

Faculty of Engineering and Industrial Sciences
Swinburne University of Technology

HES1115 – Sustainable Design

EWB Challenge - Semester 2, 2011

Biogas Plant Proposal

Devikulam, India

CHAGUMAIRA, Isaiah - 7199201

FYFIELD, Nicolas - 725489x

MANGAN, Andrew - 7187874

ROPER, Yasmin - 7194609

VELLA, Darren - 7194749

WONG, Jon - 9514252



SWINBURNE
UNIVERSITY OF
TECHNOLOGY

TABLE OF CONTENTS

INTRODUCTION	4
NEED	5
SOLUTION	5
USES AND IMPLEMENTATION	6
CONCEPT	8
DESIGN.....	10
CALCULATIONS	12
FINAL DESIGN	16
TRANSPORTATION OF MATERIALS	17
REASON FOR DESIGN	18
COST	19
SOCIAL IMPLEMENTATION	20
ENVIRONMENTAL IMPACT	24
SOCIAL IMPACT.....	25
REFERENCES	27

INTRODUCTION

India is a colourful and vibrant nation richly steeped in a wide array of traditions and religions. However, with the second largest population of any country, over 1 billion and rising, India's already strained resources are only going to be stretched further. Almost 42% of the population are below the poverty line earning less than \$1.25US per day. Access to substantial shelter can be limited and clean drinking water is particularly difficult to obtain in rural areas. The compaction of these factors sees the life expectancy in India at 64 years at birth compared to 81 years at birth in Australia (UNICEF, 2010) (Index Mundi, n.d)

The town of Devikulam is South East of Mumbai in the state of Tamil Nadu with a population of 358 people. Of the 86 households spread across the town, at least 71 live below the poverty line. The majority of the population here are agricultural workers and every household owns livestock.

NEED

It has been reported that only 7 households have access to a latrine seeing the widespread practice of open defecation behind homes as the norm. This system not only results in an unpleasant odour but it is also a health risk. The spread of disease is increased during monsoon season when these deposits are washed into water sources that in turn become contaminated.

The use of firewood or kerosene fuelled stoves indoors is everyday practice in most of India. In Devikulam in particular, this is the method of choice for all but 7 households (*Engineers Without Borders, 2011*). The use of such stoves is not only particularly bad for the environment but it also has detrimental health effects. Health problems due to smoke inhalation cause 1.6 million deaths per year (*Engineers Without Borders, 2011*), 28% of deaths due to indoor air pollution occur in India (*ODAM, 2011*). These effects also account for 20% of fatalities in children under 5 years of age (*Poverty Action Lab, n.d*).

SOLUTION

To alleviate or end some of these unsustainable and dangerous practices the installation of a biogas settler with a latrine facility feed has been proposed. The system will collect waste from both human and animal faeces and convert it to energy and fertiliser.

USES AND IMPLEMENTATION

This proposal aims to provide a solution to the current waste problem in Devikulum where waste is being left in the open increasing the chance of disease. Currently human faeces are deposited behind the houses along with livestock manure where they are left un-buried and untreated. These unsanitary conditions can lead to the build-up bacteria seeing the community susceptible to disease. The proper implementation of a biogas digester would solve this problem while also taking the load of the local power problem by providing the community with another energy source in the form of biogas. They would be able to use the biogas for a number of things but primarily in biogas stoves for cooking which are quite efficient. The other product made from the bio-digesters is fertigation water. This water when implemented into the local irrigation systems and farming areas would benefit the crops and agricultural yield that the area produces.

The Position of Bio-digester in relation to the town is dependent on the size and how the waste is being collected. Our proposal also includes the construction of central village latrines and animal manure collection points.

The actual implementation into the community of the bio-digesters would require the education of how all processes or at least primary functions of the unit would entail, the precautions needed with the use of the biogas and possibilities of infection with the misuse and storage of the fertigation water. The way this water can be incorporated into the village is by adding it to the existing irrigation system which would enrich the towns

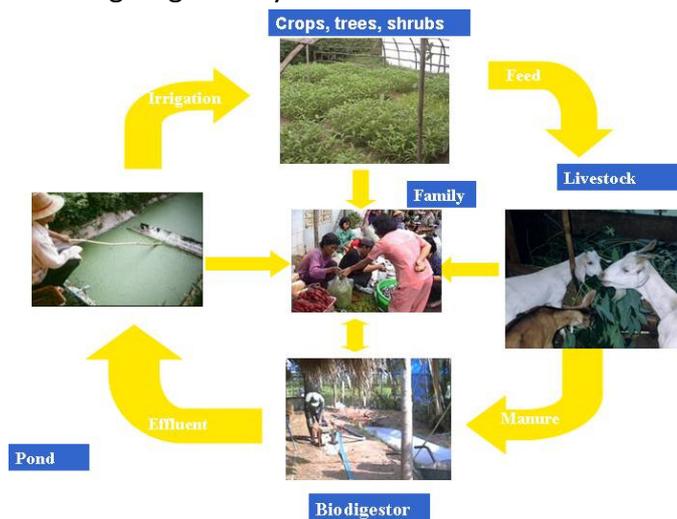


Figure 1 – Bio-gas digester flow chart, explaining the cycle of usage (SOURCE)

