EWB Challenge 2011

Devikulam

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Team B1
Executive Summary

Daily, the people of Devikulam face a fundamental problem: how do we deal with human waste? Open defecation causes communicable diseases to spread rapidly, mainly bacterial induced diarrhoea. The aim is to treat human waste onsite, at people’s homes, without centralised infrastructure or large volumes of water. A variety of EcoSan systems are being trialled and used throughout the developing world but current designs are failing to dehydrate and decompose faeces in good time.

Given the urgent need for sanitation solutions, the team considers that an electric technology would be appropriate, especially since on-site solar electricity technologies are also improving rapidly and becoming affordable. This design would be offered to the community along with training, a demonstration model, community mobilisation using the Community-Led Total Sanitation approach, a community education programme in hygiene and latrine use, and a marketing programme involving an influential Indian person.

The Electric Boosted Urine Diversion Dehydration Latrine dehydrates faster and kills pathogens more quickly through the use of a low power electric heating element. The core system is based upon existing Urine Diversion Dehydration Latrine (UDDL) designs - notably the EcoSan. A regular UDDL comprises of two elevated brick chambers built side by side with squatting toilets built upon them. A urine diversion system built into the toilet pan removes as much urine as possible from the system. Only one chamber of the two is active at any given time into which faeces is deposited. The faeces is stored in the brick chamber underneath and ash or saw dust is added to slowly dehydrate the faeces. This takes 6 to 18 months depending on the climate.

This design uses only a single brick chamber but with a brick divider in the centre, with under floor heating produced by a simple resistive nichrome wire circuit. This circuit is hooked up to mains power and delivers a constant amount of thermal energy and therefore the heating element will always be above ambient temperature. The system has a large thermal mass (bricks and slab) and a high heat capacity. The heated floor heats the faecal matter which in turn heats the air mass above the faecal matter. This changes the relative humidity of the environment allowing the warm air to hold more
moisture. The warm air is vented passively through a large diameter vent in the ceiling. Cool dry air is passively drawn in through vents placed near the floor in the door. The vent has the added effect of a constantly moving air body over the faecal matter, helping remove moisture.

The heating circuit is simple, low cost, virtually maintenance free, lasts a very long time and is safe. They are tried and tested (similar to those used in an electric blanket). The design only draws a relatively low wattage. Power failures, even extended ones, are only a small setback with the system being able to withstand a long period without power at which time it acts as a regular UDDL.

Fully dehydrated faeces has minimal bacterial, viral or fungal pathogens present. The volume of the faeces is reduced by dehydration, making disposal easy. The system involves burial of the dehydrated matter in a specific plot reserved for this purpose. This only needs to be done every three to six months.

The dual function toilet pan diverts urine through a secondary system. Urine is piped into a small garden plot that contains multiple high nitrogen dependent trees. These should be any variety of citrus tree depending on availability. The fruit from these trees does not need to be harvested but given time it is expected that the people will become accustomed to the trees and start harvesting the crops.

Cost and environmental considerations come into play in this design. The unit as a whole will require a small investment. Electricity is currently provided free of charge but this may change in the future in which case the municipal government or community would need to pay for it. The use of electricity presents a small environmental concern since the sourcing of the electricity may be from a non-renewable energy source. This is justified by the overriding and urgently needed health benefits this design can give to the community. The systems would be paid for by households as a private investment in their own health and lifestyle, motivated by community education and marketing. A small industry will grow as a result of training, community demand, and supply networks for materials. The aim is to provide an improved latrine technology, to market toilets as modern and desirable, and to ensure they are available and profitable as a commercial item.
Team Reflection

Our team of six entered the EWB Challenge bright-eyed and bushy-tailed, ready to change the world. We were vastly underestimating the complexities of the challenge. Our overambitious approach wasted valuable time with us considering a project that was out of the realm of possible. This led to a grand false start to the project, although, it wasn’t our largest obstacle.

Our largest obstacle was a lack of effective team communication. While we all worked well together, we were not working as a team. Our goal, while united, was not being pursued actively with everyone deferring to the ambiguous “group entity” that would surely get the work done. We under-researched previous challenge winners - excluding a valuable resource. We didn’t ask enough questions of our teachers - excluding a wealth of knowledge.

After acknowledging our false start we started with new enthusiasm from the point where we should have started at day one, only now with a greatly reduced time to complete our work. We acknowledged that without meeting and working as a team we were just a group of like minded individuals - blind to the work of our colleagues. We elected a temporary leader to focus our work over the remaining weeks to ensure that no time was wasted, that everyone was doing a part that helped the whole, and that our work was accounted for.

The challenge has brought us enjoyment in knowing that we can engineer something that would benefit someone else without the means to otherwise do it. This has a follow on benefit that we are more interested in helping others with a tangible outcome, rather than simply achieving high grades. To know that if we apply ourselves in the right way we can not only work well together, but work as a team, is a great boost to our future selves.

If we were to do it over again, we would try to gain an understanding of the scope and context in the first week, and conduct extensive research into the EWB project including the suggested outline and the work of past winners. We would find out exactly what was the expected outcome, and spend a lot more time all the way along. Being
provided with a small budget or a cache of materials to build a prototype would be immensely helpful.

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1 Problem Definition

1.1 Problem Scope

The people of Devikulam practice open defecation, as is the traditional and common practice in rural India. This endangers the health of the entire population for two main reasons. The first is that disease is spread rapidly via contamination of feet, hands, food, and utensils. The second is that fecal matter leaches into groundwater and surface water, and this water is used in drinking and cooking. Samples of Devikulam’s tap water in 2010 showed 124 to 504 coliforms per 100ml (with 12 to 184 being E coli). Disease spread by fecal matter include gastroenteritis, cholera, dysentery, typhoid fever, and hepatitis A. These can be deadly particularly to small children, elderly people, and women (Dror, van Putten-Rademaker & Koren, 2009).

Also, sanitation is an investment in people’s financial wellbeing (Willetts, Wicken & Robinson, 2009). Children and particularly teenage girls do not go to school if toilets and safe water are not available there. Productivity is increased with clean water and women have a safe environment for child-rearing and food production.

This is a multi-faceted problem and this solution addresses two aspects of the problem. First, how can residents of Devikulam effectively deal with human excrement? Second, how can the construction of latrines be promoted? Using a simple design with local resources, this design offers a sustainable solution to that question.

1.2 Technical Review

1.2.1 Background information

1.2.1.1 Sanitation Interventions: Systematic reviews have found that sanitation interventions reduce diarrhoea risk by about 36% (Cairncross, Hunt, Boisson et al, 2010). Interventions for critical at-risk populations MUST be low-cost, simple and locally acceptable (Rheingans, Dreibelbis & Freeman, 2006) and must include an educational element, particularly with regard to handwashing which reduces the risk of diarrhoea by 48% according to reviews (Cairncross, Hunt, Boisson et al, 2010).
1.2.1.2 Population data: The population of Devikulam is 358, with 86 families spread across the village. A household ranges from four to seven people.

