CHAPTER III

RESEARCH METHODOLOGY

In this study, the organic fraction of NU solid wastes was collected for biological treatment by anaerobic digestion process as a part of solid waste management strategies. The research was conducted on lab scale digester. The wastes for the feedstock were collected from NU cafeteria. After collecting the wastes, the manual part of the easily degradable organic fractions was carried out from the garbage. The collected wastes were fed into the shredder to obtain the average particle size of 10 mm. The inoculums were merged to the shredded small sized waste particles to increase the start-up of the digestion process. To control the bacteria and reduce the digestion period the experiment was carried in thermophilic condition and mesophilic condition.

Materials

The system of temperature control system development for biogas production consists of 2 parts as below:

1. Biogas system
2. Hot water system

Biogas system

The bioreactor had a working volume of 70 L. It consists of 2 tanks as below acid digester tank and methane digester tank. Acid digester tank was 35 L (an internal diameter of 30 cm and height of 50 cm). And methane digester tank was 35 L (an internal diameter of 30 cm and height of 50 cm) The methane digester tank was double wall container to provide hot water bath in order to maintain the temperature inside the digester. The storage tank was 75 L. (an internal diameter of 40 cm and height of 60 cm). The methane digester tank wrap with glass wool of 5 cm thickness. In bioreactor install the agitator for mix food waste and inoculums. The agitator had a working volume of 30 minutes/ hour. The speed of motor was 15 cycle /minute.

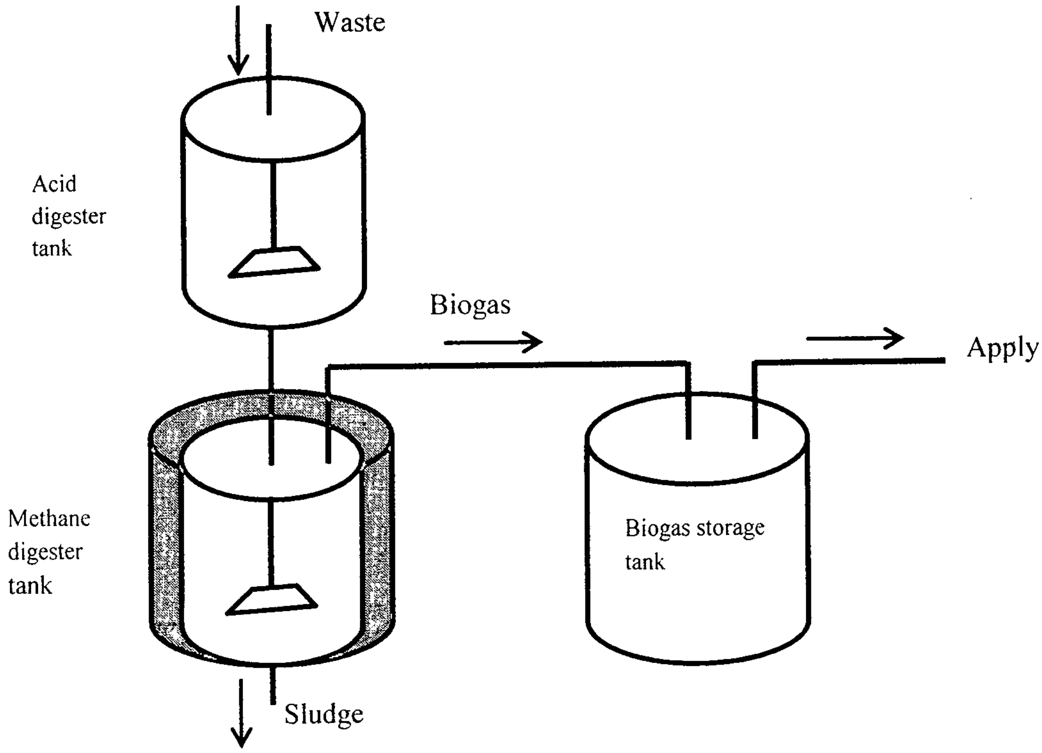

Figure 45 Anaerobic digestion systems

Hot water system

The heating required for the bioreactor was performed using a solar collector combined with biogas energy. Water contained within the jacket of the bioreactor was 35 L. Heating this volume of water to 35-60°C for the solar collector design.