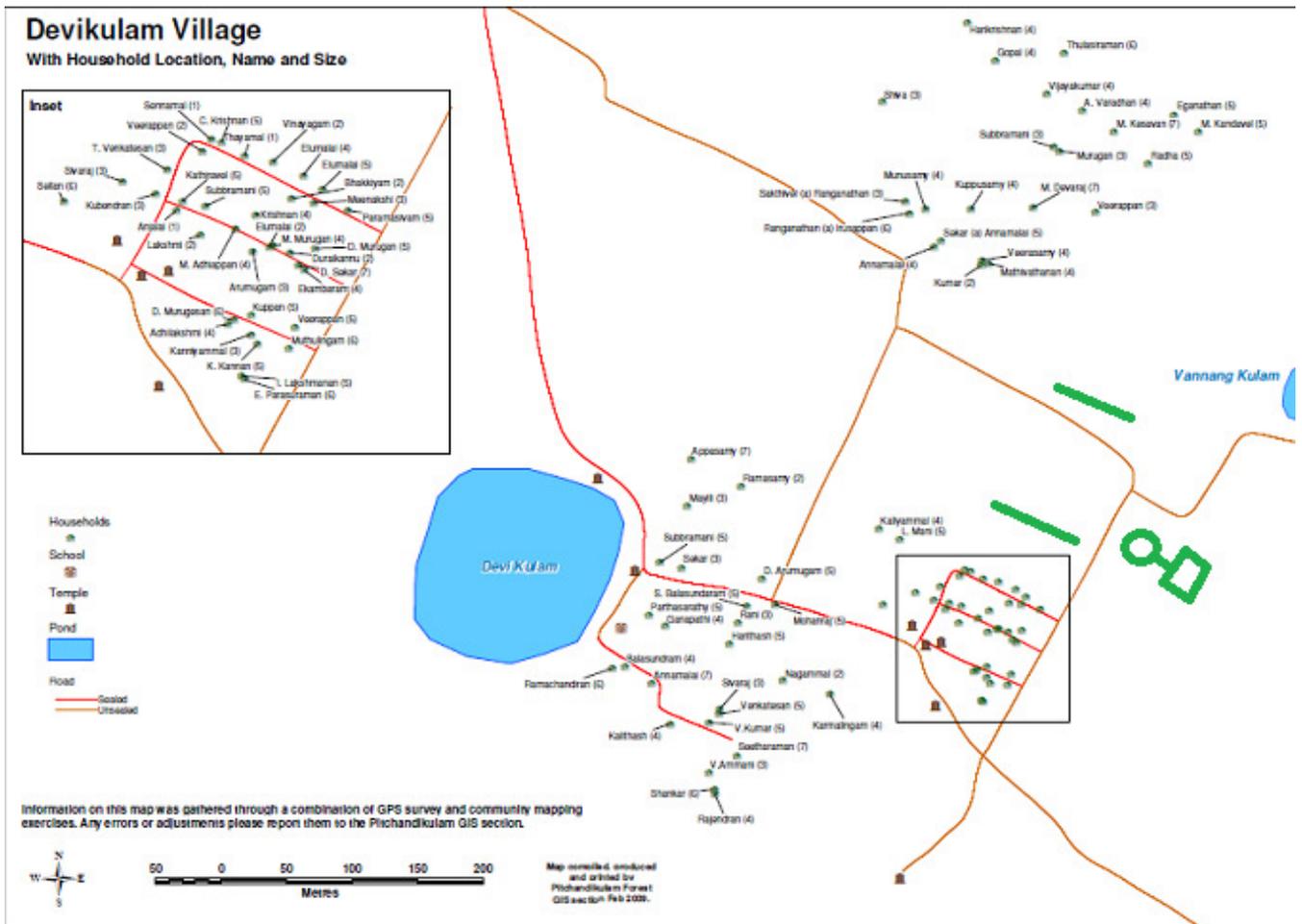


Figure 2 – Map of Devikulam Village with position of digester and latrines indicated (Engineers Without Borders)

Biogas digester setup away from the main village roughly one hundred metres minimum with a fertigation water storage tank which links to the villager’s irrigation and watering systems once implemented properly.

CONCEPT

The concept of a biogas settler is to treat the waste products entering it to create a usable gas and a safe product to be used for fertilisation. The design of a biogas settler is similar to that of a septic tank, however the design incorporates the ability of biogas to be harnessed and stored.

The by-products of the fertilisation and biogas are possible through a process called anaerobic digestion. The airtight chamber develops sludge at its bottom and with the lack of oxygen in the chamber a chemical reaction takes place that creates a methane rich biogas that is able to be used in household gas appliances such as stoves and lamps. With the lack of oxygen in the chamber, and as the influent may take 60-80 days to pass through the system, most harmful pathogens are destroyed and the effluent liquid and slurry are able to be used for fertilisation of the surrounding farmland, reducing the waste and increasing the sanitation of the area.

The use of a biogas settler is ideal in this situation as the initial cost of the unit is relatively low, it requires little maintenance, has no energy consumption as opposed to many similar design that may be affected by flood, the biogas settler will not be affected by its location in such a wet area. The advantages of the settler far outweigh its negatives, one of which being the removal of the sludge; approximately every 5 years the sludge will accumulate to a level at which it will need to be removed and whilst many of the harmful pathogens have been removed by this stage, it is required to be done by skilled personnel. This sludge will usually then be placed in a drying bed before it is used for fertilisation.

Large retention times on the influent and warmer temperatures of the chamber are ideal in the treatment of the effluent to increase the effectiveness of the removal of harmful products, resulting in by-products higher nutrients and more suitable for uses as fertilisation. Ideally the hydraulic retention time (HRT) would be close to 100 days and chamber temperature would be close to 55°C to ensure pathogens are destroyed. By placing the chamber below ground, the temperature can be regulated much more easily with the chemical reactions inside creating its own heat within the chamber. An expert design is then required to ensure the HRT is as large as possible whilst still producing a consistent amount of biogas for the colony's demands.

