

Small Scale Biogas plants for the treatment of Food Waste

Final Report Submitted to the Waste Management Board on the
completion of Contract (10587)

Dr Jaya Nair

Environmental Science, Murdoch University

April, 2010

Contents

1.0	Introduction	2
2.0	Anaerobic treatment process	3
3.0	Pilot Project at Murdoch University	4
4.0	Problems encountered, lessons learned and modifications made	6
5.0	Significance of this project to Zero Waste Strategy	7
6.0	Constraints for project implementation and recommendation	10
7.0	Acknowledgements	11
	Appendix 1. Pamphlet prepared for publicising the technology	13

Small Scale Biogas plants for the treatment of Food Waste

1.0 Introduction

Food and vegetable waste come under putrescible waste which is a serious environmental and economical concern all around the world. The fast and highly decomposable nature of this waste demands efficient management for it to become a sustainable operation. Since these wastes are generated in large quantities in highly populated and urban areas, the space available for it to be handled is very limited. It has become a global threat to the environment and health due to its inappropriate disposal in the developing countries, while in developed countries a majority of them is still ending up in landfills. In many places vegetable waste are taken away by farmers as animal feed, however mixed vegetable and food waste is still a problem to manage. Alternate methods to landfilling these wastes include composting and anaerobic digestion. Composting process has several practical difficulties in utilising food waste. Food waste to compost has been tried and tested in many parts of the world, UK, Australia (Ozharvest, Sydney, nsw; Greentable Canada). Anaerobic digestion has proved to be an efficient process to handle animal and human waste and has received attention as a renewable energy production method while treating wastes simultaneously. However the technology is not yet developed for small scale application in urban areas especially to deal with putrescibles wastes.

It has been estimated that in Australia around 2.17 million tonnes of food waste is thrown out by the food industry and almost 90% of waste in the bins from restaurants and caterers are recyclable or compostable and 25% of which is food. This food waste is worth around \$5.2 billion per year. The foods most wasted are fresh fruit and vegetables and take away/restaurant food. In general, it was found that higher

the household income and the lower the number of occupants, the more food was wasted. (What a waste (2009) www.tai.org.au).

2.0 Anaerobic treatment process

The technology involves treatment of organic wastes in a closed system in which a series of processes occurs where micro organisms break down biodegradable material in the absence of oxygen. This technology can be integrated with waste treatment, energy generation and organic fertiliser production systems very efficiently. Environmental legislations in UK and in other developed countries have increased the application of anaerobic digestion as a process for managing waste as well as source of renewable energy. Almost any organic material can be processed with anaerobic digestion although it is widely used to treat wastewater sludge farm and agricultural wastes with the exception of woody wastes. Using centralised large scale systems for treating municipal waste is also becoming common throughout the world. Farm-based anaerobic digestion systems are common in India and China as well as in other Asian countries due to the potential for cheap, low-cost energy for heat and electricity.

Anaerobic digestion of organic wastes therefore has several advantages:

- Treat organic waste without any emissions as that occur in landfills
- Gases generated from the process can be easily converted to renewable energy
- Nutrient rich treatment effluent can compensate for the industrially-produced chemical fertilisers.
- Reduced dependency on fossil fuels while also contributing to electrical power grids.

The four key biological and chemical processes of the treatment are hydrolysis, acidogenesis, acetogenesis and methanogenesis which occurs normally in a sequential pattern depending on the function of the system. A well functioning system will be able to maintain methanogenesis stage without getting stuck at the acidogenesis and acetogenesis stage. The task of technology standardisation is to

achieve this condition by adjusting the input (ingredient) quantity and quality, pH with the temperature conditions. The digestors are designed depending on the input and output requirements as

- Batch or continuous
- Single stage or multistage
- Mesophilic or Thermophilic
- Liquid or solid wastes

3.0 Pilot Project at Murdoch University

The present project was aimed at standardising a small scale continuous, single stage, mesophilic digester for treating food and vegetable waste. A need was identified for small scale digestors as considerable amount of putrescibles waste such as kitchen, food and vegetable waste can be diverted from the main waste stream and managed efficiently with recoverable outputs.

During this one year project, a 2 ton digester was designed, fabricated and upgraded as and when hurdles were encountered and standardised the technology (figure 2). Both biogas and digestate, the products of the process were assessed for their quality and quantity..



Fig 1. Small scale biogas plant at Murdoch University

The study showed that food and vegetable waste can be effectively treated in small scale digestors such as the 2 ton plant under study. This plant is a continuous treatment process with a capacity of about 30-40 kg of solid waste (food and vegetable waste) per day, taking around 10-15 tones of waste from landfill/centralised treatment facility per year.

