diameter PVC pipe is built into the mould where the urine will exit the bowl; it should protrude from the mould by at least 5cm to allow the actual pan to be built around it later. Allow the created mould to cure (1-2 days should be long enough).
2. Cut sections of wood the lengths of the edges of the UD pan, these pieces will be joined together to make the frame in which the pan will be made. Once you have cut the wood you should have: 2 pieces of length 51cm, 2 pieces of length 20cm and 4 pieces of length 9.9cm. Lay these pieces out on the flat construction surface to form the shape of the UD pan. If the work surface is a piece of wood the frame can be secured in its shape by nails in the
sheet, alternatively solid objects can be used to keep them in place. If the frame will still not hold its shape then cut the ends of some of the pieces of wood at angle so that the pieces will sit flush with each other, they can then be secured together using nails, glue or even a piece of string around the outside of the frame.

3. Once the framework has been secured on the work surface place the 20cm diameter pot and the urine basin mould inside the perimeter at their specific locations (refer to the technical drawings for locations). The pot may need to have a weight placed on top of it to prevent it from moving around or seeping concrete under its edge when pouring occurs. The urine basin mould will need to be covered tightly in plastic or powdered to make sure that the high strength pan concrete does not bind to it.

4. Once the pot and the mould are in place the concrete for the pan needs to be mixed. The concrete will use a ratio of 1:2:3, that is 1 part Portland cement to 2 parts sand to 3 parts aggregate. Make sure that when mixing the cement as little water as possible is used so that it is workable but also ensure the mix has been thoroughly hydrated (The final mix must not have too much slump as it needs to be worked up and over the urine diversion bowl mould).

5. Pour the concrete into the framework so that it fills the frame at a depth of just over 1.5cm. Now lay the strips of bamboo longitudinally all around the bed. Where two bamboo pieces come together they should pass each other by 3cm or more, 2 pieces should be laid in all spaces of the cement bed with a minimum distance between each piece of 1.5cm (make sure bamboo is also laid in the area between the pot and to UD pan mould). Now fill the framework to a total height of 3cm, all bamboo should be well covered and the surface of the concrete should be smooth.

6. Around the pot build up the concrete in what will make a small lip (about 2cm high, this will add strength to the faecal matter opening). Next build the concrete up and over the urine diversion pan mould, the cement should cover the mould uniformly at a depth of no less than 3cm. Ensure that the PVC pipe of the mould is not covered over and work the cement appropriately around this also.

7. The concrete should now be left to cure in this state for a period of about 3 weeks, after this time it will have gained 90% of its final strength. While the pan is curing it should be lightly watered on a regular basis (once a day).

8. Once the concrete has cured remove the wooden framework and pot from the pan. Lift the concrete pan, place it on its side and remove the urine diversion basin mould from the concrete (be careful when lifting the mould it could weigh up to 20 kg and at least 2 people should be present to lift it). The hole that remains in the basin part of the pan is where the PVC pipe for the urine bowl needs to be placed. Cut about a metre of 2.63cm diameter PVC pipe and put it inside the hole so that it just sticks through into the urine basin. It may be difficult to fit the pipe inside but it will fit. After it has been fitted into the bowl the edge around it will need to be sealed with a mix of Portland cement and water to make watertight.

9. The urine diversion pan is now nearly complete, all that is left to do is paint the top and sides of the pan with high gloss paint. Two coats of this paint should be applied with a drying time of about 6 hours between each coat.
The urine diversion pan is now ready for use and can be placed inside the toilet building. As mentioned at least 2 people should carry the pan oriented on opposing sides (this will also help to maintain the pans shape and integrity).