Once biogas is initiated, the pressure level within the main chamber is increased, for this reason a compensation tank is needed. Connected to the lower of the main chamber, as pressure increases, the sludge is then forced through a pipe into the compensation chamber, thus reducing the absolute pressure in the main chamber and preventing fractures in the frame. This compensation tank is then open to atmosphere as the sludge stored within it is practically harmless and can be placed within the drying beds. The benefits of a biogas plant seem endless- low construction costs, low running costs and a clean source of energy. However the system can have some downsides, such as gas loss if chamber suffers a fracture and the dependence on the community to participate in the use and production of the biogas plant.

DESIGN

Biogas settlers involve the construction of carefully calculated chambers in order for them to produce the biogas efficiently. The following diagram shows a good representation of the system and how it is hoped to be implemented.

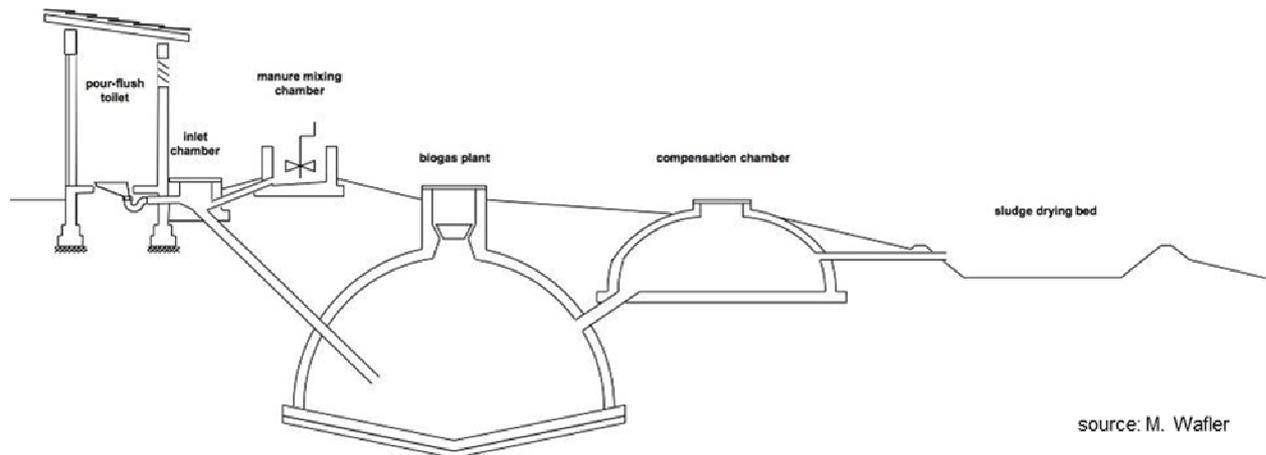


Figure 3 - The initial design of a biogas plant, including all aspects- latrines, animal waste entry and chambers

The toilets will be placed in latrines near the villages for which people can use to contribute to the production of the biogas and the manure mixing chamber allows for farmers and villagers to dispose of their livestock waste into the biogas plant. Once gas begins to be produced the sludge can then flow into the compensation chamber and eventually into the drying bed, where now almost pathogen free is harmless to humans. Once left in the drying bed for approximately a month, it is then able to be used as a nutrient rich fertiliser.

Many areas are involved in the calculations that make for an effective system, including usage and production of the biogas itself, as well as the time the waste will spend in the chamber. The following table outlines the values of which I will be using to develop a suitable chamber.

animal species/ feed material	daily manure yield		fresh-manure solids		liveweight	C/N	gas yield		
	manure	urine	DM	ODM			range	average	
	[kg/d]	[% _{lw}]	[% _{lw}]	[%]	[%]	[kg]	[-]	[l/kg ODM]	
cattle manure	8	5	4 - 5	16	13	135 - 800	10 - 25	150 - 350	250
buffalo manure	12	5	4 - 5	14	12	340 - 420	20		
pig manure	2	2	3	16	12	30 - 75	9 - 13	340 - 550	450
sheep/goat droppings	1	3	1 - 2	30	20	30 - 100	30	100 - 310	200
chicken manure	0.08	4.5	-	25	17	1.5 - 2	5 - 8	310 - 620	460
human excreta	0.5	1	2	20	15	50 - 80	8		
corn straw	-	-	-	80	73	-	30 - 65	350 - 480	410
water hyacinths	-	-	-	7	5	-	20 - 30	300 - 350	325
vegetable residues	-	-	-	12	10	-	35	300 - 400	350
fresh grass	-	-	-	24	21	-	12	280 - 550	410

Figure 4 – Gas Yield (ÖKOTOP)

In order to fulfill the need of the Devikulum community by reducing harmful pathogens in the air, increasing sanitation and providing a cleaner source of energy, the production of the biogas in the plant must be greater (but only slightly) to that being consumed, to avoid a potential build-up of gas.

Luckily though, due to the current nature of the Devikulum community, we can expect some villagers may refuse to alter their current ways. In this way, the following calculations have taken into account the likelihood of only 75% of the community embracing the new biogas production plant. This also allows for flexibility in the biogas plant's production- should gas usage be higher than first anticipated, villagers will still be able to use previous methods for cooking etc. to allow the biogas levels to increase again. The plant must also be able to cater for demand when gas is not being produced and will consequently need storage room for the gas.