Methane started to generate in 30 days of start up from the 2 ton plant with vegetable and food waste to about 1-3 cum/day. Because of this low quantity generated from a 2 ton plant, this capacity may not a feasible as a energy generation option and larger plant capacities should be able to generate gas to a quantity that could be used for heating purposes (hot water systems) (Figure 2). It was found that food wastes produce more biogas than vegetable waste.



Fig 2. Biogas collected and used for cooking from the treatment of food waste

A minimum daily monitoring and management is necessary to operate the plant which could be, putting waste to the pulper and feeding the digester, making sure there are no plastics or non degradable material in the waste stream, daily monitoring of the temperature and pH and disposal/reuse of the effluent.

Table 1 shows the general treatment of the meat and bakery waste from Woolworths Store. The digestate was tested for their quality and against the fertiliser quality. The digestate as shown in Figure 3 which is rich in plant nutrients and odourous liquid that needs further dilution/treatment for onsite use as a fertiliser. Studies related to the use of the digestate as fertiliser as the method of application, dilution required and treatment of odour are under investigation.

Table 1. The treatment achieved for food and vegetable wastes

Parameters	Input	Digestate
pH	3.73	5.50
COD (mg/l)	7860	428
Total solids(%)	36	
TVS/g	44	
Nitrate(mg/l)		0.00
Phosphate(mg/l)		212.00
Ammonia(mg/l)		23.20



Fig 3. Pulped meat and bakery waste (left) and the treated digestate from the digester

Studies are continued with changing parameters as to different feed strength and two stage process to improve the efficiency of treatment.

4.0 Problems encountered, lessons learned and modifications made

Formation of scum: During the initial trials after two months of feeding with food waste, lawn clippings and vegetable waste, a thick scum was produced which

completely blocked gas production. It was identified that lawn clippings are not a suitable feed material for small digestors although that was the main material used in several laboratory scale research.

It was noted that the digester work better in terms of treatment and gas production if the feed is pulped. Therefore a pulper was designed, fabricated and used in the study.

pH was found to highly fluctuate and more in the acidic range when using meat and food waste as the ingredient. In small scale single stage digestors, pH adjustment through inputs such as lime is essential.

Temperature stabilisation was found to have an impact on methane production. Simple insulation of digestors should be sufficient to maintain a mesophilic temperature in the plant.

Methane production: Methane production in small scale digestors particularly that treat food waste is highly variable. As a result even if the methane output is not the maximum, the effluent achieves a good level of treatment and is usable as a liquid fertiliser. In those cases methane generation/ energy conversion should not be the sole indicator of the success of the project, rather a treatment plant for a highly complicated waste stream. Small Scale digestors should be benefited from converting highly putrescibles and complicated waste to handle to a useful byproduct such as organic fertiliser for market gardens.

5.0 Significance of this project to Zero Waste Strategy

 **How has your project contributed in improving the environmental impact of waste within your project 'priority area'? (please state which priority waste area your project was addressing)**

The project as envisaged has proved that

- It is possible to treat the highly complicated food waste as the meat and salad waste onsite without any negative impact on the environment
- The gaseous output can be completely trapped and used as fuel or energy onsite preventing any GHG emissions to the environment

- The liquid output has been proved to be a good organic fertiliser, and the usage criteria were also identified. This has a potential of reducing chemical fertilisers, improve organic content of the soil and save water for irrigation.

✚ Was your project successful in the way you expected? If not, why not?

Yes the project was successful however it was hoped that there will be at least one plant implemented outside this project during this period. Although other projects were discussed no project/ contract has been started. A few projects that are under discussion are the future hope for this project.

✚ What lessons were learned through the project? Please describe any strengths or weaknesses of the project and what, if anything, you would do differently if you were to do the project again

The project identified several design problems for the small scale digestors and most were rectified. Some knowledge achieved through this project will be utilised in the next opportunity. The project revealed that pilot scale projects are important to test the validity of laboratory results as some different observations were obtained as to the type of waste that can be incorporated and the technical problems that could arise in a real system. Consistency in methane production is also questioned in the pilot project in contradiction to the laboratory studies.

The main hurdle identified is in the implementation of the plant for specific industry. The waste disposal strategy of the councils needs to be revisited to improve onsite management of waste and to find the full potential of this method for organic waste management.

✚ Were you able to complete your project in the approved timeframe?

Yes, the project was completed on time.

✚ If there were variations, what were the cause(s)?

NA

✚ How did you acknowledge the Strategic Waste Initiatives Scheme funding you received?

The funding was acknowledged in all publications and in all references made on the small scale biodigester project with other potential projects.

✚ Was any promotional material for the project produced? (if so, please attach copies of flyers, brochures etc)

One brochure was prepared and attached is the copy

✚ Were there any promotional opportunities for the project? (if so, please attach copies of newspaper articles, photos etc)

Attached are the hard copies of the promotional materials. Besides, this project gave an opportunity for the investigator to be part of Bioenergy Australia and Biogas Australia discussion groups.