Devikulam Village’s occupational web is fairly small, being mainly an agricultural village. The workers are farmers and farm-assisting laborers. In order to help with the expanding of Devikulam Village’s occupational web, the system design needs to be simple. In order for job opportunities to be provided, four elements need to be considered: the existing knowledge of the people, the aspects of the system that will allow the people to get involved, the amount of people that can work/assist with the system construction, and the amount of time required to educate the villagers to perform jobs.

1.2.1.3 Health data: Diarrhoea is rapidly spread by open defecation and is an enduring threat to life and health in India, according to an editorial in the Indian Journal of Medical Research (Deb, Kanungo, Nair & Narain, 2011). Of 1.83 million child deaths each year, 13 per cent are caused by diarrhoea. This has not changed very much since the 1990s. Diarrhoea also occurs in severe outbreaks, and is associated with under-development, poverty, and an inadequate health system. Adequate sanitation is one of the interventions required to address the problem of diarrhoea. But it is a complex web of pathways that spread diarrhoea and other water-borne diseases. This is why any approach must be multi-faceted, including education, resources, and infrastructure (see Appendix A).

Apart from diarrhoea, at least three other diseases are spread by open defecation. Parry-Jones and Kolsky (2005) describe them and how they are transmitted. (1) Intestinal worms are parasites that can lead to malnutrition, anaemia, retarded growth and compromised cognitive abilities. They are spread by contamination of environment with faeces containing parasite eggs, which are transmitted to a new host via ingestion of soil or uncooked vegetables. (2) Trachoma is the leading cause of preventable blindness worldwide. Flies act as vectors for the infection, and they breed in scattered human faeces. (3) Schistosomiasis causes anaemia, impaired growth, poor cognition, substandard school performance, potentially bladder cancer, and serious liver, kidney or spleen complications. Parasites enter surface water through faeces and urine, develop in a freshwater snail for a short time, then infect new human hosts.
Women, the elderly, and children under five are most vulnerable to water-borne illness. However, the strongest predictors of illness are household type, income, education, and size of family (Dror, Putten-Rademaker & Koren, 2009).

1.2.1.4 Local practices: No data is available to report on the practice of open defecation in Devikulam, but data from another rural southern region was published recently. Banda and colleagues (2007) conducted a survey in rural southern India to investigate defecation practices, water handling, and sanitation. Barren land and fields around the outside of the village were used, and water from irrigation pumps were used for cleaning. Usually people went alone to defecate, although children went with women in the early morning. Children also tended to defecate in public places in the village, and their mothers cleaned up after them later in the day. Respondents to this survey said that open defecation was an age-old custom and tradition with no stigma. They did not want to accumulate human waste near their houses. For some it was a social outing; for others, they could not afford to build a toilet and did not want to maintain one, so open defecation was the remaining option. Some felt that water scarcity precluded the building of toilets. Most did not believe that open defecation was associated with diarrhoea, and some thought it was hygienic because the sun treated the feces over time.

1.2.1.5 Existing infrastructure: Devikulam covers a small surface area of land compared to the country of Tamil Nadu and has a simple network of sealed roads in the village. Due to the relatively small area of the village, the households run parallel with the sealed roads; and are predominately within a fixed distance of fifty metres of the sealed roads.

The people of Devikulam generally do not have toilets; they practice open defecation. Jack Sim, founder of the World Toilet Organization, says that the main reason so many people are without toilets is because they do not see a need for one, not simply because they cannot afford one (World Health Organization, 2010). It is believed by some in the World Health Organization that free toilets will not be used, and only toilets that are wanted and built by the community themselves will be used.

1.2.1.6 Sacred symbols and objects: To the people of Devikulam and in fact India as a whole, animals are revered as sacred objects are not to be harmed in any
This ethical stance is born of the dominant religion of Hinduism that Devikulam/ India follows. As a result of this universal view in the Hindu community, many Indians are vegetarian. This view of preservation is in close connection with sacred symbols that are worshipped by Hindus. Some of these symbols include the rooster and the cow. The cow represents the ever-providing Earth and is allowed to roam free over villages and towns and the rooster represents wisdom.

Particularly in Devikulam, many people are in possession of domesticated livestock such as cows and roosters. In considering the sacred element of the livestock, elements of the design will need to be addressed, for example whether the position of the project is suitable, whether containment of the worksite will be required, and whether any measures will be incorporated to allow animals to coexist at project sites.

1.2.2 Geographical and meteorological considerations:

1.2.2.1 Climate data:

The village of Devikulam, in Tamil Nadu, is situated near the east coast of India. In this location, the climate the region experiences is the Tropical Dry and Wet.

This climate produces a dry period over the winter and into the early summer. In terms of temperature, in winter an average of 18°C is expected. In contrast, the summer temperature is reaches 46°C (refer to Appendix B).

In the country of Tamil Nadu, the main time period of rainfall is from October to December, as this is the region’s Monsoon season. This season brings about over half of the annual precipitation of Tamil Nadu. The average rainfall for Devikulam is between 80cm -100cm (refer to Appendix B).

It is crucial to take climate and rainfall into account when developing water storage or septic tank type solutions. This will influence the timing of construction, the distance above sea level of any structure, the material of piping to withstand extremities in temperature, and other factors.

1.2.2.2 Topography:

The elevation of the Devikulam village is relatively flat, being only approximately between sea level to 150m above sea level (refer to Appendix C).
1.2.2.3 Natural vegetation:

The east coast region of India is a tropic dry deciduous zone (Maps of India) and Devikulam is situated in this zone. In this region is the Pitchandikulam forest and also in Devikulam’s region are coconut trees, which combined with the forest prove to be a fluctuating mass of vegetation. Particularly around the village, vegetation is thick and concentrated.

1.2.2.4 Soil analysis:

India features a diverse range of soil types, all of which have different characteristics that influence drainage of water and absorption rates of water. In the Devikulam village area, the common soil type is alluvial (refer to Appendix D).

Alluvial soil consists of a range of sands, silts and clays; and has small grain sizes (The Free Dictionary). The silts and clays absorb water and the high fertility of the soil allows crops to grow. However, clay doesn’t allow water to transmit through it easily (Post, 2011), which could lead to flooding of the area in the event of a massive storm or downpour.

1.2.2.5 Aquifers and groundwater zones:

Aquifers are rock structures or soil structures that can hold and transmit large quantities of water. These systems which circulate and hold water are used by the Indian people; and in particular the people in Devikulam, for water consumption. When water is taken from these water accumulations, the amount held in the aquifer recedes. These aquifers however also are recharged (water restored) annually, by the rivers, lakes and more predominantly the rainfall. In Devikulam’s region the aquifer/groundwater recharge amount is approximately between 20mm -100mm annually (refer to Appendix E).

1.2.2.6 Water quality:

Three samples of Devikulam’s tap water from 2010 are available for consideration. They show 124 to 504 coliforms per 100ml (with 12 to 184 being E coli). The Australian Drinking Water Guidelines require zero coliforms to be present in drinking water (National Health and Medical Research Council, 2004). This suggests strongly that the
groundwater is being contaminated by human and/or animal faecal matter, and is a reason to take urgent action.