CALCULATIONS

From the information given by the EWB challenge, the following population statistics can be estimated-

- 358 People: approx. 131 in village, 121 in bottom colony, 99 in top colony
- 38 households in village, 27 in bottom colony and 23 in top colony
- 4 goats per household in top and bottom colonies (75% of households)
- 4 cows per household in top and bottom colonies (75% of households)
- 2 goats per household in village (25% of households)
- 2 goats per household in village (25% of households)

These values will form the basis of all following calculations

Gas production

$$\begin{aligned}\Sigma \text{ goats} &= \# \text{colony households} \times 75\% \times 4 \text{goats} + \# \text{village households} \times 25\% \times 2 \text{goats} \\ &= (27+23) \times 0.75 \times 4 + 38 \times 0.25 \times 2 \\ &= 169 \text{ goats}\end{aligned}$$

$$\begin{aligned}\Sigma \text{ cows} &= \# \text{colony households} \times 75\% \times 4 \text{cows} + \# \text{village households} \times 25\% \times 2 \text{cows} \\ &= (27+23) \times 0.75 \times 4 + 38 \times 0.25 \times 2 \\ &= 169 \text{ cows}\end{aligned}$$

$$\begin{aligned}\text{Cows yeild } 250\text{L per head per day of gas. (Fig 1)} & \quad \therefore \text{Yeild (cows)} = \Sigma \text{ cows} \times 250 \\ &= 169 \times 250 \\ &= 42,250 \text{ L/d}\end{aligned}$$

$$\begin{aligned}\text{Goats yeild } 200\text{L per head per day of gas. (Fig 1)} & \quad \therefore \text{Yeild (goats)} = \Sigma \text{ goats} \times 200 \\ &= 169 \times 200 \\ &= 33,800 \text{ L/d}\end{aligned}$$

$$\begin{aligned}\text{Humans yeild } 40\text{L per head per day of gas. (Fig 1)} & \quad \therefore \text{Yeild (humans)} = \Sigma \text{ humans} \times 40 \\ &= 169 \times 40 \\ &= 14,320 \text{ L/d}\end{aligned}$$

$$\begin{aligned}\therefore \text{Yeild (total)} &= 42,250 + 33,800 + 14,320 \\ &= 90,370\text{L/d} \\ &\approx \mathbf{3,760\text{L/hr}}\end{aligned}$$

Gas Usage

(Due to the unpredictable nature of the energy usage of the village (not knowing cooking habits etc.), a case study has been adapted for the purposes)

A community consisting of 8 people similar to the Devikulum community conditions used a total of 200L/d of gas in their daily duties including cooking, making tea and using gas lamps [NETSSAF].

By dividing this by 8, we can get the average usage per person, but multiplying this by 358 will provide a decent estimation to the energy consumption of the entire Devikulum community.

$$\therefore \text{Usage (per person)} = 2000 \div 8 = 250\text{L/d}$$

$$\therefore \text{Usage (total)} = 358 * 250$$

$$= 89,500 \text{ L/d}$$

$$\approx \mathbf{3,730\text{L/hr}}$$

***Estimated gas production > estimated gas usage, and therefore effective ***

Gas Storage Capacity

Using the above case study, the maximum gas consumption for the small community was 470L/h, by adapting this value for the consumption of the Devikulum community using the same technique as above:

$$\therefore \text{Consumption (max)} = 470 \div 8 \times 358 = \mathbf{21033\text{L/h}}$$

However, biogas is still being produced as this its being used, therefore the maximum decrease in gas is the maximum usage minus production

$$\therefore \text{Consumption - Yeild} = 21033 - 3760 = \mathbf{17283 \text{ L/h}}$$

As the case study community consumed the gas at this rate for 3 hours the total storage required will be the rate at which its being consumed multiplied by the time

$$\therefore \text{Volume (gas storage)} = 17283 \times 3 = \mathbf{51,850\text{L}}$$

And in order to account for fluctuations in this, it is then multiplied by a safety factor of 1.25, to ensure adequate gas should consumption increase by 25%.

$$\therefore \text{Volume (gas)} = 51,850 \times 1.25 = 65,000\text{L}$$

Sludge Storage Capacity

In order to cope with the amount of waste coming into the chamber and the amount of time it stays there before it leaves to the compensation tank and finally the drying bed, it has to be of sufficient size. In order to calculate this, the volume of waste going in needs to be estimated and the hydraulic retention time (HRT) needs to be decided. The higher the HRT, the greater efficiency of the biogas settler, however the volume is then increased resulting in a larger area required and increased costs. Ideally, the HRT would be over 100 days, but anything over 40 days is acceptable, for this case a HRT of 80 days will be used.

The quantity of manure (slurry) will be measured as follows:

Cows produce 8kg per head per day of manure. (Fig 1)

$$\begin{aligned} \therefore \text{Quantity (cows)} &= \Sigma \text{ cows} \times 8\text{kg} \\ &= 169 * 8 \\ &= 1352 \text{ L/d} \end{aligned}$$

Goats produce 1kg per head per day of manure. (Fig 1)

$$\begin{aligned} \therefore \text{Quantity (goats)} &= \Sigma \text{ goats} \times 1\text{kg} \\ &= 169 * 1 \\ &= 169 \text{ L/d} \end{aligned}$$

Humans produce 0.5kg per head per day of manure. (Fig 1)

$$\begin{aligned} \therefore \text{Quantity (humans)} &= \Sigma \text{ humans} \times 0.5\text{kg} \\ &= 358 * 0.5 \\ &= 179 \text{ L/d} \end{aligned}$$

$$\begin{aligned} \therefore \text{Quantity (total)} &= 1352 + 169 + 179 \\ &= 1700 \text{ L/d} \end{aligned}$$

Now as this will be stored in the tank for the HRT of 80 days, this will need to be multiplied by 80 to get the final volume of sludge in the tank.

$$\begin{aligned} \therefore \text{Volume (sludge)} &= 1700 \times 80 \\ &= 136,000 \text{ L} \end{aligned}$$

Volume of Tank

Now that the volume required for gas and that for sludge are known, these can simply be added together to determine the volume of the chamber

$$\begin{aligned}\therefore \text{Volume (total)} &= \text{Volume (gas)} + \text{Volume (sludge)} \\ &= 65,000 + 136,000 \\ &\approx \mathbf{200,000L}\end{aligned}$$