This project received considerable interest locally and nationally. Articles on this project appeared in Murdoch University newsletter, DEC Waste management news, Waste Magazine etc. Based on that, there were considerable interests and the plant was visited by officials from several institutions. Some of them are EMRC, Corrective services, Fremantle council, Rottnest Island Management, Belmont Council and Ascot Race Course.

Training provided

- 1 PhD project
- 1 Honours Project
- 1 Master's Project
- 1 fourth year undergraduate project
- 2 research assistants
- Hundreds of school students as well as officials from various departments visited the project.

✚ Did any opportunities or ideas arise during the project?

A research on modelling the capacity of the digester vs the methane utilisation potential is under way which will be completed in two years time. The potential and the limitations of using the treated effluent are studied through an honours research which will be completed in June 2010. There are some small projects that were

undertaken and are planned for specific waste stream such as the Ascot Race Course.

Other projects that emerged out of this are

- Hakea Prison waste audit and management options
- Casuarina Prison waste and wastewater treatment and management options
- Woolworths Store, Southlands shopping Centre meat and bakery waste treatment (In discussion with their Central Office for large scale project)
- Request for consultancy of setting up and standardising a large scale plant for food waste treatment in Melbourne (under discussion)
- Treatment of Ascot Race Course solid waste from stables and premises (discussion with EMRC, Belmont council and Ascot Race Course)

Besides there has been several interest some of which might turn out to be successful in future.

Other funding received

- Discoverer's grant, Murdoch University- \$19,456
- Strategic Research Grant for sludge treatment- \$21,000
- Hakea Prison waste audit-\$3200
- Casuarina Prison project-\$3200

6.0 Constraints for project implementation and recommendation

Funding for institutions for setting up a waste treatment plant was found to be a major drawback. The current convenient disposal method adopted by the institutions makes them reluctant to consider alternate options. Specifically waste disposal to council bins and the regular collection currently in place in urban areas takes the responsibility out of the waste generators without bothering on onsite treatment or end artefact of the waste that gets generated.

Councils should take strategic steps to encourage onsite treatment of putrescibles waste generated from businesses. This could be by imposing businesses to show solid waste treatment and disposal arrangements in the business plan, increasing

the putrescibles waste collection charges, providing space, financial and technical support for businesses.

7.0 Acknowledgements

I greatly appreciate the funding from Waste Management Board (SWIS grant), DEC to undertake this research. The supplementary funding from Murdoch University as Discoverers grant and Strategic Research grant has also helped to undertake research further than the scope of individual project.

A number of students, research students and research assistants were involved in this project at various stages and at various capacities. The design and fabrication support of the pulper from Leslie Westerlund is greatly acknowledged. The help and input from Melchior Matak, Supot Phaotanyak, Willie Liberty, Bernhard Baeumi, Robbie Cocks, David Goodfield, Sergio Domingos are thankfully acknowledged.

Treat Organic Wastes in a simple On-Site Anaerobic Digester

Troubled times with regard to various environmental issues have led to an increase in environmental awareness among many sectors. Organic waste management in particular is a major area of concern and there is a need for proper waste management. Traditionally, organic waste is collected by the Council waste collection facility and is deposited in landfills. Disposing of waste in landfill has numerous problems.

1. Release large amounts of greenhouse gases into the atmosphere – approximately 1.287 ton CO_2e /ton putrescible waste
2. Take up much needed space for increasing landfill area
3. Fuel utilization in the transportation of waste to landfill sites
4. Infrastructure and management costs of landfills are exorbitant

These pressing issues have led the Western Australian government to introduce the 'Towards Zero Waste' Initiative to promote diversion of waste from landfills. The main strategy will be to treat organic waste at its point of generation. Anaerobic digestion is a process that treats organic waste in the absence of oxygen. This results in the production of biogas and some effluent. The biogas produced comprises of approximately 80% methane (CH_4) and 40% carbon dioxide (CO_2).

Operations of an anaerobic digester (AD)

Putrescible waste is blended with liquid and fed into an air tight AD. Waste degrades anaerobically in the digester producing biogas and a liquid sludge as by products of decomposition. The biogas can be collected separately and the effluent stored in storage tanks for use as fertiliser. The biogas can be used as a gaseous fuel for heating or potentially be converted to electricity. The process of treating putrescible waste via anaerobic digestion is shown in Figure 2.

Faced with the need to seek alternative waste management strategies to landfilling, there are numerous advantages to support on-site anaerobic digestion for the treatment of organic waste.