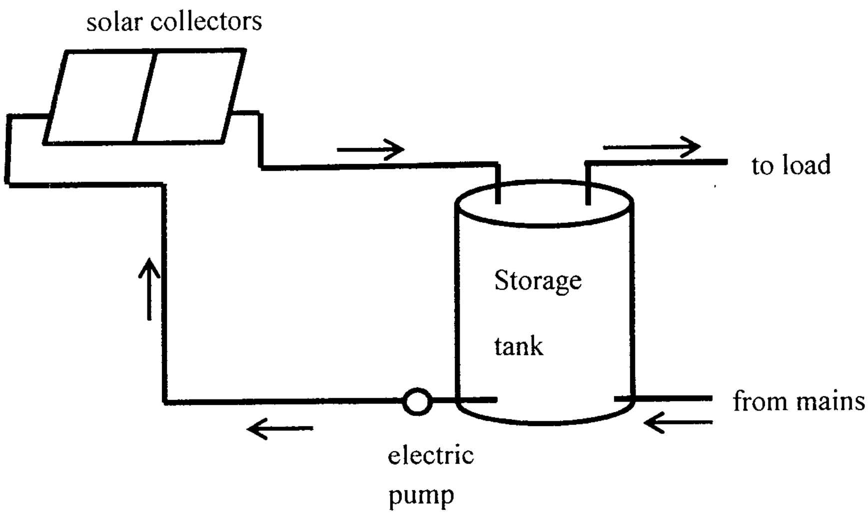

Figure 46 Solar hot water systems

Lab scale digestion system

Design of the digester

The digester was designed according to the organic loading rate and the retention time. The two stage anaerobic digestion was operated at different organic loading rates to optimize the biogas production and to research operational parameters. The digester was cylindrical with double wall container to provide hot water bath in order to maintain the temperature inside the digester.

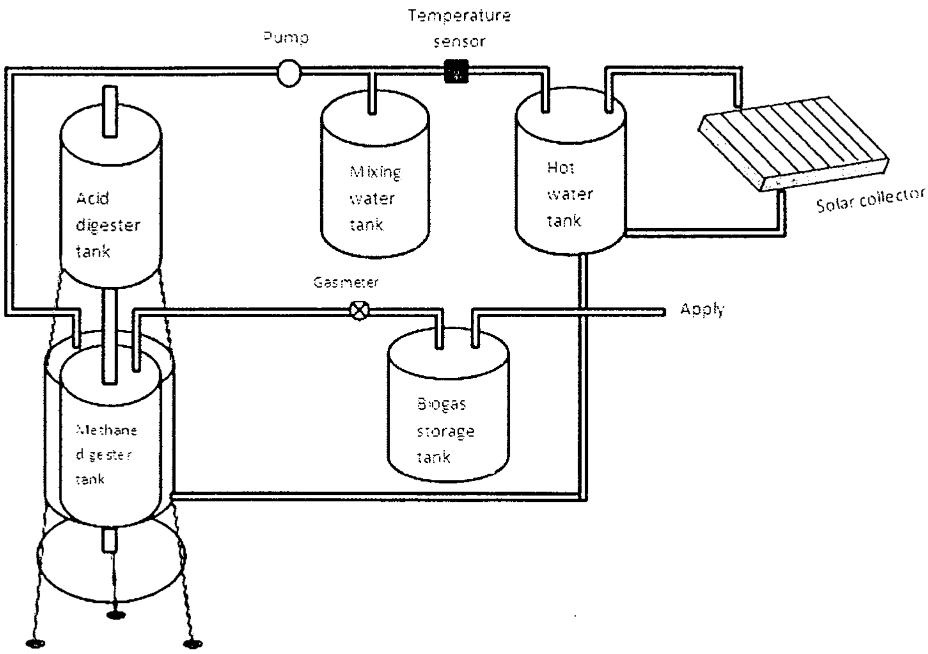

Figure 47 Design of lab scale anaerobic digestion systems

Volume of water

$$V = \frac{m_{water}}{\rho} \qquad \text{Eq.1}$$

where V = volume

m_{water} = mass of water

ρ = density

Heat energy

$$Q = m\, c_p\, \triangle T \qquad \text{Eq.2}$$

Where; Q = heat energy

m = mass

c_p = specific heat

$\triangle T$ = change in temperature (final - initial temp)

Experimental procedure

Feedstock composition

The solid wastes from NU cafeteria were used as substrate for the AD system. The compositions of which were determined by solid wastes analysis techniques. Accordingly the representative wastes were collected and the weights of wastes were reduced to sample size of 50-100 kg. The feedstock was comprises of food wastes.