As we do not expect the whole of the Devikulum community to embrace the new system, we will then need to multiply this number by 0.75, for the 75% of villagers that will end up using this system

$$\begin{aligned}\therefore \text{Volume (adjusted)} &= 200,000 \times 0.75 \\ &= 150,000L\end{aligned}$$

By using the formula for the volume of a hemisphere, it can then be calculated that the radius of the chamber will be in the vicinity of 4.2m

$$\begin{aligned}150,000 &= 150\text{m}^3 \\ 150 &= (2 \cdot R^3 \cdot \pi) / 3 \\ \therefore R &\approx 4.2 \text{ m}\end{aligned}$$

Volume of Compensation Tank (CT)

The volume of the compensation tank is equal to that of the volume of the gas in the main chamber, in order to allow for an excess of gas being produced without excessive pressure in the chamber.

$$\begin{aligned}\text{Volume (gas)} &= 65,000L = \text{Volume (CT)} \\ \therefore \text{Volume (CT)} &= 65,000L \times 75\% \\ \therefore \text{Volume (CT)} &\approx 50,000L = 50\text{m}^3 \\ 50 &= (2 \cdot R^3 \cdot \pi) / 3 \\ \therefore R &\approx 2.9 \text{ m}\end{aligned}$$

FINAL DESIGN

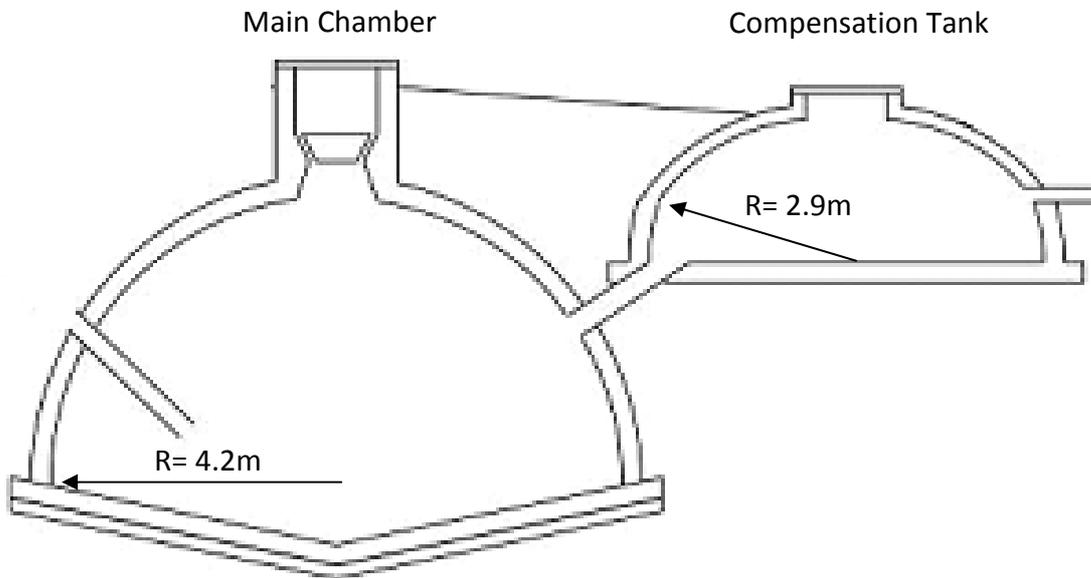


Figure 5 - Final design of the biogas chambers including the radius in order for it to be effective (ÖKOTOP)

TRANSPORTATION OF MATERIALS

To implement this project, we must first transport all necessary goods to the site of location. Pondicherry possesses all necessary resources to do so. However, road conditions leading into Devikulam very poor, especially in wet season and the roads are also rather narrow. This affects the size of the trucks meaning they would have to be smaller therefore either more trucks will have to be hired or the trucks would have to make more rounds. In order to limit the impact of the trucks on the environment, it will be better if more trucks were used rather than making more than one rounds. Once materials have reached the village, wheel barrels and possibly ox carts or something similar would be used to transport the materials to the main site where it will all be build.

A one way trip to the village will take approximately 1 hour at minimum. However travel time may vary depending on factors such as weather, state of road and frequency of people using it. The total distance of Devikulam from the city of Pondicherry is approximately 50 kilometres. A map with a suggested route to take has been provided below.