**1.2.3 Prior information relevant to the problem.**

The prevention of communicable disease is complex, with several social and cultural elements involved, and human behaviour is a critical factor. Infrastructure or technology alone cannot solve problems of hygiene and health, as Deodhar (2003) explains. But improvements in each element of the problem can make a difference. Interventions that improve water quality, sanitation, and hygiene are very effective in preventing diarrhoeal disease and other communicable illnesses (Cairncross, Hunt, Boisson et al, 2010). Any such interventions have a good cost-benefit ratio, even if not part of combined schemes involving water, sanitation and hygiene (Fewtrell, Kaufmann, Kay et al, 2005). But all these technologies can be improved with regard to both effectiveness and cost. The task for engineers is to continue innovation and work with other professionals to achieve their goals. Creativity is needed to find a range of solutions for poor communities all over the world which can be adopted by the private sector, generating new sources of income as well as saving lives through sanitation. For example, the Cambodian Department of Rural Health sponsors an annual latrine competition with a national prize. The best latrines (most innovative and cost-effective) go into a catalogue of low-cost latrine designs to spread ideas (Willetts, Wickens & Robinson, 2009). Notably in this case, the ideas come from the local people rather than the developed world.

**1.2.3.1 Onsite treatment**

On-site treatment is viewed as the ideal way to deal with human waste, particularly in the context of rapid population growth and urbanisation, and water shortages. EcoSan (ecological sanitation) has been presented and developed as an alternative for several years (Lamichhane, 2007). The costs of such technologies are very low compared with modern wastewater treatment plants, and the biggest cost avoided is the construction and management of central large-scale infrastructure (Green & Ho, 2005). Green and Ho (2005) describe seventy technologies available in 2005.
The key to the success of dry latrines is that the products must be completely sanitised. If not, there are risks associated with emptying and maintaining the pathogen-ridden latrines, as found in Vietnam by Plan International (Willets, Wicken & Robinson, 2009).

In rural Panama, urine-diverting composting latrines still contained pathogens after six months, despite having the ideal pH and having sawdust and wood ash added to lower moisture levels and provide carbon for decomposition. The main finding was that compost latrines tend to fail to reach the temperatures needed to destroy pathogens. (Mehl, Kaiser, Hurtado et al, 2010). These authors suggest that composting have conflicting goals: destruction of pathogens versus aerobic composition.

The South African Government in 2008 was working to improve sanitation by building and improving pit latrines (sometimes called VIPs) as a basic minimum requirement. The pit latrine and urine diversion technologies are presenting many technical challenges; systems are filling up faster than expected, faeces is not breaking down at optimum rates, and humid conditions are problematic despite the use of drying agents, according to Bhagwan, Still, Buckley and Foxon (2008). They provide a discussion of these issues and the impact of the challenges on the Millennium Development Goals for sanitation.

Regmi (2005) reports on dry toilets in Nepal, one using the sun’s rays and another without sunlight, with respect to destruction of faecal coliform. This paper describes the cost savings and water saving in an urban area in Nepal.

### 1.2.3.2 Offsite treatment

The use of water to deal with human waste is a major problem all over the world (Willetts, Wicken & Robinson, 2009). Even in developed countries where public health is at a very high standard, it is an inefficient system. “Flush and discharge” systems “mixes comparatively small quantities of potentially harmful substances with large amounts of water and the magnitude of the problem is multiplied” (Langergraber & Muellegger, 2005). In poor countries this technique contaminates water tables, rivers and lakes.
1.2.3.3 Public versus private facilities

Communal facilities are an improvement on open defecation but they present new problems, according to research by Biran, Jenkins, Dabrse and Bhagwat (2011). Men and boys were twice as likely to use communal latrines than women and girls. Almost all users only used the communal toilets for defecation. The latrines became more highly used as time went on. Communal latrines were little used for infants’ or young children’s defecation, leaving plenty of faeces to contaminate the environment. People were more likely to use latrines if they were closer, if the latrines were clean, if the cost was low, and if the latrines had been there longer. Restricted opening hours were a problem. These authors suggest that a free trial is a necessary step towards increasing communal latrine usage. Poorer households, and homes with more young children, were less likely to use the latrines. Adults with several children found it difficult to find the time to bring children and supervise them at the facilities. The most serious finding, according to the authors, is that women were half as likely as men to use the facilities. The reason was unclear, but they suggest that the demands on women’s time could be the most important factor. They conclude that while sanitation is supposed to be especially beneficial to women, communal latrines did not appear to be serving this purpose. It was also questionable whether pay-per-use communal latrines were economically sustainable.

1.2.3.4 Community education

Community education is a vital aspect of any new technology, and sanitation technologies are particularly reliant upon user knowledge. World Vision (2007, p. 11) emphasises that all water or sanitation projects must have an education and communication element. Grimason and colleagues (2000) describe some of the problems in Malawi when people are not taught correctly about sanitation, hygiene, and use of a latrine: particular problems included using doors for wiping hands, disposing of children’s faeces, and inadequate location and surcharging. More than half the people in their survey said they did not receive any education about health and maintenance of their latrine.

It seems that no public health intervention can succeed without education alongside it. A large-scale programme in poor rural Indian communities in 2007 offered a range of
sanitation options to the community, and provided whichever options the community wanted. Unfortunately the communities did not request hygiene education, so it was not provided, and it is not surprising that the evaluation found no improvement in diarrhoea compared with non-intervention villages. While more private taps and latrines were built and used, handwashing and other key hygiene practices did not increase. The researchers concluded that overall socioeconomic development was responsible for decreasing diarrhoea throughout the area, rather than the piped water and latrines themselves (Pattanayak, Poulos, Yang & Patil, 2010).

Handwashing is a simple intervention, through education, that has stunning results (Cairncross, Hunt, Boisson et al, 2010). But one study in rural India found that while people’s knowledge increased, handwashing did not necessarily increase, although social norms may change in the long-term (Biran, Schmidt, Wright et al, 2009). Reported handwashing increased after the intervention, but observed handwashing did not change, even though the participants knew they were being observed. These authors offer some possible explanations for this finding: perhaps behavioural change takes longer than the evaluation period allowed, or perhaps water or soap were not readily available. They confirm the previous finding that education alone is not enough to change behaviour: there must be an emotional reason to change, as well as having access to the necessary supplies or technology.

1.2.3.5 Subsidies and other financial inducements

The Institute of Development Studies newsletter (2009, p. 2) discusses the problems with subsidised hardware programs - like welfare dependency, they can cause the community to become complacent, wait for others to do the work, or feel that it is not their problem. Such programs are also open to abuse by collecting subsidies illegally, or by the richer people benefiting most. It can be disempowering because it makes the community feel as though they are the poor powerless victims, unable to help themselves. The Community Led Total Sanitation program has a philosophy of no material incentives or rewards, instead focusing on pride, self-respect, health and convenience as natural rewards. Their research in Zambia demonstrates that households are willing to invest in their own infrastructure in the absence of hardware.
subsidies, and it is claimed that self-sufficiency rather than dependency results in more rapid uptake of sanitation services (Harvey, 2011).