Feedstock preparation

After manual sorting of the wastes material it was converted into averages size of about 10 mm by using shredder. The surface area is more at the smaller size and the hydrolysis process happen faster which is the limit factor of the methane formation in anaerobic digestion. Fresh wastes were mixed with the inoculums to enlarge the start-up process and were fed into the digester based upon the organic loading rate.

Inoculums

Inoculum source is a very important operational parameter. Also, it is decisive the selection of waste/inoculum ratio as well as the assessment of anaerobic biodegradability of solid wastes. The percentage of inoculation for acid organic fermentation of organic urban wastes is approximately 30% (w/w). Cow dung, digestion material, anaerobic sludge was used as inoculums components. The constituent of inoculums was cow dung, anaerobic sludge and digestion material in the ratio of 2:1:1. The purpose of using these mixtures was to increase the microbial diversity inside the reactor.

Sampling and analytical procedure

The analysis in this study was made for feedstock, digestion and biogas produced. The parameters to be analyzed for feedstock and digestion were Moisture Content (MC), TS, and VS. These parameters were used to compare the system performances and were controlled to provide the stability of the system. All analytical determinations were performed according to "Standard Methods". In addition to above mentioned operational parameters, nutrients (nitrogen, phosphorus, potassium, carbon) in the new wastes and digestion were also analysis.

Solid waste analysis

Both new waste and digested waste were subjected to solid analysis. Solid waste analysis was conducted before feeding into the digester and after withdrawing the digestion from digester. Representative grab sample of Solid waste were collected and were analyzed for parameters such as moisture content, TS, VS and bulk density.

Moisture content

The percent moisture of the MSW samples was determined by weighing 100 g of the samples into a pre-weighed dish and drying the samples in an oven at 105°C for 24 hours to a constant weight. The percent MC and TS were calculated using Eq.3 and 4. The analysis was conducted in duplicates. After determining the moisture content, the samples were further tested for volatile matter content as explained in the section that follows.

$$\%\,\text{MC} = \left(\frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Wet Weight}}\right) \times 100\% \qquad \text{Eq.3}$$

$$\%\text{TS} = 100\% - \%\text{MC} \qquad \text{Eq.4}$$

Volatile solid

The volatile solid content was determined by the method of ignition of the sample at 550°C for 1 hour. The same sample as was determined for moisture content and total solid was used for determining volatile solids. The dried samples were pulverized into fine solids and were mixed properly to ensure homogeneity. After that the pulverized sample were weighed for 2 g. and were placed on several crucible dishes. Then the sample was evaporated for at least 1 hour at 550°C in the muffle furnace. After drying the sample was placed into desiccator for cooling and was weighed immediately by using analytical balance. Thus volatile solid was calculated using Eq.5.

$$\% VS = \frac{w_o - w_f}{w_o - w_f} \times 100\% \quad \text{Eq.5}$$

Where w_0 = weight of sample and evaporating dish after 105°C

w_f = weight of sample and crucible dish after 550°C

w_e = weight of empty dish

Total solids and Volatile solids loss

The feedstock entering into the digester for AD process has an incipient total wet weight of TW_0 and dry mater M_0. The residue for the overall process has the final total weight of TW_1 and dry matter M_1.Total solid loss can be determined by using Eq.6. The Eq.7 gives the dry weight of material before feeding into the digester whereas Eq.8 depicts the dry weight of digestion. For calculating the loss of volatile solid, Eq.9 can be used similarly Eq.10 and 11 represents the amount of volatile solids in the feedstock and digestion respectively.