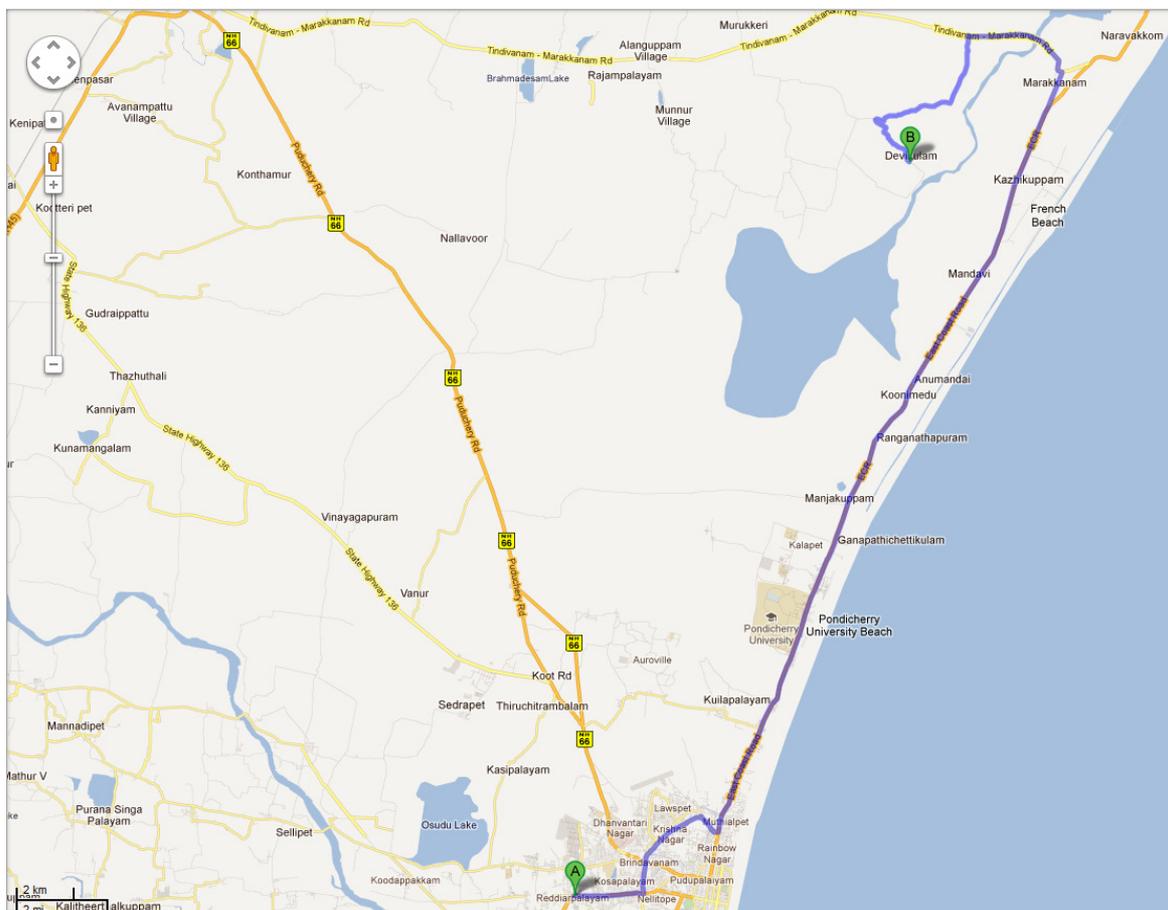


Figure 6 - Suggested route (Google Maps, 2011)

REASON FOR DESIGN

In order to accommodate the entire village, a 200 000 litre tank is required. However, it is expected that not all the villages will fully cooperate with the idea. Therefore the tank has been reduced in size by 25% to a 150 000 litre tank. People in the village who have lived without using toilets ever since were born will require time and education in order for them to accept the new plan. This can be done by teaching the villagers the many possible benefits that the plan may provide and that there is nothing wrong with using a toilet.

COSTPARTS

Biogas Digester:

Concrete:

- Base: 56 x 0.4m x \$50 per m (cubed)	\$1,120
- Walls: $(4/3\pi r^2 \text{ cubed}/2 - \text{inside}) \times \50	\$2,320
- Base (small tank) 28m(sqrd) x .4 x \$50	\$560
- Walls (small tank) $(1/2)4/3\pi r^2 \text{ cubed} - \text{inside}$	\$713
- Corrugated Iron: 50m sqrd x \$80/m sqrd.	\$4,000

Gas Pipes: 3000m x \$7/m \$21,000

Toilet Room: \$300

DELIVERY

Transportation: \$5,500

SETUP

Installation: \$2,000

Connection to Homes: homes 38 x \$50 \$1,900

LABOUR

On site engineer: \$2000

Hourly rate x # of labourers: \$30 x 10 x 40hours \$12,000

MAINTENANCE

Labour: \$1,000/year

Allowance for damages: \$500/year

SAVINGS

Gas: \$2,000/year

Fertilizer: \$200/year

TOTAL COST: \$52,713

SOCIAL IMPLEMENTATION

For any new program or service to work successfully in rural India it is important that the entire community is on board. Forcing a scheme upon the group will result in resistance and see the scheme fail due to lack of use and support. To ensure that the biogas settler is used to its full potential a well-developed behaviour change program must be created with the views and values of the community kept in mind.

On a broad scale, the following behaviour change models may prove useful in both the planning and implementation of this project;

- *TRANSTHEORETICAL MODEL (TTM)*: Developed by Prochaska and DiClemente in 1985, this model gives an insight into the thought process taken when people are faced with change (Department of Transport (Vic), n.d). As there may be communication barriers and delays between those implementing the program and the citizens in the planning stage must be thorough. To make the most of face to face contact time the TTM model can be used as a planning and understanding tool.
- *DIFFUSION OF INNOVATION*: This concept attempts to estimate the rate of take up of change (National Centre of Sustainability, 2011). This model makes an attempt to understand and analyse the time difference in innovation acceptance between participants. It will be useful in the planning stage as it provides further insight into how and more importantly when the group may react to the innovation.

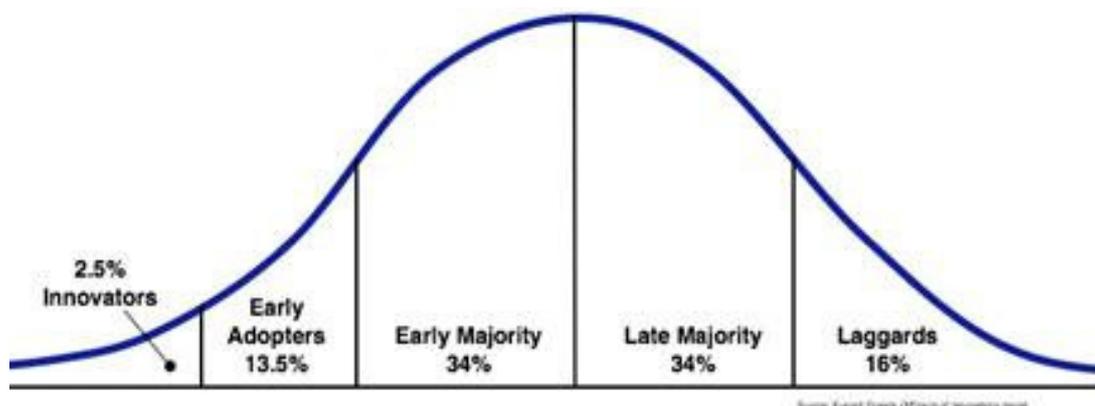


Figure 7 – Diffusion of Innovation Curve (National Centre of Sustainability, 2011)

- *COMMUNITY BASED SOCIAL MARKETING (CBSM)*: Detailed planning and preparedness will assist in implementing a successful program with few surprises and hitches along the way. The CBSM model will be a valuable tool here, providing a useful framework for the entire project life time.