Part 2: Toilet Block

Materials/Items

- 4 Thick Bamboo Trunks (10.0cm Diameter, at least 3.75m tall, 4.00m max)
- Portland Cement (about 120.0kg, 5 bags)
- Sand (fine – medium grade, about 450.0kg)
- Aggregate (small - <7mm, about 400.0kg)
- Masonry Blocks (39cm * 19cm *19cm, 44 in total)
- Pieces of Wood (for framework, no less than 10cm wide)
- Bamboo (1.0cm - 3.0cm Diameter)
- Bamboo Strips (1.0cm – 2.0 cm wide, thinly sliced or shaved)
- Sticks (thin, 1.0cm, for roof thatching)

Method

1. Begin by levelling and clearing the construction area, it should be at least 5m * 7m. Measure out a rectangle 1m * 1.4m in the centre of the cleared area and mark each of its corners. At each of these corners dig a hole approximately 1m deep by 0.20m across. These will be the positions of the 4 thick bamboo supports.
2. Use the pieces of timber to construct two rectangular frames of dimensions 1.4m * 1.85m*0.1m and 1m * 0.75m * 0.1m. The first framework should be placed centred around the previously dug bamboo support holes, the second framework should be placed at the front of the centre of the larger framework. These two frameworks then need to be made open to one another so that they are part of the same perimeter (the smaller framework is the base for the stairs). Place the thick bamboo supports in the previously dug holes and support them so they stand directly upright in the centre of each hole (a level may be useful for this part). The bamboo poles should be at least 3.75m high and no taller than 4.00m.
3. Mix a batch of concrete, ratio 1:4:5 (cement: sand: aggregate), it will be required to fill a volume of approximately 0.45 cubic metres (approx. 2.5 bags of cement, 270kg sand, 510kg aggregate). Ensure enough water is added in the mixing process for workability and concrete hydration (the cement is only being used for the foundation and as such exact quantities are not that important).
4. Fill each of the holes in which the bamboo trees are standing with concrete and go on to fill the framework area in to a depth of no less than 10cm. Bamboo sections need to be laid throughout the inside of this bed and should be done so at a practical interval in the pouring process. Allow this bed of concrete to cure for about 3 days.
5. The steps and the walls now need to be built using the masonry blocks and mortar. Begin by mixing the mortar, the ratio is one part cement to three parts sand (about 100L of mortar will be required for to build all the walls and the stairs). Now lay a 2cm thick area of mortar on top of the foundation slab where the rear wall will be located (refer to technical diagram
for specific location). Lay two of the masonry blocks longitudinally next to each other on the mortar and continue to build the block wall, this rear wall will be a total of 2 blocks long by 4 blocks high, all mortar joints will be 2cm thick (the same applies for all of the walls and steps). When the wall is completely built up fill the two end openings of masonry block wall with foundation concrete mix and bamboo uprights (this will give the wall extra strength).

6. Next the side wall closest to the rear wall should be built, it is a total of 2 blocks long and 4 blocks high, and has exactly the same dimensions as the rear wall. The two end openings of the wall should be filled with bamboo and concrete her also.

7. After the rear side wall has been completed the steps need to be constructed, the extended section of the foundation slab was created for these to be built upon (refer to the technical drawings for location). Each masonry block will serve as a step, so the base of the steps will be 4 blocks wide by two blocks across, the next level 3 blocks wide by 2 across, then 2 blocks wide and 2 across and then the final step 1 block wide by 2 across. When building up the steps remember to lay foundation mortar and fill all of the joints to a thickness of 2cm. All of the blocks in the steps should be laid with their openings up except for the blocks that will serve as the actual steps, these should be laid flat side up. The two end openings of the open side up block rows should be filled with foundation concrete and bamboo as was done with the supporting walls.

8. After the steps have been completed the final supporting wall closest to the steps should be constructed. This wall is made out of a stack of 4 blocks and then joined to this stack is two blocks standing upright on top of each other. This gives a total wall length of 39cm + 19cm + 2cm = 60cm. Make sure that as per usual all joins are 2cm thick, also ensure that this wall butts up against the stairs. It will be noticed that the two vertically standing blocks will not quite reach the same height as the 4 block stack so they should be built up with concrete accordingly. The centre most hole of the stack of 4 bricks should be filled with concrete and bamboo. It is important to not disturb the foundation bamboo poles when these walls are being built as the concrete is still curing and will continue to do so for about 3 weeks, also regularly check that the bamboo poles are still standing completely upright.