### 1.2.3.6 Social change campaigns

Regarding sanitary improvements in today’s poorest communities, Coombes (2010) says that universal sewage and flushing toilets are an impossibility due to the expense, and therefore the sanitary revolution, still to occur in regions like India and Africa, must be community-led. Movements like ‘Community Led Total Sanitation’ aim to mobilise the community to create ‘open-defecation-free villages’. Their focus is on behavioural change, followed by infrastructure. The engineer’s role, then, is to design and build simple, cheap, appropriate solutions while working with public health experts and community leaders to enable sanitation improvements in each village.

Another innovative program involves the influence of women. The “No Toilet, No Bride” campaign, initiated by the Indian government, brings young Indian women to the fore of the sanitary revolution in a country where more people have mobile phones than toilets (Bhowmick, 2011). This simple program encourages young women to require a potential groom to provide a toilet for their home. No toilet, no wife. But for this campaign to succeed, the technology and resources are essential for hopeful young men to access.

It is notable that health and hygiene are not the only motivating factors for Indian people to build and maintain and use latrines. The desire to be seen as modern, to look good when guests come, and to earn respect from others influences the demand for latrines (Banda, Sarkar, Gopal et al, 2007). So education campaigns will benefit from ‘marketing’ latrines as modern and desirable. One problem is that the water flush toilet has become viewed as the best sanitation system, so new sustainable technologies must be competitive (Langergraber & Muellegger, 2005).

### 1.2.3.7 Economic considerations in public health programmes

Recent reports suggest that resource constraints do not necessarily stop countries from achieving better sanitation, as shown by Willetts, Wicken & Robinson (2009). Keys to success even in poor countries include the following: making sanitation a priority in development frameworks, basing sanitation policies on community demand, and
increasing the participation of individuals, communities, and the private sector. The cost of sanitation is too high to be met by public finance and international aid, so interventions need to be designed to trigger the expansion of the private business sector in sanitation.

### 1.2.3.8 Recycling of nutrients from human waste

Ecological approaches to human waste raise the question of using human excrement as a fertilizer, although this idea is not accepted by the villagers as it is against their ideology and moral standards (EWB website, 2011). Organic matter, as well as nitrogen and phosphorous, from human waste are problematic in seas, rivers, and groundwater, but they are valuable in the soil, according to EcoSan proponents (Langegraber 
Muellegger, 2005). Some advocates believe that over time cultures can be convinced that recycling of waste products is safe and acceptable (Willetts, Wicken 
Robinson, 2009), and this can improve food security especially for small-scale farming operations such as families in Devikulam. Any sanitation system proposal ought to leave this open as a possibility in the future.

### 1.3 Design Requirements

#### 1.3.1 Contains, dehydrates or decomposes waste

The solution must isolate human biological waste from people and the environment, and render any faecal matter disease-free so that coliform bacteria are not spread. One month is the target for this design, giving ample time to safely recycle the dehydrated material throughout the agricultural cycle (Jensen, Phuc, Dalsgaard 
Konradsen, 2005).

#### 1.3.2 Economically viable

The solution must be affordable for most families, with a good cost-benefit ratio. Cost savings are likely to be made in healthcare (less diarrhoeal and other enteral illness) and productivity (less time lost being sick). The solution tries to avoid a heavy subsidy or welfare approach, which tends to generate dependency or devalued facilities (Willetts, Wickens 
Robinson, 2009). Ideally it would provide a new industry, a source of livelihood for locals.
1.3.3 Culturally acceptable

The solution must fit with current behaviour, requiring only a small change in behaviour and infrastructure. It must also take into account any cultural taboos. It must respect the values of the local community, and do them good rather than harm. For example, it should be safe to use and easy to maintain and clean. The solution must be well-used and long-lasting.

1.3.4 Environmentally sustainable

The solution must have only a positive or neutral impact on the environment. Potential negative effects must be identified and justified or resolved.

1.4 Ethics Statement

The *Engineers Australia Code of Ethics* (2010) states that engineers must demonstrate integrity, practice competently, exercise leadership, and promote sustainability. There are several challenges in the present project. Acting on the basis of a well-informed conscience and on the basis of adequate knowledge is not so simple when working in an environment entirely different from one’s own. Rural India is vastly different both culturally and physically from urban Australia, so it is essential that engineers are humble enough to conduct careful research and to be willing to learn from the local people. Promoting sustainability is a challenge when working with disempowered people who may need support and encouragement to participate and to balance their needs with the needs of future generations.
2 Design Options

2.1 Option 1: Continue Open Defecation

Open defecation does not contain, dehydrate or decompose waste. While the sun may dehydrate, and over time the material may decompose, fecal matter is not contained and presents a danger to the community and to any water systems nearby, including groundwater. It appears economically viable to many who practice it because it involves no cost (Banda, Sarkar, Gopal et al, 2007), but this is not an acceptable trade-off considering the illness and death resulting from diarrhoeal disease which is spread rapidly by open defecation. It is culturally acceptable in many parts of India, although this is changing through sanitation campaigns and also (perhaps more strongly) the influence of Western culture which portrays the water flush toilet as the modern ideal (Langergraber & Muellegger, 2005). Open defecation is not environmentally sustainable, but it is an age-old practice that is obviously sustainable as a communal tradition.

2.2 Option 2: Pit Latrine

The pit latrine is the most commonly used “drop and store” technique in developing countries (Langergraber & Muellegger, 2005). It typically comprises a concrete slab with a hole for excrement and a pit dug into the ground where the excrement is stored. The pit is lined and is pervious to allow the liquids to sink through and break down or decompose naturally in the pit (refer to Fig 2.2.1).

The pit latrine allows the waste to seep through the soil and can potentially contaminate groundwater sources. Soil and groundwater contamination, bad smells, flies and mosquitoes, collapsing pits, and distance from the house are all additional problems (Langergraber & Muellegger, 2005). Furthermore, the breakdown of
faecal matter is very slow and only partial breakdown results insides the pit (Stauffer & Spuhler, 2011).

The affordability of the pit latrine is excellent, requiring little initial cost to set up the system. There is a small cost involved when the pit reaches full capacity and needs to be pumped or dug out to be used again. The practice of scavenging pit latrines is highly pathogenic to those employed to do so (often from the ‘untouchable’ caste). An additional cost is required if a company is hired to pump out the human waste and move it to an isolated location.

Pit latrines, like all latrines, require that people defecate in a fixed place rather than at a variety of convenient locations. The latrine must therefore be sensibly located, and it must be accompanied by education and other motivators (e.g. ‘shaming’ of those people persisting in open defecation). Any system that stores fecal matter is in accord with the cultural perspective that human waste is “repulsive and not to be touched” (Langergraber & Muellegger, 2005). While using a latrine is not the traditional Indian custom, it is becoming acceptable throughout developing countries, due to advocacy and the influence of the West. The use of a latrine is (or will become) culturally acceptable, contingent upon its location and sufficient education.