The stage which calls for the development of tools to overcome possible change barriers will be priceless in pre-empting participant resistance and hopefully provide options for addressing such issues. The key steps in this process are;

- Identification of the behaviours to change
- Brainstorming of barriers and drivers
- Development of tools to overcome barriers and reinforce drivers
- Piloting and implementation of the program
- Evaluation of the program and adjustment of its running accordingly

There are a number of factors that may hinder the effectiveness or success of this initiative from technical, cultural and economic standpoints. The first hurdle that must be overcome pertains to the design of the plant. It is important that the plant is not too large or too small as both errors will result in underfeeding of the system and consequential failure. Projected participation rates of householders and the wastes they contribute must be accurate so to ensure that the most efficient size digester is built. Unexpected events such as drought, flood and alike must also be factored in to the design as they will all effect the unit directly as well as the biomass sources.

Construction is also a very important issue to consider. It has been reported in other cases across India that prudence when it comes to finding, employing or training skilled workers has seen the failure of a number of systems (*Lawbury, J, n.d*).

Government support for such programs can be very difficult to secure and can be unreliable once secured. This further highlights the need for true support of the community of Devikulam themselves.

Persuading the citizens to approve of as well as actively engage in the biogas settler initiative will be pivotal to the program's success. It is important that the unique concerns of the population are understood and addressed as well as any other barriers to this change. In a town where only three houses own fridges, the installation of a large 'machine' may be prove daunting (*Engineers Without Borders, 2011*). There is also the possibility of religious or cultural beliefs reducing the use and acceptance of the unit. The following plan has been developed in an attempt to avoid or overcome some of these barriers and support a successful innovation;

- *Education* – the citizens must be schooled in how the innovation works in simple to understand terms that all of them can comprehend and appreciate. This will be most effective if done by a person who speaks the local language and is from a nearby area as there may be a better sense of trust between them and more chance of the citizens asking questions and alike. This education should include the inputs into the system, how the system converts these products and most importantly the resulting products of the system and the advantages of using them.
- *Involvement in planning and construction* – as the citizens will have to 'feed' the system it is vital that they are satisfied with placement, layout and construction plans for it. Comments and concerns of citizens should be taken on board when finalising the planning stage. Implementing the construction of the system as a town project and getting as many people as possible involved in some part of the construction and logistics surrounding it will help to create a sense of ownership over the system and hopefully increase the chance of take up.
- *Post installation jobs* – there will be a need for a small amount of citizens to be employed to maintain the system as well as engage in the de-sludging process. This task will provide jobs for the community or could even be based on a rotational timetable system.
- *Examples from other villages* – the voice of other locals who have had biogas settlers installed in their villages will work wonders in Devikulum. These examples can demonstrate how successful and fruitful the scheme can be and also help to dampen any concerns the citizens have.

- *Cultural* – there is a concern that cultural values and beliefs may conflict with the use of this system. This issue has been dealt with in other communities by reinforcing the vision of the revered Mahatma Gandhi and his belief that one day Indians would live in self-sufficient communities obtaining their needs from the local environment and generating income and benefits from co-operative structures (Lawbury, J)

ENVIRONMENTAL IMPACT

As previously mentioned, present day waste management and energy sources in Devikulum are substandard. This project will have many positive environmental effects seeing a sustainable shift in the area, these include;

- Lower odour due to reduction in open defecation
- Reduction in spread of disease due to less waste left openly across the town
- Reduction of greenhouse gas emissions of present fuel/energy sources
- No external energy source required
- Generation of sustainable and cleaner biogas
- Generation of sustainable natural fertiliser
- Reduced demand on electricity grid

SOCIAL IMPACT

There are a total of 350 people (86 families) living in Devikulum (2010). The Devikulum household occupancy is generally between 4 - 7 people per family. Their houses are mostly hut styles built with either cement or mud floors, walls are usually made from mud or burnt brick with a thatched roof or one that is made from palm leaf and this is a clear reflection of their low social status. Most of the houses generally have thatched bathrooms without a toilet most community members rely on open defecation as the common practice, which poses a lot of health issues to the whole community. According to Nag and Vizayakumar (2005) 'solid waste provides an attractive habitat to disease vectors' such as flies or rodents. These are some of the health hazards that could be reduced if the biogas settler project were to be implemented successfully. Most households own some livestock with a variation from cattle, goats or chickens and in most cases ownership of such animals could be a measure of wealth within their households, meaning the more livestock you have the more capable you are of feeding your family.

The main form of employment for the people of Devikulum is limited to farming and agricultural labour, practiced mainly within their communities. A few lucky people are employed as prawn farming labourers in surrounding farms or by the local fishing industry. Again this is a reflection of their low social status which in turn determines limited access to health care. With the introduction of the biogas settler it is anticipated that disease prevalence will be lower and the community would improve their health status.