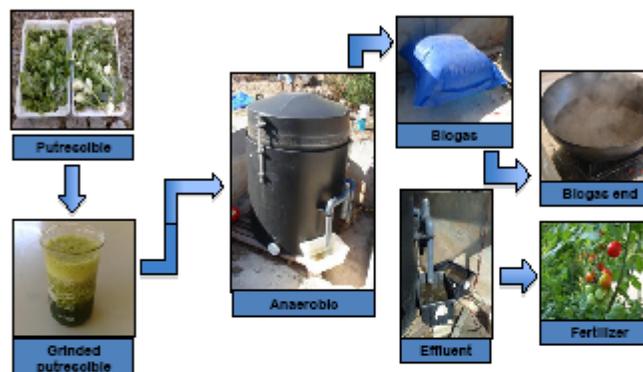


Figure 2: Process flow diagram of treating putrescible waste via anaerobic digestion. This process and images originate from a pilot scale plant located in the Environmental Technology Centre

Advantages of On-site Anaerobic Digestors

1. Divert waste away from landfills/minimal environmental footprint
On-site treatment of waste eliminates the usage of transportation to landfills. In addition, diverting waste from landfills reduces the demand of valuable land for landfill expansion.
2. Help mitigate climate change
 CH_4 is a greenhouse gas (GHG) which has a global warming potential 25 times that of CO_2 . In landfills where landfill gas is not captured,

approximately 1.287 ton CO_{2-e}/ton putrescible waste is produced. On-site anaerobic digester captures the CH₄, preventing its release into the atmosphere. In addition, the biogas produced can be used as a form of energy, creating potential carbon offsets. An approximate estimate of GHG emissions from various waste management strategies are presented in Figure 3

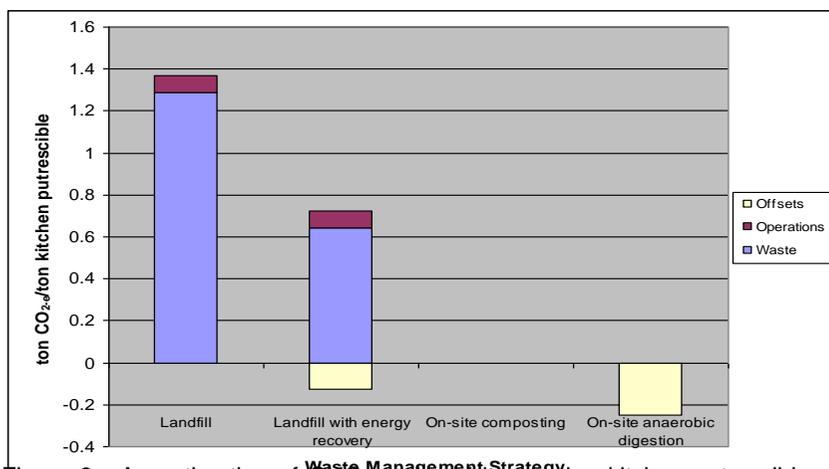


Figure 3: An estimation of GHG produced by treating kitchen putrescible waste through a variety of waste management options (Lou, 2008)

3. Treat both liquid and solid organic waste

Unlike other organic waste treatment technologies such as composting or wastewater treatment systems, anaerobic digestion can treat both solid and liquid waste together in one process.

3. Reduced pests, dust and odour issues

As the anaerobic digestion process is in an air tight container, vector, dust and odour issues are minimal as compared to utilizing a landfill or composting approach.

4. Reduce labour and operational cost

Once built, the anaerobic digester requires relatively simple management with the main expenses being employing casual labour to oversee their operation and to feed them with waste daily.

5. Potential generation of green energy (WASTE TO ENERGY)

The biogas produced is high in CH₄, which can be used directly as a fuel gas to operate gas fuelled devices like a gas stove or hot water system. There is also the potential of electricity generation using a generator.

6. Production of fertiliser

The effluent produced from the anaerobic digester can be used as a high quality fertilizer. The digestion process increases the solubility of the nutrients, facilitating improved nutrients uptake by plants. The effluent can be used in organic farming which will reduce the cost and need of having to purchase fertilizer off-site.

7. Availability, Flexibility and Portable

Unlike certain renewable energies such as solar and wind, energy produced from anaerobic digestion is available all the time. An on-site anaerobic digester is fairly portable and has a small foot print. The digester can be scaled according to the quantity of waste to be treated. Anaerobic digesters can be utilized by councils, mining villages, remote and rural communities, supermarkets, zoos and housing estates among other applications.

(The project is supported by SWIS grant of Waste Management Board, DEC, Discoverer's grant and Strategic Research grant of Murdoch University, Western Australia)

For more information, please contact:

Dr Jaya Nair
 Director
 Environmental Technology Centre
 Murdoch University
 Email: j.nair@murdoch.edu.au
x.lou@murdoch.edu.au
 Phone: (+61)8 9360 7322

Xian Fang Lou
 PhD Candidate

Email:

Phone: (+61) 8 9360 6399