The environmental impact of the latrine pit system is more adverse than positive (although it is a step up the “sanitation ladder”, an improvement on open defecation, according to Willetts, Wicken and Robinson, 2009). The allowable seepage of excrement can potentially contaminate groundwater, due to pathogens in the waste that have not completely broken down. In fact human faeces must be treated in order to be safe or to be re-used for agriculture; it is not reliable to simply leave faeces in storage. Counter measures can involve removing the excrement from the hole to stop contamination of groundwater, or having an impervious lining installed. Ultimately, it is not environmentally sustainable.

The pit latrine system is able to be constructed by people with few expertise in construction and plumbing. Furthermore, this system is incorporated mainly in remote villages or communities. A pit latrine, well maintained, can last up to thirty years and would be used extensively with the right conditions. It can provide an industry for unskilled workers, although the employment of scavengers is a concern.
2.3 Option 3: Ventilation Improved Pit (VIP) Latrine

A VIP Latrine is a pit latrine with a ventilation system. A pipe running from the pit up to the open atmosphere is attached and the odour is partially removed from the area. The degree to which the odour is still smelt depends on the complexity and efficiency of the ventilation system. Some ventilation systems use exhaust fans.

Considerations of cost, acceptibility, environmental sustainability and community sustainability are similar to the ordinary pit latrine, as described above, except that it would be slightly more acceptable because of the reduced odours.

2.4 Option 4: EcoSan and the Urine Diversion Dehydration Latrine (UDDL)

EcoSan is an alternative approach to dealing with human waste, attempting to “close the cycle” of household waste rather than introduce it to the wider environment, and aiming to use human excreta and water as a resource rather than waste (Langergraber & Muellegger, 2005). These were introduced in Sweden during the 1940s as summer toilets, and have been adopted in many other regions around the world.
(Moe & Rheingans, 2006). The principles are as follows, according to Moe and Rheingans (2006):

- conservation of water;
- containment of human excrement to protect the surrounding environment and transmission of disease;
- treatment of excrement to kill pathogens;
- recycling nutrients for agricultural improvements.

EcoSan technologies may therefore include natural water treatment, compost toilets, simple household installations, and other systems increasing in complexity.

The urine diversion dehydration latrine is a combination of effective waste storage and disposal techniques which provides an efficient solution to faecal waste management in third world conditions. The urine diversion splits the waste disposal area to separate urine from faecal matter (designs differ depending on whether the users would commonly be sitting or squatting). This is an important cost saving: only the faecal matter needs to be treated. Urine is the most useful product for agriculture, assuming some provisions and preparations are undertaken (Langergraber & Muellegger, 2005).

The faecal matter is stored and usually treated in some way to speed up dehydration. Critical factors are long storage time, high temperatures, and high pH (Langergraber & Muellegger, 2005).

This design is less affordable than the pit latrine because it requires a particular fitting for the urine diversion. But it is still considered to be attainable, especially as a communal facility. It certainly involves cost savings in terms of health, death, productivity, and hygiene (Haller, Hutton & Bartram, 2007).

As discussed in Option 2, using a latrine of any sort is one step up from open defecation. However the UDDL designs require a small extra effort to ensure that urine and faeces are kept separate. One potential drawback for the urine-diverting system is that men are sometimes reluctant to sit or squat for urination, and this would cause urine to mix with faeces, slowing the dehydration or composting process. But the team considers that the range of UDDLs are (or would soon become) culturally acceptable.
2.5 Option 5: Solar Boosted Urine Diversion Dehydration Latrine (SBUDD)

To deal with some of the problems implicit in a simple UDDL, solar energy can be utilised to speed up the breakdown of faecal matter. The storage area is placed under well-ventilated, warm conditions in order to dehydrate the solid waste, most optimally achieved if urine is kept completely separate. A ventilation system, normally a vent pipe, is inserted into the storage area and water piping is laid below the area where the water is warmed by solar energy. The water in the piping is heated outside by using a parabolic reflective surface which focuses light onto the piping. The heated water then expands in the pipe and by carefully positioning of one-way valves in the piping, pressure build up will cause the heated water to move through the piping. Once dehydrated, the waste in the storage area is then removed and disposed of in a selected area.

This design has additional costs in the way of copper piping, a stainless steel or aluminium parabolic reflector, and if the passive pump has too little flow an electric pump will be needed. The design is more complex requiring a frame for the parabolic reflector that can be adjusted for the seasonal shifts in the suns position. The piping will need to be periodically checked for leaks.

2.6 Option 6: Electric Boosted Urine Diversion Dehydration Latrine

The electric boosted urine diversion dehydration latrine is similar to the previously mentioned UDDL except that it has thermal energy provided by electrical resistance.
This heating mechanism is used to dehydrate the faecal matter at an accelerated rate. While this design does have a negative on the environment (using electricity which is generated by burning fossil fuels or whatever processes they use), it is stable and reliable. This design does not rely on weather and sunlight and can withstand repeated breaks in electricity supply. The dehydration container is designed to retain heat. The design requires minimal electricity to keep the container heated. However with power cuts occurring daily it is possible that the dehydration process may take longer presenting an issue in cold conditions. This design is comparable with the others with differences in Environmental sustainability.

The urine is channelled and distributed onto a nearby plantation while the faecal matter is collected in a dehydrating latrine. The dehydrating latrine is a heated waste containment device which increases the rate of dehydration by exposing the faecal matter to high temperatures and minimising moisture content. Once the process is complete the faecal matter is safe to be buried, which in time will become a nutrient-rich soil. Men can choose not to use the toilet for urine only.

Anal cleansing will be performed in their traditional manner utilising a bucket of water. A gutter and water tank could be installed to collect rain water but this is not included in the design.

2.7 Option Selected

<table>
<thead>
<tr>
<th></th>
<th>Continue Open Defecation</th>
<th>Pit Latrine</th>
<th>VIP Latrine</th>
<th>UDDL</th>
<th>Solar Boosted UDDL</th>
<th>Electric Boosted UDDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contains, dehydrates or decomposes waste.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Economically viable</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Culturally acceptable</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Environmentally sustainable</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 1.
The proposed solution is the Electric Boosted UDDL. It changes the only environmental factor which can be cheaply altered - temperature - from a readily available energy source. It is an adaptable design and can be built in either a public or private capacity. It can have a shelter and toilet pan built on top (as the proposed solution does) or it can forgo this and have only a dehydration chamber which people dispose of their faeces into.
3. Design Description:

3.1 Summary

The design is based on the EcoSan UDDL and comprises a single brick chamber with a brick divider in the centre. It has under floor heating produced by a simple resistive nichrome wire circuit. This circuit is hooked up to mains power and delivers a constant amount of thermal energy and therefore the heating element will always be above ambient temperature. The heated floor heats the faecal matter which in turn heats the air mass above the faecal matter. This changes the relative humidity of the environment allowing the warm air to hold more moisture. The warm air is vented passively through a large diameter vent in the ceiling. Cool dry air is passively drawn in through vents placed near the floor in the door. The has the added effect of a constantly moving air body over the faecal matter, helping remove moisture.