9. Now the floor slab for the toilet room will be created. A simple wooden framework needs to be constructed to build it, it has dimensions 1.5m * 0.9m. Another smaller wooden frame needs to be created for what will be a hole in the slab that holds the urine diversion pan in place, it has dimensions 0.51m *0.2m. When made this hole will be centred on the width of the slab but not on the length so the positioning of this centre frame should be determined from the technical drawings before commencing construction.

10. Once the frameworks are in the correct positions the concrete should be mixed and poured. The mixture for this slab is 1:2.5:3 (about 30kg of cement, 70kg of sand and 80kg of aggregate). Pour the concrete into the framework at a depth of about 5cm and then place lengths of bamboo in the direction of the length of the slab, about half as many pieces should be laid across the width of the slab. Where two bamboo pieces come together they should pass each other by 3cm or more, pieces of bamboo should be separated by a distance of 2cm or more. Once the bamboo is laid continue to fill in the rest of the framework to a total depth of about 10cm. The slab should be allowed to cure for about 3 weeks, during this time the foundation, wall and step concrete will continue to cure to full strength also.
During this 3 week period the walls and roof frame for the building need to be made. The walls will be rectangular sections of vertical bamboo pieces held together by horizontal supporting beams. Two bamboo walls with dimensions 1.8m * 1.5m need to be made and another two walls of dimension 1.8m * 0.9m (one of these will become a door). At the same time an A frame should be made out of bamboo with base dimensions of 1.5m * 0.9m. The slope and height of the frame should be determined by the villagers according to the methods they used for thatched roofs.

After the 3 week curing period has expired the framework is to be removed from the floor slab and it can be manoeuvred onto the walls of the toilet block building. At least 4 people should do this as the slab needs to be placed centred on the walls and will need to be manoeuvred between bamboo support poles.

Once the floor is in place the walls should be attached to the bamboo uprights. The bottom of the walls will begin at the level of the floor slab. To secure these walls use bamboo strips or sting (they are not load bearing but the tie should be strong and secure to resist wind). The wall facing the steps needs to be fixed as a door and as such it should only be tied on one of its edges so that it can swing open and closed. Care should be taken to ensure the door stays shut, if necessary attach another piece of thin, hinge bamboo that will fulfil this purpose.

Now secure the bamboo A-frame to the top of the thick bamboo supports and cover it with thatching, the front and end of the A-frame can be left uncovered to improve ventilation of the room.

Finally place the urine diversion pan into the hole in the floor slab (the urine bowl should face the stairs) and insert the waste capture containers underneath the floor aligned with their respective urine diversion pan openings.

The urine diversion dehydrating composting toilet is now complete in its entirety. Once again remember that given values and dimensions may not be perfectly achievable in reality and this is ok, as long as the deviations from the values are not too great (margin of error generally). In the end the design as a whole is very strong and is capable of supporting a large amount of weight. With respect to lifetime we can expect concrete parts of the building to last for about 50 years, biological components of the structure are expected to last 5 years (except for the thick bamboo supports than could last anywhere between 5 and 20 years). Building lifetime can be increased by curing the thick bamboo supports of the structure, there exist many traditional methods for doing this and we recommend for one drying out the bamboo for at least 3 weeks before using it.
4.2 Implementation Plan

The project consists of two parts, one part a physical solution to water supply contamination and the other an educational solution. For the best effect both parts need to be functioning at the same time.

The toilet plans need to be delivered and construction completed while the educational mechanisms are introduced in the community. The women's group needs to be instructed first, through them the children can be trained to use the new toilet facilities using specific educational tools. Once the toilet construction is complete the signs can be erected by the same artisans, these signs form the part of the system targeted at the adult men in the community. The 'Toilet Sign' must be placed on the toilet block to identify the object referred to by the other signs that direct users to the toilet. The 'Not here. Use toilet' signs are intended to discourage defecation in the areas near the water supply but instead to use the toilet block. These signs can be printed on any material suitable for mounting throughout the target areas.