Poor communities like Devikulum are always faced with health and environmental issues such as the problem of waste disposal and the lack of sustainable energy sources like most developing countries in the third world. In most cases such communities discharge untreated waste or rely on untreated water for their daily consumption according to Amuda and Ibrahim, (2006). Lack of infrastructure facilities, such as the simple biogas project, poses a lot of health and wellbeing challenges and often leave these communities exposed to diseases.

If successfully implemented, the biogas settler project has the potential to improve the quality of air in the atmosphere, particularly around Devikulum, by eliminating odours from waste

that is dumped everywhere. There is anticipation for an increased demand for a variety of agricultural products arising from increased use of fertilizer that is a by-product of the whole process. This will in turn make more food available to the community and with a wide choice than the present state.

As a result of the project there is a likelihood of social issues such as the creation of employment opportunities for those who would be in charge of the project maintenance. The expansion of agricultural activities could result in increased food production and most importantly improved health and wellbeing. The biogas settler project would enhance Devikulam people's ability to develop sustainable economic activities that are designed in such a way that it could reduce poverty in their community.

REFERENCES

- Amuda, O.S and Ibrahim, A.O (2006) *African Journal of Biotechnology*, Vol 5 August, Academic Journals, Lagos.
- Department of Transport (Vic), Theories and models of behaviour change.pdf. Available at: [http://www.doi.vic.gov.au/doi/doielect.nsf/2a6bd98dee287482ca256915001cff0c/ea8a984b717095bca256d100017ba50/\\$FILE/Theories%20and%20models%20of%20behaviour%20change.pdf](http://www.doi.vic.gov.au/doi/doielect.nsf/2a6bd98dee287482ca256915001cff0c/ea8a984b717095bca256d100017ba50/$FILE/Theories%20and%20models%20of%20behaviour%20change.pdf) [Accessed August 30, 2011m].
- Devikulam Information, Story of Devikulam. Available at: http://www.buzza.in/Gramap2/Devikulam_information.html [Accessed August 20, 2011].
- Engineers Without Borders Australia, 2011
[<http://www.ewb.org.au/explore/initiatives/ewbchallenge/2011ewbchallenge/maps>]
- Engineers Without Borders, 2011, available at
[<http://www.ewb.org.au/explore/initiatives/2011ewbchallenge/transportation>]
- Engineers Without Borders, 2011. Energy - Engineers Without Borders Australia. Available at: <http://www.ewb.org.au/explore/initiatives/2011ewbchallenge/power> [Accessed September 15, 2011].
- Google Maps, 2011, available at
[http://maps.google.com.au/maps?hl=en&sugexp=gsis,i18n%3Dtrue&cp=13&gs_id=49&xhr=t&q=devikulam+tamil+nadu&pq=trucks+to+devikulam+india&safe=off&biw=1920&bih=971&gs_upl=&bav=on.2,or.r_gc.r_pw.&um=1&ie=UTF8&hq=&hnear=0x3a536ddcd68e31f:0x87baccd5be10afa4,Devikulam,+Tamil+Nadu,+India&gl=au&ei=49xuToq9FK3ymAWZsqWPCg&sa=X&oi=geocode_result&ct=title&resnum=1&sqi=2&ved=0CBgQ8gEwAA]
- Index Mundi, Australia Life expectancy at birth. Available at: http://www.indexmundi.com/australia/life_expectancy_at_birth.html [Accessed September 12, 2011].
- Lawbury, J., Biogas Technology in India: More than Gandhi's Dream? Available at: <http://www.ganesha.co.uk/Articles/Biogas%20Technology%20in%20India.htm#Table> [Accessed September 14, 2011].

Nag, A. and Vizayakumar, K. (2005) *Environmental Education and Solid Waste Management*, New International Publishers, New Delhi.

National Centre of Sustainability, Course Materials. *Blackboard Learn*. Available at:

http://ilearn.swin.edu.au/webapps/portal/frameset.jsp?tab_group=courses&url=%2Fwebapps%2Fblackboard%2Fexecute%2FdisplayLearningUnit%3Fcourse_id%3D_107750_1%26content_id%3D_2252543_1%26framesetWrapped%3Dtrue [Accessed August 20, 2011].

NETSSAF (2006)- Small-Scale Biogas Sanitation Systems

[http://www.google.com.au/url?q=http%3A%2F%2Fwww.netssaftutorial.com%2Ffileadmin%2FDATA_CD%2F06_Step6%2F10_Biogas_Sanitation_Systems_-_NETSSAF_20080714.ppt&sa=U&ei=pw9fTvfBE-rViAKz1Zi2Dg&ved=0CB4QFjAF&usg=AFQjCNFY1v0I6Pjk8bDYZrVZkzXu43G_pA]

ODAM, 2011. Charcoal Briquette. Available at: <http://www.odamindia.org/our-projects/climate-change/charcoal-briquettes/> [Accessed August 20, 2011].

Poverty Action Lab, Cooking Stoves, Indoor Air Pollution, and Respiratory Health in India.

Available at: <http://www.povertyactionlab.org/evaluation/cooking-stoves-indoor-air-pollution-and-respiratory-health-india> [Accessed September 15, 2011].

Raven, P.H. Berg, L.R. Johnson, G.B (1998) *Environment* 2nd Ed, Saunders College Publishing, New York.

SSWM (2010)- Biogas Settlers [<http://www.sswm.info/print/1249?tid=854>]

SSWM, Direct Use of Biogas, 2011, <http://www.sswm.info/category/implementation-tools/reuse-and-recharge/hardware/reuse-energy-products-form-waste-and-was-1>

T R Preston and Lylian Rodríguez, Low-cost biodigesters as the epicenter of ecological farming system, [<http://www.mekarn.org/procbiod/prest.htm>]

UNICEF, 2010. India - Statistics. Available at:

http://www.unicef.org/infobycountry/india_statistics.html [Accessed September 12, 2011].