The volume of the faeces is reduced by dehydration, making disposal easy. The solution involves burial of the dehydrated matter in a specific plot reserved for this purpose. This only needs to be done every two to four months.
The principal in use here is changing the most easily controlled variable, which is temperature, to increase the temperature of the faecal matter, which will increase the rate of vaporization of water molecules, and to lower relative humidity. As temperature increases, the relative humidity of the air decreases and the amount of moisture that can coexist in the air increases.

It has a dual function toilet pan that diverts urine through a secondary system. Urine is piped into a small garden plot that contains multiple high nitrogen dependent trees. These should be any variety of citrus tree depending on availability.

3.2 Functional Description

Functionally the design can be divided into three parts. The base with dehydrator; the urine diversion system; and the shelter on top.
The base consists of a concrete foundation with single brick chamber with a brick divider in the centre. The foundation has a resistive heating wire embedded in it. Running from 220v it will be insulated wire. The heating element does not have a thermostat and instead delivers a constant amount of thermal energy and therefore the heating element will always be above ambient temperature. The heated floor heats the faecal matter which in turn heats the air mass above the faecal matter. This changes the relative humidity of the environment allowing the warm air to hold more moisture. The warm air is vented passively through a large diameter vent in the ceiling. Cool dry air is passively drawn in through vents placed near the floor in the door. The has the added effect of a constantly moving air body over the faecal matter, helping remove moisture. Being made of concrete and bricks the system has a large thermal mass and a high heat capacity. This creates a thermal energy buffer if the heating element loses power or if there is cold weather.

Faeces is deposited through the toilet pan built into the top of the chamber. This is diverted by a small section of PVC pipe to one side of the central brick divider. The other side is already full of faecal matter and is undergoing the extended drying period whereby it becomes full dehydrated with no new material added. Faeces can also enter by the main brick chamber door to the active half of the chamber. This enables faeces collected from outside to be put inside to dehydrate. Collected faeces is taken to a designated field in fallow and buried.

The dual function toilet pan diverts urine through a secondary system. If the toilet user can urinate into the front section of the pan then they should. This urine is directed by a
PVC pipe into a small garden plot that contains multiple high nitrogen dependent trees. These will be any variety of citrus tree depending on availability. The fruit from these trees does not need to be harvested but given time it is expected the people will become accustomed to the trees and start harvesting the crops.

The shelter built on top has a wood stud frame with zinc plated corrugated iron used as cladding. It has a slanting roof that can be connected to a gutter and PVC pipe which leads to a storage tank. The door has a wood frame with a piece of corrugated iron as cladding. There is enough room in the shelter for a parent and some children.

Alternate Design: An easy and cheap alteration of this design is to only build the dehydration chamber - i.e. no toilet pan, shelter or urine diversion systems. This can then be placed into public defecation areas for safe disposal of faecal matter.
### DESIGN COMPONENTS

<table>
<thead>
<tr>
<th>DESIGN COMPONENTS</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>Main structural element which everything attaches to.</td>
</tr>
<tr>
<td>Heating Element</td>
<td>Provides thermal energy.</td>
</tr>
<tr>
<td>Brick Chamber</td>
<td>Isolates and contains excrement, contained from water, moisture and air.</td>
</tr>
<tr>
<td>Chamber Door</td>
<td>Provides access to chamber</td>
</tr>
<tr>
<td>Ventilation inlet and outlet</td>
<td>Creates a convection flow of air in the chamber.</td>
</tr>
<tr>
<td>Shelter floor</td>
<td>Provides a roof to the dehydration and a floor to walk on and place a toilet pan in</td>
</tr>
<tr>
<td>Stud walls</td>
<td>Main structural element for shelter</td>
</tr>
<tr>
<td>Wall and roof cladding</td>
<td>Weather and thermal barrier from outside element</td>
</tr>
<tr>
<td>Urine diversion piping</td>
<td>Redirects urine to outside garden</td>
</tr>
<tr>
<td>Toilet Pan</td>
<td>Directs faeces and urine into position</td>
</tr>
<tr>
<td>Steps</td>
<td>Allow vertical transition to water closet</td>
</tr>
<tr>
<td>Rail on steps</td>
<td>Provides stability for vertical ingress</td>
</tr>
<tr>
<td>Shelter</td>
<td>Allows all weather use of water closet</td>
</tr>
<tr>
<td>Shelter door</td>
<td>Provides privacy and shelter to users</td>
</tr>
</tbody>
</table>

3.3 Implementation

This is a multi-step plan. First, leaders must be approached and consulted regarding the entire project. Second, community mobilisation and education using the Community-Led Total Sanitation approach will trigger the community to act (refer to Appendix F).

Community-Led Total Sanitation (CLTS) aims to help villages become open-defecation-free (ODF) and recognises that simply providing toilets does not improve usage or hygiene. The investment is made in community mobilisation and in marketing a new improved latrine design. It also aims to provide a new livelihood for some members of the community - in this case, building the new toilet design. The plan is not to provide free toilets, but to train villagers in constructing their own, set up supply networks for the necessary materials, educate the villagers on hygiene and sanitation, and market the toilet as modern and desirable.
Education will be targeted to five different target groups, and may require translators.

1. Meet with town leaders and teachers to discuss the importance of hygienic practices and the benefits to the new facilities. Introducing the team, building trust and rapport, and carefully explaining the proposal will establish support with leaders and teachers, who can ensure the success of the programme.

2. Address the women and men of the community separately. The CLTS approach involves triggering the community to realise that as a result of defecation they are ingesting each other’s faecal matter. The key is to trigger introspection into their behaviour and to feel shocked by the practice of open defecation. The opportunity then arises to educate them on the advantages to the facilities and its effect on the environment, and to focus on recommended hygienic practices (with a focus on handwashing) and the privacy the facilities provide. The promotional material for the new toilet design will be introduced, including the endorsement by an Indian celebrity or influential person. This will add more social value to the product.

3. A school workshop will focus on educating young children on this exciting new technology which deals with the waste for them. This workshop will include detailed methods of proper hygiene, especially handwashing, and the repercussions that can occur if not followed. It is more likely that the younger generation will utilise the facilities and the generations that follow will automatically use the facilities (Majra & Gur, 2010).

4. It would be effective to appeal to the farmers of the community, display the benefits of the new facilities including projected result of reduced faecal matter being washed into the lake; this has the effect of the lake becoming usable over a period of time. Dehydrated waste is rich in nutrients and acts as a great fertiliser, appeal to the farmers offering better crops if this free fertiliser is utilised. While human waste is subject to taboo in India, other countries successfully use dehydrated human waste in agriculture. One problem has been the slow process of composting in regular EcoSan toilets. In Vietnam one study found that farmers used human waste on their crops every fourth month according to their agricultural needs, rather than waiting for the waste to completely compost, resulting in potential contamination (Jensen, Phuc, Dalsgaard & Konradsen, 2005). Recycling these nutrients is a benefit of this design, but pathogens need to be broken down faster in order to suit farmers’ needs.
There will be those who are not going to utilise the new facilities and it would be a waste of time trying to push this new technology on them. Offer them the alternative of placing their faeces into the dehydrating compartment via the container doors.

