ANAEROBIC DIGESTER IMPLEMENTATION STUDY IN A LOW INCOME COMMUNITY

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Abstract. *This work analyzed the feasibility of implementing a micro-scale anaerobic digester at Jardim Conceição, a low-income community in the outskirts of São Paulo metropolitan region (Brazil). The initial idea was to replace the cooking gas for biogas formed by the anaerobic digestion of organic waste generated by their own households. A quantitative survey on production of organic waste and consumption of cooking gas from a portion of the population of the community was conducted, indicating that the weekly potential of biogas production per capita is about 0,12 m^3 versus a demand of about 1,12 m^3 per capita. As the initial idea was not feasible, the usage of families' organic waste to electricity generation for the community centre was analyzed. The proposed system configuration is a battery of 14 batch biodigesters, a 3,5m^3 gas tank and a 750W generator, and the implementation costs are estimated to be R$ 10.970,00.*

Keywords*: Anaerobic Digestion, Organic Solid Wastes, Low-Income Community, Energy generation*

1. INTRODUCTION

One of the world current most serious problems is urban waste. This problem is directly related to the steady growth of populations that require increased food production and industrialization of raw materials, thus contributing to the increase of solid waste.

Solid waste is defined by Brazilian Standard NBR 10004 (ABNT, 2004) as solid and semi-solids resulting from industry, domestic, hospital, commercial, agricultural, services and sweeping activities. One example is the slurry from water treatment systems, generated in equipment and plant for pollution control as well as liquids the characteristics of which make them infeasible for launching in public sewers or water bodies, or which require technically, technologically and economically unfeasible solutions.

A fact to be considered is that as populations grow, especially in large urban centers, the areas available for waste disposal are reduced. The improper disposal of waste without any treatment can pollute the soil, altering its physical, chemical and biological condition, besides making it an esthetic problem and a refuge for animals and insects, posing health risks.

According to the 2008 National Survey of Public Sanitation, conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2008), 259.547 tons/day of garbage are produced in Brazil, and Table 1 gives us an idea of its final disposal nowadays. Comparing 2008 figures to the same survey conducted in 2000 (IBGE, 2000), there is a significant improvement in the final packaging of waste, as dumping in open dumps fell from 21,3% to about 17,6%, and there is an increased representativeness of landfills, jumping from 36,4% to 64,6%.

Garbage, despite being waste, presents a considerable energy potential; some landfills are known as power-producing, as quoted Aisse & Zeny (1986), as they have systems that capture methane from decomposing organic waste and use it to generate electricity. Considering that the average organic waste fraction in Brazil is 52,5% (Naval & Gondim, 2001), and analyzing the quantities disposed in open dumps, it can be verified that there is a significant energy potential being wasted. While in European countries the energy potential of solid waste is widely used, in Brazil is still a little explored area.

Table 2 presents the Brazilian annual food consumption per capita, considering family monthly income, according to the 2002-2003 Consumer Expenditure Survey (IBGE, 2003). Such table also present estimates for provides data on the weekly average of food waste generation per capita (Akatu, 2003).

Based on this scenario, our objective was to examine the feasibility of implementing a solid waste digester for biogas production by anaerobic digestion of food leftovers in low-income neighborhoods. Among the advantages of anaerobic digestion, are the reduction of the volume for final disposal, free air pollution conversion, producing of a stabilized sludge with desirable characteristics that can be used as fertilizer and methane formation which can be used as fuel (Gorgati & Lucas Jr., 2000).

The site chosen for the study was the Jardim Conceição neighborhood, located in the outskirts of Osasco, a city belonging to the metropolitan region of Sao Paulo, Brazil. The neighborhood started with the land occupation late in 1987 and since then the disordered occupation has expanded. Nowadays there are about 11.000 inhabitants in the neighborhood, predominantly low-income families.

The analysis included possible usages for the energy potential of biogas to be generated. It was analyzed the feasibility of replacing the families LPG (liquefied petroleum gas) for cooking, as well as replacing grid-purchased electricity demand of the community center. Independently of the final biogas usage, it is possible to provide a sustainable solution to the community and also to establish sustainable practices in Brazil and to foster activities involving social responsibility.

Table 1. Brazilian solid waste disposal

	2000		2008	
	ton/day	%	ton/day	%
Open pit dump	48.322	21,3	45.710	17,6
Dump in wetlands	233	0,1	46	0,0
Controlled dump	84.576	37,2	40.695	15,7
Landfill	82.640	36,4	167.636	64,6
Composting Plants	6.550	2,9	1.635	0,6
Recycling units	2.265	1,0	3.122	1,2
Incineration units	1.032	0,4	67	0,0
Others	1.566	0,7	636	0,3
Total	227.184	100,0	259.547	100,0

Table 2. Annual food acquisition and weekly food waste estimate per capita and income range

Family monthly income range R$	Annual food acquisition per capita kg	Weekly food waste estimate per capita kg
Less than 400,00	213,50	0,82
400,00 - 600,00	234,67	0,90
600,00 - 1.000,00	248,42	0,96
1.000,00 - 1.600,00	268,26	1,03
1.600,00 - 3.000,00	300,81	1,16
More than 3.000,00	331,45	1,27

2. LPG REPLACEMENT FEASIBILITY

To analyze the feasibility of replacing cooking gas with biogas in Jardim Conceição, the first step was to perform a statistical survey in order to determine average consumption of LPG and organic waste production, and to compare the generation potential of biogas from food waste and LPG demand.

