Biomass Treatment
& Biogas Production
Through the use of EM

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(September 2004)

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1. Introduction

The results from a series of trials organised by ZME Envirotech Ltd, aiming at controlling foul odours from a piggery located at Athienou, Cyprus, using Effective Microorganisms (EM) were indeed impressive. This is clearly one of the fields where EM could make an impressive entry to the Cyprus market (see [2] for other work in the area of EM use for odour control).

Swine production in Cyprus is very intense with major environmental problems associated with it. In certain areas, where swine production is highly concentrated and consequently manure production rates are very high, severe foul odours cause havoc among residents who justifiably demand that a solution be found to this problem immediately. The swine industry is therefore under considerable pressure to deal with this and other environmental problems that the industry causes.

Manure treatment is almost non-existent in Cyprus and manure is generally sprayed in fields untreated. Over the past 3 years, **NPRO Engineering Ltd**, having recognised the extent of the swine manure problem, has introduced the method of anaerobic digestion as a potential total solution to it. Anaerobic digestion stabilises manure, removes pathogens, and generally minimises pollution, but only partly solves the problem of foul odours since manure does not immediately enter the treatment plant.

For the reasons mentioned above, it became obvious to the two associated companies, NPRO Engineering Ltd and ZME Envirotech Ltd, that there was a need to investigate the effect of EM spraying on anaerobic digestion.

2. Description and Aim of Experimental Work

Because of the relatively high cost of anaerobic digestion of swine manure, economic feasibility is necessary to encourage the installation of such systems. The economic benefits of anaerobic digestion are related to the biogas and consequently the energy produced. It is therefore vital that the use of EM does not compromise but rather enhance biogas production. The aim of the experimental work carried out was therefore, to introduce EM at varying ratios, to samples of swine manure of similar composition. Hence we would make conclusions by analysing the anaerobically treated samples of manure and by measuring the biogas produced.

It was decided to use 5% EM activated because the quantities that would normally be required to be sprayed for odour control in a farm would be quite high and hence the relative cost of a higher concentration EM Solution may discourage its use. Hence, the following procedure was used:

STEP ONE

- 5% EM activated was prepared – activation period: 48 hours.

STEP TWO

- Fresh manure from a piggery farm was collected using a bucket and immediately poured into five 1-litre plastic bottles to ensure minimum variation in the contents of each bottle.

STEP THREE

- Air tight caps were placed on each bottle, before they were carried to laboratory room to ensure that no changes took place during transport.
- One by one, each bottle was shaken (to ensure that contents were well-mixed), opened, manure was either added or removed to bring to desired level, and then the 5 % EM activated solution was added.
- Final level of all bottles was 900ml (manure + quantity of 5% EMA = 900ml).
- The EM content for each sample was as follows:

  Sample 1

  Quantity of EM = 0ml, Quantity of manure = 900ml, % of EM = 0

  Sample 2

  Quantity of EM = 25ml, Quantity of manure = 900ml, % of EM = 2.75%

  Sample 3

  Quantity of EM = 50ml, Quantity of manure = 900ml, % of EM = 5.5%

  Sample 4

  Quantity of EM = 100ml, Quantity of manure = 900ml, % of EM = 11%

  Sample 5

  Quantity of EM = 200ml, Quantity of manure = 900ml, % of EM = 22%

STEP FOUR

- Bags made from inert plastic were fixed on top of each bottle to collect biogas
- Experiment period was 10 weeks. The contents of each bottle were shaken by hand twice/day (morning & afternoon).
- Bottles were placed at a dark spot with minimum temperature fluctuations. Room temperature varied between 20 and 25^{o}C.

3. Results & Discussion

Within 2 weeks, for some of the samples, it was observed that the plastic bags begun to collect gas. These were samples 3 and 4 (5.5% & 11% EM). 2-3 days later, we observed that all bags were beginning to collect gas. However, the bags belonging to samples 3 and 4 contained a visibly larger quantity of gas whereas the bags with the lowest quantity of gas were the bags that belonged to samples 1 and 5 (0% & 22% EM).