This implementation is gradual and may take decades. Research shows that latrine usage increases gradually over time (Biran, Jenkins, Dabrase & Bhagwat, 2011).

3.4 Materials needed

These materials will be needed to construct the EBUDDL.

Building Implementation.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubble (base grade)</td>
<td></td>
</tr>
<tr>
<td>Grey Sand/Sand</td>
<td></td>
</tr>
<tr>
<td>Concrete (1 cubic meter) (bags premix)</td>
<td></td>
</tr>
<tr>
<td>Construction wood</td>
<td></td>
</tr>
<tr>
<td>Reinforcing bars</td>
<td></td>
</tr>
<tr>
<td>Steel mesh (6mm x 100mm x 100mm)</td>
<td></td>
</tr>
<tr>
<td>Plastic sheeting</td>
<td></td>
</tr>
<tr>
<td>Construction bricks</td>
<td></td>
</tr>
<tr>
<td>Mortar</td>
<td></td>
</tr>
<tr>
<td>Corrugated iron</td>
<td></td>
</tr>
<tr>
<td>Dyna bolts 1100mm, 6mm diameter</td>
<td></td>
</tr>
<tr>
<td>Nails (cleats)</td>
<td></td>
</tr>
<tr>
<td>Viscource</td>
<td></td>
</tr>
<tr>
<td>Insulated Heating Wire</td>
<td>$50 per square meter of coverage</td>
</tr>
</tbody>
</table>

3.5 Construction Guide

This is a simple guide to the construction of the EBUDDL.
<table>
<thead>
<tr>
<th>Choose Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Close to populated areas</td>
</tr>
<tr>
<td>- Able to excavate with ease to bury dehydrated matter</td>
</tr>
<tr>
<td>- Able to plant citrus trees for urine diversion</td>
</tr>
<tr>
<td>- Doesn’t flood</td>
</tr>
</tbody>
</table>

Mark out the site (dimensions, excavations)

**Excavation**

Lay Dolomite/ Gravel/ Grey Sand

**Compression**

Lay Fornacon

**Concrete Prep**

- formwork (carpenters)
- Structural Steel (Mesh, Rubber)

Install heating element

Pour concrete

**Removal of formwork**

**Finishing of Concrete**

Lay Bricks (Structural bricks)

Leave space for diversion trap

Install door to container

Bondex floor on top of bricks (Galvanized concreting prep)

**Form Work**

- Leave space for latrine hole

**Pour Slab**

Remove formwork

**Finish Concrete**

Insert squat loo

**Stairs to concrete slab (materials to be confirmed)**

- steps constructed and fixed to base slab

**Construct timber stud wall frame**
<table>
<thead>
<tr>
<th>Fix to base slab with dyna-bolt fastener</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct timber roof frame (rafters)</td>
</tr>
<tr>
<td>Safety mesh</td>
</tr>
<tr>
<td>Fix corrugated iron to rafters</td>
</tr>
<tr>
<td>Apply black plastic between slab and timber stud walls</td>
</tr>
<tr>
<td>Fix corrugated iron to stud wall</td>
</tr>
<tr>
<td>Apply flashing</td>
</tr>
<tr>
<td>General safety and structural integrity inspection</td>
</tr>
</tbody>
</table>

Table 5
4 Evaluation

4.1 Contains, dehydrates or decomposes waste

The solution must isolate human biological waste from people and the environment, and render any faecal matter disease-free so that coliform bacteria are not spread.

This testing ought to be done at six months, in order for this design to be competitive with other EcoSan designs. The evaluation process will include testing the rate at which it dehydrates in that particular environment and location. It will be necessary to remove samples in order to test levels of harmful bacteria, viruses, protozoa, fungus in the dehydrated faeces. Observational studies and soil testing of the soil around the units will determine whether the chambers are containing the waste.

Evaluating the effect of the intervention on the rate of diarrhoea is important but difficult. A review by Cairncross, Hunt, Boisson and colleagues (2010) shows the difficulty in isolating the cause of a reduction in diarrhoea after sanitation programmes. Part of the difficulty is that households that tend to use latrines more also tend to have more hygienic behaviour in general, thus complicating the findings. In the case of Devikulam, evaluation would need to include the whole village population over an extended period of time to detect any change, and look at the association with the number of latrines and their usage. Still it would be difficult to prove that the latrines are the cause of the decline, but any decline in diarrhoeal disease is welcome, and if incidence increased, it would signal that something is wrong and an investigation should be conducted.

4.2 Economically viable

The solution must be affordable for most families, with a good cost-benefit ratio. Cost savings are likely to be made in healthcare (less diarrhoeal and other enteral illness) and productivity (less time lost being sick). The solution tries to avoid a heavy subsidy or welfare approach, which tends to generate dependency or devalued facilities (Willetts, Wickens & Robinson, 2009). Ideally it would provide a new industry, a source of livelihood for locals.
To measure this, the team could estimate the cost, and then conduct a cost-benefit analysis, and identify the start-up cost relative to average income for the region.

Survey data could help estimate the out-of-pocket savings to households from improved sanitation, including reduced medical expenditure and increased productivity rates from health gains.

Pattanayak, Poulos, Yang and Patil (2010) demonstrate how researchers can evaluate the economic benefits from water and sanitation improvements in rural India. These researchers evaluated the programmes two years after initiation which began in 2005. To use their method, Devikulam would need to be matched with another village that is similar but with no sanitation programme. The survey asked questions about time spent collecting water, going to defecate, treating water, and storing water. They estimated the value of the people’s time by average wages. They asked about out-of-pocket medical expenses and lost income related to episodes of diarrhoea, and children’s time was valued in proportion to their age. Lost income per household as a result of diarrhoea in adults was US$3.18 to US$4.24 at the beginning of the project, and US $2.19 to US$3.86 two years later during the evaluation. Costs were very different between the rainy and dry seasons, so the evaluation for this proposed project would need to assess costs at both time points and provide an average or a range. It is noteworthy that the programme in 2005, which focused on responding to demand for water and sanitation options, resulted in savings in time and expenses for the villagers, but did not reduce the incidence of diarrhoea, primarily because the people did not request any educational input on hygienic practices.

4.3 Culturally acceptable.

The solution must fit with current behaviour, requiring only a small change in behaviour and infrastructure. It must also take into account any cultural taboos. It must respect the values of the local community, and do them good rather than harm. For example, it should be safe to use and easy to maintain and clean. The solution must be well-used and long-lasting.

The real test of success is latrine usage, not number of latrines constructed; and targets must be gradual and realistic (Bongartz & Chambers, 2009). For example, Pattanayak,
Poulos, Yang and Pail (2010) found that after two years, there were 7% more toilets in project villages compared to non-project villages.