The following equations were used to obtain percentage of total solid (%TS) loss and percentage of volatile solids (%VS) loss.

$$\% TS = \frac{M_0 - M_1}{M_0} 100\% \quad \text{Eq.6}$$

Where M_0 = dry weight of feedstock entering into the reactor, (g)

$$M_0 = TW_0 \times TS_0 \qquad \text{Eq.7}$$

Where TW_0 : wet weight of solid wastes entering into the reactor, (g)

TS_0 : percentage total solid of feedstock (%TS)

M_1 : dry weight of digestion extracting from reactor, (g)

$$M_1 = TW_1 \times TS_1 \qquad \text{Eq.8}$$

Where TW_1 : wet weight of digestion extracting from the reactor, (g)

TS_1 : percentage total solid of digestion (%TS)

$$\%\,VS = \frac{N_0 - N_1}{N_0} \times 100\% \qquad \text{Eq.9}$$

Where N_0 = weight of volatile solids entering into the reactor, (g)

$$N_0 = M_0 \times VS_0 \qquad \text{Eq.10}$$

Where VS_0 : percentage volatile solid of feedstock (%TS)

N_1 : weight of volatile solid of digestion extracting from reactor, (g)

$$N_1 = M_1 \times VS_1 \qquad \text{Eq.11}$$

where VS_1 : percentage volatile solid of digestion (%TS)

Table 18 Solid waste characteristics of fresh waste

Parameters	Units	Fresh waste
pH		4.38
Total wet weight	L	20
Moisture content (MC)	%	93.8
Total Solids (TS)	%	6.25
Total Volatile Solids (TVS)	kg	5.56
Chemical oxygen demand (COD)	mg/l	43,520
Nutrient analysis		
N	%	0.08
P	mg/l	7.87
K	%	0.04
C	%	0.169
C/N	%	0.17/0.08

Biogas analysis

To measure the performance of AD process, the biogas produced was observed daily. Gas samples were taken from the headspace of the bioreactors by a syringe with pressure lock. The sample was injected directly into the Gas Chromatograph install thermal conductivity sensor for analysis volume composition of biogas (CH_4, CO_2 and other gas).

Economics analysis

The cost of producing biogas is one of the common tools used to evaluate the viability of an energy system. The cost is the investment of the system in total lifetime costs of the energy system divided by the quantity of energy produced over the system lifetime. When considering the systems, capital cost of digester and solar hot water system, operation and maintenance cost of the digester and solar hot water system, and fuel cost.

Capital cost of building the system; yearly calculate

C_C = Capital cost of building the system (CRF, i, n) Eq.12

C_C = Capital cost of building the system $\left[\frac{i(1+i)^n}{(1+i)^n-1}\right]$

Where i = Interest rate (%)

n = Number of years (year)

Investment cost of the system; yearly calculate

C_C = Cost of the system (CRF, i, n) Eq.13

C_C = Cost of the system $\left[\frac{i(1+i)^n}{(1+i)^n-1}\right]$

Ruins value of the system; yearly calculate

C_S = Ruins value of the system (SFF, i, n) Eq.14

C_S = Ruins value of the system$\left[\frac{i}{(i+1)^n-1}\right]$

Expenses cost of fuel per year

C_F = (Cost of fuel x Rate of fuel consumption)
x (Hour operating per year) Eq.15

Expenses cost of electricity per year

C_E = (Power electric value per unit x Power electric for using)
x (Hour operating per year) Eq.16

Maintenance per year

$$C_M = \text{5\% of capital cost of building the system} \quad \text{Eq.17}$$

Yearly total expenses cost

$$C_T = C_C + C_F + C_E + C_M - C_S \quad \text{Eq.18}$$

Total expenses cost per rate of system production

$$\text{Total expenses cost per rate of system production} = \frac{\text{Yearly total expenses cost}}{\text{Rate of system production yearly}} \quad \text{Eq.19}$$

Expenses cost operating yearly

$$C_O = C_F + C_M + C_E \quad \text{Eq.20}$$

Expenses cost operating per rate of system production

$$\text{Expenses cost operating per rate of system production} = \frac{\text{Yearly expense cost operating}}{\text{Rate of system production yearly}} \quad \text{Eq.21}$$

Payback period

$$\text{Payback period} = \frac{\text{Capital cost of building the system}}{\text{Reward net per year}} \quad \text{Eq.22}$$