Picture below was taken 4 weeks after the experiment begun:

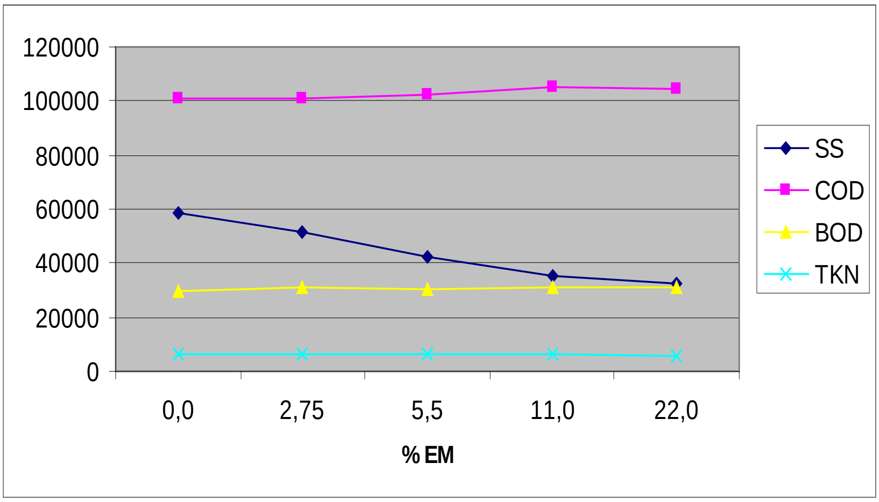
The amount of gas collected at 4, 8 and 10 weeks was measured by roughly measuring the dimensions of the blown up bags and by calculation. Because of the irregular shape of the bags, it was difficult to accurately estimate the amount of gas. However, the experiment aimed at determining trends in biogas production as EM solution quantity increased and this was measurable without the need for great accuracy.

At the end of 10 weeks, the 5 samples were analysed and compared to the sample analysed at the beginning of the experiment.

Table below shows the analysis of the treated manure.

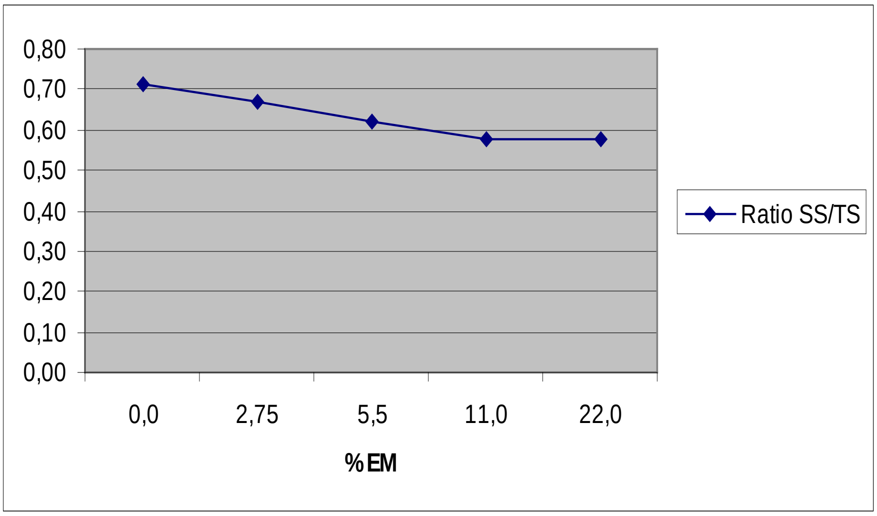
	EM Quantity	Manure	DM	TS	SS	BOD	COD	N	P
U.O.M.	%	grams	%	grams	ppm	ppm	ppm	ppm	ppm
Untreated sample	-	900	9,9%	89,1	76428	31024	103630	8633	1689
No EM - Sample 1	0,0	900	8,3%	74,3	58600	30000	100700	6539	1392
EM - Sample 2	2,75	900	7,7%	69,3	51590	30853	101250	6420	1376
EM - Sample 3	5,5	900	6,8%	61,2	42180	30309	102220	6385	1362
EM - Sample 4	11,0	900	6,1%	54,7	35100	31000	105440	6362	1357
EM - Sample 5	22,0	900	6,0%	54,4	34810	30928	104300	6320	1353

From the table, one can observe that only the parameters of Suspended Solids (SS) and Total Solids (TS) show large variations. The figure below is a graph of the main parameters (BOD, COD, SS & Total Nitrogen) versus EM concentration.



From the graph, one can observe that suspended solids are reduced with EM concentration whereas changes in BOD, COD and Total Nitrogen are minimal. It appears that a correlation exists between suspended solids, and biogas produced. The obvious conclusion is that it is mostly suspended solids that were biodegraded and converted to biogas.