Commissioned survey data is the key here. First, the team would survey the levels of usage of the toilet at monthly intervals, and ask how happy the locals are about it. Also, surveys of knowledge and behaviour are essential, to find out whether the educational element has fit into the local culture and been successfully adopted.

Survey done in the local school. Do a baseline study, and then another shortly after the intervention. Initially, contact the local school, speak to the head of school, explain the study, ensure confidentiality, gain informed consent. Possibly engage medical interns or students from Pondicherry. Survey on knowledge about sanitation, defecation practices, toilet use, attitudes to all of these, and practices. Conduct same survey after the intervention. Looking for increased knowledge, changed attitudes and practices (see Majra & Gur, 2010). Biran, Jenkins, Dabrse and Bhagwat (2011) also report on a survey method for determining latrine use and its associations with demographic characteristics in India.

4.4 Environmentally sustainable.

The solution must have only a positive or neutral impact on the environment. The comparison practice is open defecation.

Consideration should be given to the materials and energy that go in, and what comes out, and where it is put. Once a final design is established, engineers should conduct an environmental impact analysis. Its impact will be compared with the current practice of open defecation.

The team should measure electrical usage (and find out whether it can be adjusted to a lower more optimum level). Can electricity be sourced from a renewable source? Are the materials used renewable?

This project will need to evaluate water quality by taking samples from water holes, wells, and any other exposed water source at monthly intervals and testing for coliform contamination levels. A baseline test will be followed by six-monthly testing for two
years. Drinking Water Standards in India (IS 10500) require that no coliforms be found in water from taps. This project would not be able to achieve zero coliforms (since other pathways introduce coliforms into groundwater, and no alternative drinking water is part of this proposal), but coliforms ought to be reduced.

To gain further information on the effect of the latrines, samples should be taken from taps, groundwater and surface water, and mapped in conjunction with data on latrine location and frequency of use (from surveys). Geographic information systems analysis can show how the coliform levels in the water samples relates to the latrines and their usage, as demonstrated in a 2009 study by Gopal, Sarkar, Banda and colleagues in rural India. In that particular evaluation study, water was found to be unfit for human consumption and so point-of-use water disinfection was recommended until more appropriate solutions were engineered for sanitation and water supply.

4.5 Cost Analysis

Construction Cost

The project is estimated to cost around AU$1000 and will take around four weeks to complete. Some of the material can be replaced by another assuming that the engineer sees it fit to do so. Most of the materials seen can be bought locally, which keeps the cost of the latrine low as well as eliminate the cost of shipping to the village. Cost for the location of the land is a factor that has also been taken into consideration. In Australia this amounts to one or two week’s average income, so in India it may hold a similar value. This is not the cheapest method of building a latrine, but it will be much more effective. In addition, the proposed marketing campaign aims to make latrines more desirable (noting that most villagers own a television and a mobile phone, but not a toilet). Typically a citrus tree would cost $35 in Australia but it is expected that an agricultural community could obtain citrus trees very cheaply.
<table>
<thead>
<tr>
<th>Materials</th>
<th>Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>$200 per cubic meter</td>
<td>$200</td>
</tr>
<tr>
<td>Grey sand</td>
<td>$20 per 5Kg bag</td>
<td>$400</td>
</tr>
<tr>
<td>Timber (90x35)</td>
<td>$17.75 per 6m</td>
<td>$360</td>
</tr>
<tr>
<td>Timber (90x90)</td>
<td>$59.10 per 6m</td>
<td>$120</td>
</tr>
<tr>
<td>Timber (150x150)</td>
<td>$65.10 per 6m</td>
<td>$150</td>
</tr>
<tr>
<td>Timber (290x45)</td>
<td>$77.70 per 6m</td>
<td>$77.70</td>
</tr>
<tr>
<td>Reinforcing Bars</td>
<td>$1.50 per meter</td>
<td>$140</td>
</tr>
<tr>
<td>Corrugated iron</td>
<td>$7.8 per a meter</td>
<td>$250</td>
</tr>
<tr>
<td>Dyna Bolts</td>
<td>$0.50 each</td>
<td>$10</td>
</tr>
<tr>
<td>Nails</td>
<td>$60 for a pack of 100</td>
<td>$60</td>
</tr>
</tbody>
</table>

table 6

Implementation Cost

A crucial aspect of this proposal is to hire a well known Indian personality to promote the product. The prices association with this person include the payments for the trip to and from the village, as well as the accommodation for the period of time he/she would be staying. There are also the factors of halls being hired for training and workshops and the equipment that goes along with it. The facilitator and materials for the CLTS workshops and community meetings will be another small cost. The latrine has to be looked after, and the solution implemented is a maintenance man or woman who will clean out the brick chambers when needed and keep the inside and outside clean and presentable.
5. Discussion and recommendations

Strengths and weaknesses of this proposal:

<table>
<thead>
<tr>
<th>Weak</th>
<th>Strong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted Use</td>
<td>Strong, permanent structure</td>
</tr>
<tr>
<td>Contrary to customs</td>
<td>Faster than current designs</td>
</tr>
<tr>
<td>Moderate complexity</td>
<td>Small power footprint</td>
</tr>
<tr>
<td>Moderate startup cost</td>
<td>Effective faecal containment</td>
</tr>
<tr>
<td>Public</td>
<td>Effective pathogen removal</td>
</tr>
</tbody>
</table>

Dealing with human waste is an everyday dilemma for millions of people in developing communities. It presents an urgent health need, and involves complex pathways.

This project proposes to address this need by offering an improved design for dehydrating human waste. But it also incorporates education and marketing, so that both knowledge and desirability converge to make the improved latrine more popular and the entire project more effective by providing barriers in the cycle of transmission of pathogens (see Appendix E).

The Community-Led Total Sanitation approach is paired with this solution to aim for long-term social change with appropriate technology. It is not expected that this approach would work overnight, but rather it is hoped that mobilisation of the community, with a modern marketing strategy, will increase the uptake of new latrine technologies.
References:


National Health and Medical Research Council (2004), *Australian Drinking Water Guidelines*. 


World Vision (2007), Getting the Basics Right: Water and Sanitation in South East Asia and the Pacific (with Water Aid Australia), Melbourne, Australia.
Appendix A: Rainfall and Temperature data for Pondicherry.

http://www.mustseeindia.com/Pondicherry-weather
Appendix B: Topography of India

Appendix C: Soil types of India.

http://www.mapsofindia.com/maps/schoolchildrens/major-soil-types-map.html
Appendix D: Groundwater and aquifer recharge in India.

Source:

http://4.bp.blogspot.com/_saMrqhd2slo/SQrENCFXBPI/AAAAAAAAAnU/7EfmyY329Ml/s1600-h/groundwater_india.png
Appendix E: Transmission of disease from faeces.

Diarrhoea can be spread via many hosts, therefore a multi-faceted approach is necessary. Latrines can provide a primary barrier to stop pathogens spreading to fluids, flies and fields. Handwashing and hygiene education are secondary barriers that can stop the spread of pathogens to food.


Adapted from Kawata, 1978