Training needs also to be given to those who will support the new facilities. The waste products need to be removed and disposed of in a hygienic manner. Repairs may also need to be done to maintain the environmental safety of the toilets.

After the initial implementation of the two part system some follow up sampling should be done to determine the effectiveness of the project. This would include health monitoring of the villagers and coliform tests on the well water. Information should also be gathered to determine if any parts of the system are being rejected on cultural or religious grounds to avoid distancing the target audience due to misunderstandings.
5.0 Evaluation

5.1 Evaluation Plan

The implementation of a toilet system being complemented with an education in good hygiene practices and proper use of the waste disposal should provide an improvement in the health and wellbeing of the community. The advancement in hygiene practices will see increased use of self-cleaning products such as soap, which will reduce bacteria spreading and causing illness. Encouraging the use of the toilet systems will see the elimination of open defecation which results in pathogens in the water supply being reduced. It is imperative that the correct use of waste management is used as any deviation will slow the success of the project. The hygiene success can be measured through the reduction in open defecation and the increase of Western hygiene practices such as the use of soap.

Sustainability is essential in the success of any project. Allowing the project to be carried out with a sight to environmental, social and economic responsibility will the see the design provide the largest benefit to the community. The access to money for the project and ongoing costs mean that it must be used with restriction. As the village relies on the land for income and food, it is vital that it is not harmed in the construction of the toilets and ongoing maintenance. The design must be accepted and utilised by the residents to achieve the ideal results. This will be measured by how easily the project is installed, the use of the system by the community and the little impact that it has on the surrounding environment.

The use of education and toilet systems will see an increase in water quality provided that the design remains functional for an extended period of time. It is imperative that habits instilled upon the community are still intact and as they are the key for allowing the design to take its course. Constant encouragement of the correct hygiene practices will see further and faster improvements in the water quality and this will provide the visible results that the residents will appreciate. The implementation will see long term improvements but at a relatively slow rate, therefore maintaining the longevity of the systems will be the measure of how fruitful it is.

Certain standards must be met to allow the project to be accepted by the community. Beliefs among the residents will alter how it will be implemented and used. The society has a preference to avoid reuse of human waste in agriculture and this alters how it must be disposed of. Instead of being able to utilise the waste in a way that is beneficial, the waste must be eradicated in a way that prevents it from contaminating the water supply. Adhering to these beliefs and values will encourage the villagers the use the design and deliver a successful result. The measure will be how well the design is accepted by the community and how comprehensively they use it.

Ultimately the aim of the project is to improve the quality of the water and to do this the waste management solutions must be implemented. The toilets provide a means to eradicating the faeces that run off into the water supply which increase the pathogens present. By preventing this, the water quality will improve and the hygiene habits will complement this action. The progress in the water quality will be measured by the reduction of the pathogens in the supply, the decreased amount of disease present and also the improvement of taste of the water.
5.2 Evaluation Results

Without any formal testing performed on the education systems and toilets the success cannot be completely predicted. However, similar applications of toilets have been successful in surrounding areas. Provided that certain parameters are installed, the functionality of the toilets will be highly beneficially firstly to the water quality and also the smell in the area due to the open defecation. Educating the community in the correct practice of using and maintaining the toilets will permit the ideal result to unfold.

Education of common Western hygiene practices will gift the residents the ability to improve their own health and recognise the benefits through their own work. This system is backed up by the World Health Organisation as an ideal means to solving issues arisen by poor hygiene. Despite no testing completed, there is enough evidence provided by surrounding villages and recognisable organisations to be confident in the success of the solution.
6.0 Evaluation Supporting Documents

6.1 Cost Analysis

6.1.1 Toilet System

The following table provides the cost and relative unit sizes of materials that may be used in the construction of the urine diversion dehydrating composting toilet:

<table>
<thead>
<tr>
<th>Material/Item</th>
<th>Cost</th>
<th>Dimensions/Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland Cement</td>
<td>$0.3 kg⁻¹, $451.80 m⁻³</td>
<td>25kg, 1506kg.m⁻³</td>
</tr>
<tr>
<td>Lime</td>
<td>$0.65 kg⁻¹, $312.65 m⁻³</td>
<td>20kg, 481kg.m⁻³</td>
</tr>
<tr>
<td>Sand (local)</td>
<td>$50 tonne⁻¹/Free</td>
<td>1602 kg.m⁻³</td>
</tr>
<tr>
<td>Aggregate (Local)</td>
<td>$21 tonne⁻¹/Free</td>
<td>1650 kg.m⁻³ (in mix)</td>
</tr>
<tr>
<td>Masonry Blocks</td>
<td>$3.35 ea.</td>
<td>39cm * 19cm * 19cm</td>
</tr>
<tr>
<td>Roofing, Recycled (corrugated iron)</td>
<td>$4.44 m⁻², $4.00 m⁻²</td>
<td>1m * 0.9m</td>
</tr>
<tr>
<td>Roofing, New (corrugated iron)</td>
<td>$15.09 m⁻², $11.50 m⁻²</td>
<td>1m * 0.75m</td>
</tr>
<tr>
<td>Roofing (thatched)</td>
<td>Free</td>
<td>-</td>
</tr>
<tr>
<td>Bamboo (local)</td>
<td>Free</td>
<td>-</td>
</tr>
<tr>
<td>Pine (flooring)</td>
<td>$25.67 m⁻², $2.31 m⁻³</td>
<td>1m * 0.09m * 0.021m</td>
</tr>
<tr>
<td>Treated Pine Sleeper (Flooring)</td>
<td>$18.42</td>
<td>3m(L) * 0.2m(W) * 0.05m(D)</td>
</tr>
<tr>
<td>Slab (Support - log, Treated Pine)</td>
<td>$14.70</td>
<td>2.4m (L) * 100/112mm (D)</td>
</tr>
<tr>
<td>Paint (High Gloss)</td>
<td>$15 L⁻¹</td>
<td>1 L</td>
</tr>
<tr>
<td>73 L Plastic Bin (new)</td>
<td>$24.00 ea.</td>
<td>0.604m(H) * 0.504m(D)</td>
</tr>
<tr>
<td>44 Gallon (200L) Drum (new)</td>
<td>$15.00 ea.</td>
<td>0.851m(H) * 0.572m(D)</td>
</tr>
<tr>
<td>44 Gallon (200L) Drum (used)</td>
<td>$10.00 ea. / Free</td>
<td>0.851m(H) * 0.572m(D)</td>
</tr>
</tbody>
</table>

Figure 8: Cost Analysis for Toilet System

Based on the design presented in the design detail and manufacturing process sections of this report the following table of costs was produced and the relative total materials expenditure for the project given (note that for the final design not all materials from the above table were used only those selected for the final design).
Table: Material/Item Cost Weight/No. No. Complete Units Total Cost

<table>
<thead>
<tr>
<th>Material/Item</th>
<th>Cost</th>
<th>Weight/No.</th>
<th>No. Complete Units</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>$0.30</td>
<td>125</td>
<td>5</td>
<td>$37.50</td>
</tr>
<tr>
<td>Sand</td>
<td>$50</td>
<td>450</td>
<td>1/2 tonne</td>
<td>$25</td>
</tr>
<tr>
<td>Aggregate</td>
<td>$21</td>
<td>400</td>
<td>1/2 tonne</td>
<td>$10.5</td>
</tr>
<tr>
<td>Masonry Blocks</td>
<td>$3.35</td>
<td>44</td>
<td>44</td>
<td>$147.40</td>
</tr>
<tr>
<td>Wood (framework)</td>
<td>$2.00</td>
<td>18</td>
<td>18</td>
<td>$36.00</td>
</tr>
<tr>
<td>Paint</td>
<td>$15</td>
<td>2</td>
<td>2</td>
<td>$30</td>
</tr>
<tr>
<td>PVC Pipe</td>
<td>$2.50</td>
<td>1</td>
<td>1</td>
<td>$2.50</td>
</tr>
<tr>
<td>Bamboo</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thatching</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Figure 9: Cost Analysis for Toilet Block Construction**

This table gives a forecasted materials cost of $288.90. This price does not include transport of materials or labour, these are assumed to come at no cost and whether this will remain the case at the time of project implementation is subject to site analysis and review by those who wish to use these designs.