The reduction in total solids (TS) is not one from which we can draw a definite conclusion because with the introduction of higher amounts of EM solution (which consisted mainly of water) we also diluted the samples thus reducing the total solids. Based on this argument, dilution of the samples could explain the reduction in SS also. If this were the case however, then the ratio SS/TS would not alter considerably. The following graph, is a plot of the ratio SS/TS. A lower ratio at higher quantities of EM solution (and hence more biogas) shows that either some SS become settled or they are biodegraded. Since biogas is a result of the action of anaerobic microorganisms which convert volatile organic solids to Methane gas and Carbon Dioxide (the main constituents of biogas), then we can conclude that it is mostly SS that are biodegraded for biogas to be produced.



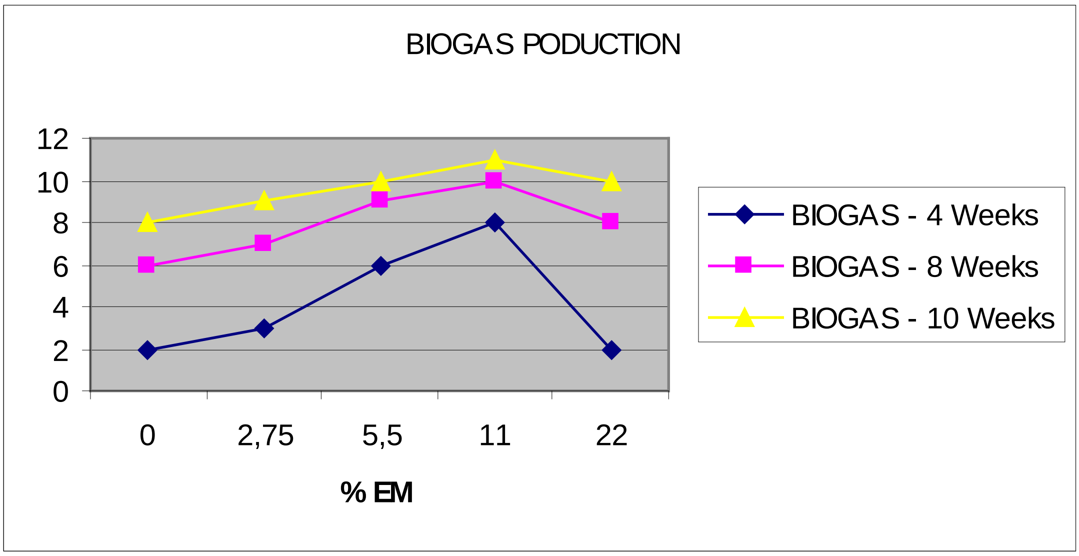
4. Biogas Production

The constituents of Biogas were analysed by drawing a sample from each bag by inserting the needle of a syringe into the bag and drawing enough amount for the analysis. Using this method meant that only a small fraction of the total amount of biogas was analysed and because one could not ensure that the gases were fully mixed, the lab was not able to draw a definite conclusion as to the ratio of each constituting gas in the biogas mixture. However the lab did confirm that the gas mixture in all cases was mainly CH_4 and CO_2 and small traces of water vapour, H_2S and NH_3.

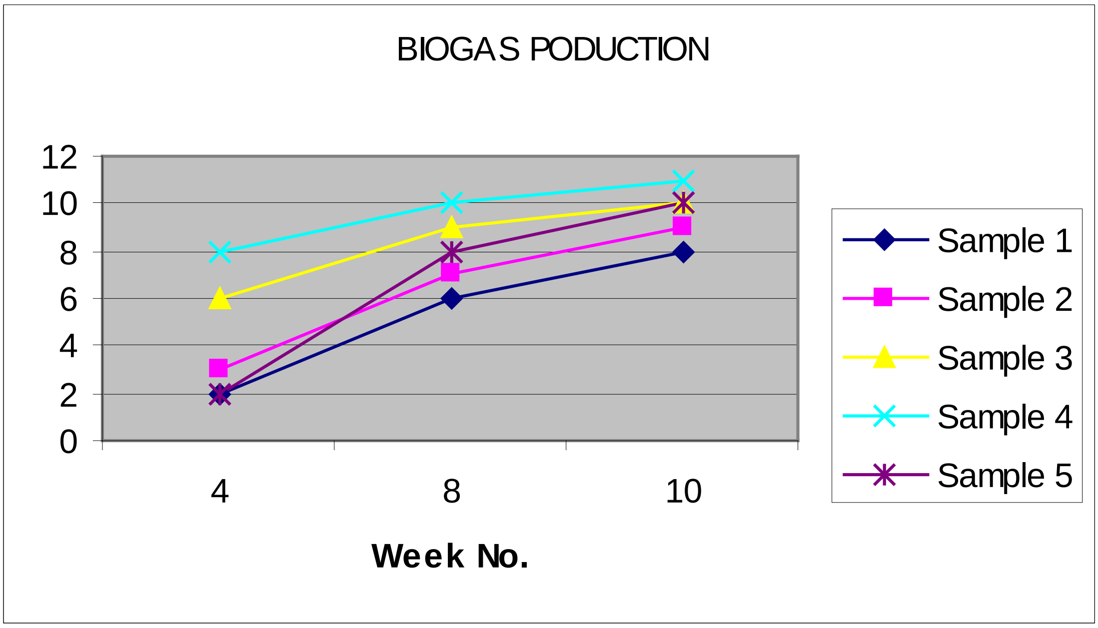
Description:	Biogas (4 weeks)	Biogas (8 weeks)	Biogas (10 weeks)
U.O.M.	Litres	Litres	Litres
No EM - Sample 1	2	6	8
EM - Sample 2	3	7	9
EM - Sample 3	6	9	10
EM - Sample 4	8	10	11
EM - Sample 5	2	8	10