To ensure the quality of results, some criteria were adopted in the choice of the families, carried out with the aid of a community leader:

- different numbers of members;
- different family profiles (with or without children, presence of elderly people);
- diversified family routines (have meals at home and at work, school, etc.);
- different monthly incomes (up to R$ 1.600,00).

This data survey was divided into two phases. The first consisted in approaching families and explaining the project, and second one was the data collection. Anticipating skepticism and fear on the part of families to be approached by strangers, the family approach was made jointly with the community leader.

Families who agreed to participate in the project received a container and were instructed to deposit in it only food waste for one week. This is an ideal period, because it includes the pattern of food consumption during weekdays and weekends, and the collection of food waste for a longer period than this would pose a problem for families, since it is a highly perishable material.

In order to ensure success in the data survey, a pamphlet was prepared with clear explanations and objective information on the study proposal and examples of what kind of waste could be deposited in the container provided. At this step, the average consumption of cooking LPG was estimated through the application of a form with the following questions:

- what size is the family?
- what are the usages for the LPG?
- which type/size of LPG cylinder is used?
- how long does a cylinder last?

The second stage took place one week later. The containers provided to families were collected and weighed.

2.1. Data Analysis

Tables 3 and 4 presents the results of data survey. Considering that families bracketed in the low-income class have monthly incomes of up to R$ 1.600,00, and the expected average weekly per capita food waste is between 0,82 kg and 1,03 kg (Table 2), Table 3 indicates that the obtained value for the organic waste generated per capita (0,84 kg) is reasonable and indicates that such result might be used as representative for the whole community. Considering LPG, all interviewed families use type P13 cylinders (13Kg), and Table 4 presents the LPG weekly consumption data per capita.

Table 3. Organic waste data

Family ID	# Members	Organic waste collected (kg) total	per capita
1	3	1,0	0,33
2	3	5,6	1,87
3	7	0,0	0,00
4	4	2,5	0,62
5	1	3,1	3,10
6	6	0,5	0,08
7	1	0,7	0,70
8	4	7,0	1,75
9	4	1,2	0,30
10	1	0,5	0,50
Average	3,4	2,0	0,84

Table 4. LPG consumption data

Family ID	# Members	LPG Usage	LPG cylinder size (kg)	duration (weeks)	LPG weekly consumption per capita (kg)
1	3	cooking	13	16	0,27
2	3	cooking	13	8	0,54
3	7	cooking	13	4	0,46
4	4	cooking	13	6	0,54
5	1	cooking	13	24	0,54
6	6	cooking	13	4	0,54
7	1	cooking	13	24	0,54
8	4	cooking	13	8	0,41
9	4	cooking	13	12	0,27
10	1	cooking	13	16	0,81
Average	3,4	——	13	12,2	0,31

Considering that 1.0 kg of organic solid waste can generate 0,1395 m^3 of biogas (cf. Gorgati & Lucas Jr., 2000), the results of Table 3 indicate that the weekly generation per capita of biogas at Jardim Conceição is about 0,12 m^3.

Assuming that the average composition of biogas is 60% methane (CH_4) and 40% carbon dioxide (CO_2) and the calorific value of methane in the literature is 35.736 kJ/m^3, the average calorific value of biogas is 21.442 kJ /m^3. In Brazil, the LPG is composed of 50% propane (C_3H_8) and 50% butane (C_4H_{10}), with a calorific power is 10.3127 kJ/m^3; therefore, 1,0 m^3 biogas is equivalent to 0,208 m3 of LPG.

As verified, the weekly average LPG consumption per capita is 0,233 m3, equivalent to 1,12 m3 of biogas, but in the same time interval the food waste digestion generates only 0,12 m3 of biogas, making it not feasible to replace LPG with biogas only from the digestion of food waste.

3. ELECTRICITY GENERATION FEASIBILITY

As the biogas production rate is not sufficient to match the needs of families' LPG, a second usage for the generated gas was analyzed. Considering the community needs, it was analyzed the feasibility of replacing the grid-purchased electricity consumption of community center by a biogas-driven generator.

Considering that previous electricity consumption data from the community center was not available, first step of the analysis was to evaluate the community center energy demand by means of listing the electrical equipment, their rated power demand and daily usage, shown in Table 5.

The maximum power demand of community center is 480W, and the energy consumption is about 27,2 kWh per week, equivalent to 97.848 kJ. Considering the calorific power of biogas (21.442 kJ/m^3), the minimum volume of biogas required (without considering generator efficiency) is 4,56 m^3 per week.