It is important to note that the prices used for this cost analysis are from Australian companies and as such this document should be used as a guideline only. The costs of these materials in India are proposed to be much lower and therefore the costing information given here could be used as a worst case/highest cost limit for materials.

### 6.1.2 Education

The costs affiliated with the education program are relatively low, the major costs coming from the signs. A single sided aluminium sign that can be attached to buildings and trees are available online and can be shipped to Devikulam. The signs are 0.813mm x 300mm x 300m with the artwork printed on one side. The cost to supply 20 signs is $440 AUD, not including the shipping of the goods to the village. The price is quoted from www.signus.com and is relevant to the 27th of September 2011.

To provide the village with enough soap to be of use during the education process and the continuation of the new practices will be available from [http://yzcentury.en.alibaba.com](http://yzcentury.en.alibaba.com). They can provide 50,000 pieces of scented soap for $0.12 AUD per bar, however if the order is required to be smaller they can accommodate. The quote given was relevant to the 27th of September 2011 and the price may change by the time the order is made.

### 6.1.3 Funding

When considering solutions for a given project the most influential factor governing final products is cost. The EWB Project has limited options in the way of funding and none of them exist with any certainty that they will be available to us. Even though this is the case, there are realistic sources of funding in the form of grants, donations and contributions that may be accessible as income, these are:

1. Contributions from the villagers
2. Donations from business
3. Government funding
Each option has its own requirements and it largely depends on the type and scale of the solution needing funding as to whether it is suitable.

**Government and Donations**

Government grants and donations from business generally fall under the same category because of the criteria which make them suitable funding options. Government and business grants can vary widely in value depending on the type although for most projects of this nature they are around $10,000 AUD. Government grants are far and few and accessing one is very difficult. That is because there are many applicants and few grants, so applicants can expect not to win the grant 99% of the time.

Business donations present the same problem. Usually a donation is only considered if it is relevant or large enough for the company to take interest. Small scale projects are generally not considered by government and business as they do not constitute large scale improvements that will have a major impact on the issues being addressed. However many smaller projects can still be bundled together to form a scheme and could become eligible for these grants.

Given the unlikely nature of receiving funding from government or business solutions should not be created based on the premise that this money will be received as realistically it will probably not become available. Instead it is more reasonable to consider funds that might be available from willing local sources such as the beneficiaries of the project.

**Villager Contributions**

Potentially, the most reliable source of funding will come from the villagers themselves. Only a small amount would be available but it will be steady and allow the implementation of projects to occur on a week by week or fortnightly basis. For projects that require a large amount of capital immediately for equipment, large infrastructure, technology etc. this option will not be suitable and the project may have to be put on hold to accumulate funds over time or to seek capital elsewhere.

Shown below is the total and average income per household in the village. Also included are contribution amounts that would become available if a villager contribution scheme were an option.

<table>
<thead>
<tr>
<th>Villager Contributions (AUD; Exchange Rate: 0.020408):</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time Period</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Yearly</td>
</tr>
<tr>
<td>Monthly</td>
</tr>
<tr>
<td>Weekly</td>
</tr>
</tbody>
</table>

**Figure 10: Village Financial Contribution**

Realistically most people would probably be open to a proposal of 1% of total household income per week which is about 5 rupees or less depending on the household. Amounts above this are probably infeasible as people would feel like they are giving up money that could be used to purchase food etc.
At 1% of household income ($7.50 AUD per week) there would be enough income to benefit some smaller scale projects i.e. $7.50 AUD is enough to buy one 20kg bag of Portland cement. Larger projects may need more than this and could appeal for larger contributions over a smaller period of time. If the project has a lot of interest from the community then it may be possible to secure these larger contributions.