Note: For reasons mentioned earlier, the volumes shown are only approximate and are rounded off.

The above volumes are plotted in the graphs below which is a plot of time versus EM Solution quantity.



The graph shows that as the experiment progressed to the 8th and 10th week, the differences from sample to sample were minimised. The explanation to this is that for samples 3, 4 and 5, most of the digestible volatile solids were digested and hence biogas production begun to slow down allowing the other two samples "to catch up". This is shown more clearly in the next graph were biogas versus time is plotted for each sample.



At week 4, the volume of biogas of sample 4 was 4 times that of samples 1 and 5. At week 10 this difference is only approximately 35%. Another interesting fact is the performance of sample 5. At week 4 the volume of biogas is only two litres (ie. 4 times less than sample 4) whereas at week 10, the volume of biogas is 10 litres (ie. Only one litre less than sample 4).

5. Summary of Results

- Minimum variations in COD, BOD & Total Nitrogen
- Larger variations in TS, SS, Ratio of SS/TS, Biogas production
- TS reduction due to:
  - Dilution (EM solution has lower solids content),
  - Biogas production (volatile solids converted to biogas)
- SS reduction due to:
  - Dilution,
  - Biogas production (volatile suspended solids converted)
- Ratio SS/TS reduction due to:
  - Biogas production
  - More solids settled with EM samples – enhanced solid/liquid separation

6. Conclusion

The following conclusions may made following the results and discussion presented in the previous section.

- EM used for odour control in farms will not compromise biogas production & feasibility of the system
- Biogas production is enhanced resulting in smaller digester volume – lower capital costs
- The anaerobic digestion process absorbs only a small amount of nutrients. The use of EM has no effect on nutrient levels during digestion (*)

* Introducing EM several hours before digestion begins (as is the case where EM is sprayed in farms for odour control) may give different results.

7. Recommended Further Experimentation

- Repetition of tests (2nd batch almost completed, results will be available in 2 weeks time) – results need to be consistent
- Tests with other types of manures (poultry, cow)
- Larger scale tests in NPRO Engineering's 12m^3 pilot digester
- Introduce EM aerobically at a time before the digestion.

8. References

1. Metcalf & Eddy: "Wastewater Engineering / Treatment, Disposal, Reuse", Third edition.
2. Kyusei Nature Farming - Sixth International Conference: "Proceedings of conference – Greater Productivity & Cleaner Environment".
3. Dr. Teruo Higa: "An Earth Saving Revolution: A means to resolve our world's problems through Effective Microorganisms (EM)"

Appendices

A1 - Calculations

To estimate the amount of methane

Sample 1

$V_{CH4} = 0.573*TDVS – 1.42*Px$ [1]

Where, TDVS = Total Digestible Volatile Solids
= 89.1 - 74.3 (From Table 1)
= 14.8g

Px = Mass of Biological Solids Produced Daily

$$= \frac{Y*TDVS}{(1 + Kd*Td)}$$

Y = Yield Coefficient = 0.055 [1]
Kd = Endogenous Coefficient = 0.04 [1]
Td = Digestion Time = 10*7 = 70 days

Hence, Px = 0.214
V_{CH4} = 8.2 L

Sample 4

TDVS = 80 – 54.7 (800g*10% DM + 100g*0% DM = 80g)
= 25.3g

Px = 0.366
V_{CH4} = 13.7 L