To match the power demand of 480W, is was selected a 750W generator that requires 0,45 m^3 of biogas per kWh, which represents a biogas demand of 12,2 m^3 per week. To achieve this volume, the participation of at least 100 people (approximately 30 families) from the community is required, totaling the required 84 kg of food waste per week.

Table 5. Community center electrical equipment list

Equipment	Quantity	Rated power (W)	Daily use (h)	Energy consumption (kWh/week)
Desktop computer	1	150	4	4.2
Computer monitor	1	30	4	0.8
Lamps	4	60	12	20.2
Sound equipment	1	20	2	0.3
Cordless telephone	1	10	24	1.7
Total	——	480	——	27.2

4. DIGESTION SYSTEM CONFIGURATION

Next step in the analysis was the definition of the digestion system configuration. As this is a micro-scale low-production biogas digestion system, it was selected a battery of mini-batch digesters connected to a gas tank, as shown in Fig. 1. The main items for the system implementation and the estimated costs are listed below.

4.1. Battery of digesters

It was considered that the substrate is to be composed of 20% volume of crushed fresh waste and 10% inoculum. The digesters can be made of 500-liters plastic drums. Using 14 digesters and substrate supply with 7-day lag time between them, a round of 98 days of digestion is attained. The digesters should be used in series, and should all be connected to the gas tank by valves and hoses. The total cost of the battery set, including valves/hoses, is approximately R$ 3.400,00.

4.2. Generator

The 750W motor-driven power generator was a budgeted at R$ 670,00.

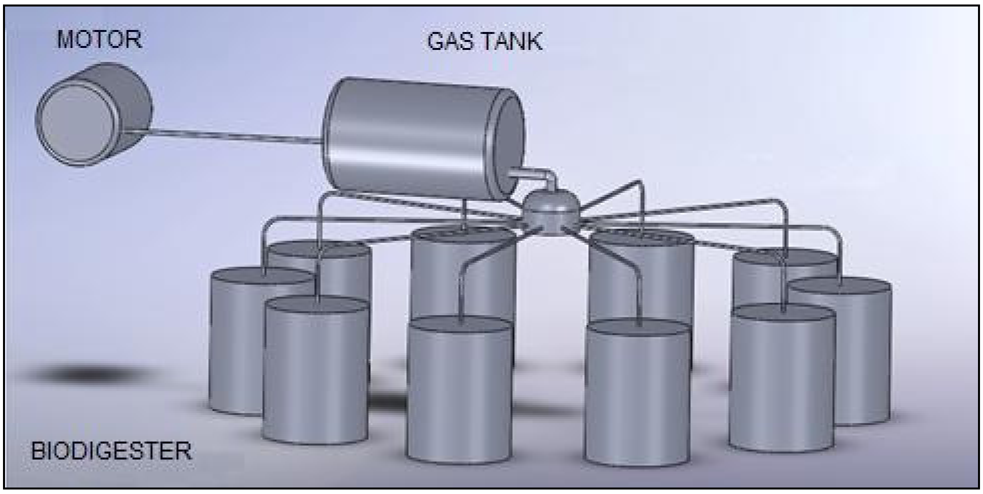

Figure 1. Biodigestion system configuration

4.3. Gas tank (gasometer)

Considering a weekly production of biogas estimated at 12,2 m^3, the gas tank must capable of storing at least 1,74 m^3 daily. Using a safety factor of 2, the gasometer must have a minimum volume of 3,5 m^3. The estimated cost for this gasometer is R$ 3.500,00.

4.4. Auxiliary equipment

Besides the main system components, it is necessary a shredder to prepare the substrate (estimated cost of R$ 900,00) and a equipment shelter for the digesters, gasometer and generator. Constructed in masonry, the shelter will need only one room to accommodate the set of digestors, and especially the gas tank, that should be well protected due to security issues. An area of 30 m^2 is suitable for this purpose. The construction cost is around R$ 2.500,00.

5. CONCLUSIONS

The analysis indicates that although the food waste has an energy potential that can be used, the amounts generated per person in the community is insufficient to maintain a self-sufficiency cycle in the production and use of biogas as replacement for LPG. Each person in Jardim Conceição needs a average weekly biogas volume of 1,12 m^3, but the estimated production of biogas is 0,12 m^3/week.

The use of this energy potential for replacing grid-purchased electricity to the community center is possible if at least 100 people contribute, but the investment of R$ 10.970,00 is very significant for a low-income community, requiring financial support from government, environmental agencies or other sources. Nevertheless, it is important to point out that this community has about 11.000 people, and a full-scale system would produce up to 1.300 m^3 of biogas per week.

Analyzing some factors that might affect the project efficiency, the educational level shows to be determinant. Because it is a low-income community, most people have low education levels. The approach and explanation of the project must thus be didactic and a simple.

The implementation of digesters is interesting in remote areas because it is an alternative energy source, but in large urban areas the scale of the project is a key point to determine whether the project is economically feasible or not.

6. ACKNOWLEDGEMENTS

The authors would like to acknowledge the Community Center of Jardim Conceição for helping the development of this work.

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8. RESPONSIBILITY NOTICE

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