**Conclusion**

For this project there is clearly little certainty regarding available funding, capital etc. As such it is necessary to develop the project within the set framework *realistically*. This means consideration should be given to what the cost of implementing a solution will be and how realistic that price is i.e. Projects requiring funds in the thousands are much less likely to be successful than a project requiring about $1000 or less.

With this in mind the advice and information included in this document can be used as a guide for what funds could become available for projects. It is important to remember though that the sources of these funds have not agreed to these proposals and it is not known if this will be the case. Therefore the information presented should be used based upon one’s own personal judgement with respect to the context in which it is to be applied.
### 6.2 Risk Assessment

<table>
<thead>
<tr>
<th>Risk</th>
<th>Safety Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Education Phase</strong></td>
<td></td>
</tr>
<tr>
<td>Soap solution in eyes while washing hands</td>
<td>Rinse hands thoroughly and use water to wash soap out of eyes</td>
</tr>
<tr>
<td>Cuts from the signs</td>
<td>Where gloves while using the sign, be aware of the sharp edges on the metal</td>
</tr>
<tr>
<td><strong>Construction Phase</strong></td>
<td></td>
</tr>
<tr>
<td>Working with tools in harvest process and construction</td>
<td>Make sure training in equipment use is implemented. Ensure only skilled people are around the hazards, and be aware of the apparent risks</td>
</tr>
<tr>
<td>Splinters and cuts due sharp edges and timber</td>
<td>Wear gloves whilst working with wood and other objects that could give cuts</td>
</tr>
<tr>
<td>Cement mortar</td>
<td>Gloves must be worn to avoid direct contact of cement to the skin, worker must be skilled in cement use</td>
</tr>
<tr>
<td>Heavy lifting</td>
<td>Ensure that any load has the correct number of people to lift and that correct posture is used</td>
</tr>
<tr>
<td><strong>Use Phase</strong></td>
<td></td>
</tr>
<tr>
<td>Contamination due to exposure to biological waste while removing from toilet</td>
<td>The removal of waste must be done in a designated area and the disposer must be shown the way to remove it correctly</td>
</tr>
<tr>
<td>Contamination due to misuse of toilet system</td>
<td>Confirm that the education provided on correct toilet use is implemented and that the waste is disposed regularly</td>
</tr>
</tbody>
</table>

*Figure 11: Risk Assessment*
Conclusion

With changes needed to further develop the village, a sustainable design is desperately required to improve the sanitation. Identifying the best means to improving the hygiene habits apparent in the community will not only decrease the prevalence of the disease and bacteria but also escalate the quality of life for the villagers themselves. By implementing an educational program combined with a technical application of a toilet system, the residents will gain a sustainable way to grow and develop the village.

The educational program will teach the children the importance of hygiene and emphasize how easily the bacteria can spread. By demonstrating the need to keep clean to the children will also encourage the parents and elders to act in the same vain. Activities using paint, glitter and song will allow the children to make the connection between hygiene and enjoyment which will act as a motivator to continue the new practices. By stressing the importance of setting an example to the parents will further demonstrate how easily and vital the application is. Reinforcement and constant reminders through visual aids will ensure that the children will uphold the new principles in force.

The costs affiliated with the program are very low, requiring only small revenue to cover the costs of soap, paint and the like. Maintaining access to soap, water and toilets is a necessity in breaking old habits and developing the new ones. However if the practices can be maintain and become the consistent then they health and hygiene of the community will benefit immensely.

The toilet system will reduce the need for open defecation and hopefully in the future to eradicate it. The need to prevent this stems from the fact that the faeces are washed off during rain and enter the water supply, tainting it. The toilet system encourages the correct practices for removing the faeces and burying it. This implementation will reduce the smell caused by the faeces improve the quality of the village. The removal of the waste will gradually improve the quality of the water and the hygiene of the village. Ensuring the correct use and maintenance of the toilets is vital in guaranteeing the success of the project.

The costs required to set up and maintain the toilets is far more expensive than the education program, however used together they provide a benefit that is worth far more than it costs. The use of local resources for construction and labour mean that the some of the costs can be covered. All this can be completed with little impact to the capital raised.

With improvements required to the sanitation within the village the use of education and toilets provide a sustainable and long term fix to the problem. The use of them in conjunction will allow education of the use of the toilets to be combined with the general hygiene education. By encouraging the changes in the community the villagers will benefit immensely from the improved sanitation.

Ultimately, the design provides a solution that is hugely beneficial to the requirements of the task whilst being sustainable in nature. There are limited costs affiliated, only small impacts to the environment and provide huge advantages to the community. With this design in place, the community will grow and develop as a result of the improved hygiene and sanitation practices.
Appendix

Appendix 1

Activities for the students

The Glitter Challenge

This activity will highlight the need for the children to not only wash their hands but also how that if they cannot use a toilet that they should defecate in a hole and bury it to minimise the risk of transferral of germs.

Put a little glitter on some students’ hands. Have those students shake hands with other students, who should then shake hands with other students, and so on. After everyone has shaken hands with at least three people, ask your students if they have glitter on them. Discuss how shaking hands can spread germs and brainstorm ways to avoid germs and the spread of germs.

The glitter also presents a challenge to wash off, just like regular germs. Start with a paper towel to wipe away the glitter. The kids will notice that some of the glitter remains on their hands. Washing with cold water and no soap gets a few more of the glitter germs off, but washing with warm water and soap will yield the best results. Help the kids relate the activity to the importance of washing hands for germ removal.

Repeat the activity, only this time have the students whose hands have glitter wash their hands before they shake hands with other students. Does your class notice a difference?

The sweet sound of washing hands

Singing a song as the child washes their hands teaches them how long to wash for. The following song should be sung twice to reach the 20 second marks. Singing a round of the ABCs also serves as a rough timer for washing hands. Choose a song that your child enjoys, as long as it takes at least 20 seconds to sing.

\[
\text{Little Peter Rabbit had a germ upon his hands} \\
\text{Little Peter Rabbit had a germ upon his hands} \\
\text{So he rubbed and he scrubbed and the germ washed away!}
\]

Hand washing chart

A Hand washing chart serves as a reminder to kids for washing their hands it can also be used as a tool of positive reinforcement. The chart can be placed in the classroom and once a child has received an allotted number of ticks for correct times to wash their hands then they will be given a prize for their great effort in keeping germ free. The prize will be a bar of soap that they can then take home and use. The chart should contain columns for each of the occasions on when they are recommended to wash their hands (such as after handling food, after going to the bathroom, before and after caring for someone who is sick, after handling garbage or pet waste, and after coughing, sneezing or blowing your nose).
Brighten up the classroom

Using paint cover the Child’s entire hands and have them press out any many hand prints as possible on a piece of paper and illustrate how stubborn germs are at staying on their hands. These can then be signed by the students and put up around the classroom to brighten it up.

Activities for the Teacher

- Placing hand washing chart on the wall and also having visual aids on correct hand washing technique around the classroom will assist the children in having clean hands.

- Be a positive role model for the students so each time you come back from a lunch break ensure your hands are washed and basically just model what you want the children to learn about washing hands and keeping germs away.

- Ensure that all students have access to soap, running water, and a toilet

- A chart for each time the child used the toilet instead of just going on the ground could be put in place with a prize for each time the student reaches a given number.

- Never use put downs always reinforce positive behaviour of the students (so no “Johnny didn’t use the toilet today and didn’t even bother to cover it up” but lots of “wow that’s great Sally you have used the toilet 7 times this week and have earned yourself a prize”)

- Use any previous knowledge the children may have of germs or anything simular in their day to day lives and link it to this new concept and information so they can make the links easier.
Appendix 2: Education Sign

Now wash your hands
Appendix 3: Education Sign
Not Here. Use Toilet

Appendix 4: Education Sign

Appendix 5: Education Sign
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