MAURITIUS RESEARCH COUNCIL
INNOVATION FOR TECHNOLOGY

COMPOSTING OF SOLID ORGANIC WASTE IN SUB TROPICAL REGIONS

Final Report

October 2000

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This report is based on work supported by the Mauritius Research Council under award number MRC/RUN-9603. Any opinions, findings, recommendations and conclusions expressed herein are the author's and do not necessarily reflect those of the Council.

MRC RESEARCH PROJECT

COMPOSTING OF SOLID ORGANIC WASTE IN SUB TROPICAL REGIONS

Final Report

Dr (Mrs) R. Mohee

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Mauritius

October 2000

Acknowledgements

I wish to thank the Mauritius Research Council for having funded this project. A special word of thanks to late Prof. J. Baguant, who had initiated this project and to Mr Marie Jeanne, the General Manager of RoseBelle sugar estate for having supported the project.
Many thanks to Mr Moothy, Agronomist at Rose-Belle sugar estate, Mr S. Bheekun, Mr P. Mungra and Mr S.Sowruth from the Chemical Engineering laboratory of the University of Mauritius as well as the University of Mauritius for their help.

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ANNEXES

1.0 INTRODUCTION

A research study, funded by the Mauritius Research Council was initiated in 1995 at the University of Mauritius in collaboration with RoseBelle Sugar Estate to assess the composting potential of sugar cane byproducts.

Composting is generally defined as an exothermic process of biological oxidation in which organic matter is decomposed by a mixed population of microorganisms in a warm, moist aerobic environment. The microorganisms require oxygen, moisture, a source of carbon and macro nutrients such as N, P, K usually found in the waste material. In the process, the organisms reproduce themselves and eventually die.

Composting to biologically stabilize these wastes into a humus material similar to soil organic matter could prove to be a viable process. The final composted product is less bulky than that of raw waste and because of the reduced volume, it will cost less to haul and apply. Also the heat produced by the compost process destroys pathogens. Numerous options exist for organic materials management, ranging from simple on site composting to capital intensive mixed waste compost facilities.

[illegible] byproducts, bagasse anci scum anci aiso study the effect of composts on sugarcane.

2.0 RELEVANCE

The sugarcane industry, produces around 1.8 million tons of bagasse and 0.3 million tons of filtercake on a yearly basis. Most of the filtercake is either sold or given to planters to be used as fertilizers in the cane fields while the bagasse is being burnt on site to produce steam and electricity.

A sugar estate in the South of the island, Rosebelle sugar estate, showed interest in developing a large-scale composting project since

1. It did not have adequate storage capacity for bagasse storage.
2. It had several rocky lands which were not giving good cane yields.
3. There was a need for a material which would enrich the soil in rocky lands where good cane yields were not obtained

3.0 OBJECTIVES

The objectives of the project were to

1. Characterise the sugarcane by products, bagasse and filtercake
2. Develop and use a laboratory composter so as to
    a. Determine mixing ratio of bagasse/filtercake
    b. Monitor composting parameters
    c. Determine maturity of composts
3. Develop windrow composting of around 10 tons of sugarcane byproducts on the premises of RoseBelle sugar estate
4. Upgrade pilotscale techniques to largescale applications of composting of around 60 tons of raw materials
5. Field application of composts produced and assess the effect on sugarcane yields

4.0 PROJECT TEAM

Members who have contributed to the initiation and conduct of this research project are

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Project Coordinator – Dr R. Mohee (on study leave in 1996)

Team Members : Prof J. Baguant (1995-1998)

Mr S. Marie Jeanne (1995-1997)

Mr Moothy, agronomist from the RoseBelle sugar estate has also contributed a lot in the project

5.0 METHODOLOGY

The project was executed in several phases to achieve the above mentioned objectives.

5.1 Phase 1 – Characterisation of wastes

Phase 1 consisted in determining physical and chemical characteristics of the two byproducts; bagasse and filtercake through laboratory testing. Tests were carried out in the laboratory at the University to determine moisture content, volatile solids, pH, bulk density and C/N ratio. More details can be found in Annex I

Analysis Techniques

Temperature

The temperatures were taken at 3 different points in the mixture by means of a Comark 2001, pocket thermometer. The different temperatures were taken daily during the project.

Moisture Content (MC) and Total Dry Solids (TS)

Samples of 70-100 g Bagasse, Broiler Litter and Mixture were taken in triplicate and dried at constant weight in an oven at 105 °C for 24 hours and cooled in a dessicator. The difference in weight was recorded and moisture content calculated as follows:

$$\text{Moisture content (Wet Weight Basis), \%} = \frac{\text{Loss in weight}}{\text{Net wet weight}} \times 100$$

Total Dry Solids (TS),% = 100 – % moisture content

Total Volatile solids (organic matter) and ash

A weighed sample of dried material obtained from the determination of total solids or that dried separately were ignited at 550 °C for 3 hours in a muffle furnace. The difference in weight between before and after heating gave the Volatile solids content (%) of the sample.

$$\text{Volatile solids, VS,\%} = \frac{\text{Loss in weight}}{\text{Net dry weight}} \times 100$$

Ash, % = 100 - % VS

Bulk density

The bulk density was determined by filling a bucket of known volume (bucket filled with water and weight is determined) with the sample and weighing it. The bucket was shaken to allow the sample to settle down.

pH

5 g of compost are dissolved in water and continuously stirred. A portable pH meter is then used to measure the value.

Carbon Content

The amount of carbon is obtained by using the empirical formula
% C = (100 - ash)/ 1.8 where % Ash = 100 - VS

Nitrogen Content

The total kjeldahl nitrogen was determined by using a special digesdahl apparatus. The sample is first digested with concentrated sulphuric acid and heated at 850°C, and then treated with hydrogen peroxide. The amount of nitrogen is the determined by using Nessler's method.

Respiration Rate

The shredded compost is mixed with water and placed in a BOD bottle. This BOD meter is connected to a chart recorder and airpump. The sample is aerated for a certain time and then the rate of oxygen consumption is determined during 30 minutes and then sample is reasserted. Around 5 -6 tests are performed for the same sample and the SOUR (Specific oxygen uptake rate) is the maximum rate obtained for that sample.

$$SOUR = \frac{\text{oxygen uptake rate} * \text{volume}}{\text{sample mass} * \text{fraction dry solids} * \text{fraction vs}}$$

5.2 Phase II – Smallscale trials

Phase II consisted in running smallscale trials to compost scum and filtercake. A bench scale aerobic composting system using a drum composter of 0.7 m^3 has been developed that has permitted the natural composting process to occur in the laboratory at the University of Mauritius. The drum was made of mild steel, the inner surface of which was coated with bitumen to prevent corrosion. It was mounted on wheels and placed in the lab. The dimensions are as follows: length 1500 mm, diameter 700 mm and volume 0.577 m^3

Mixtures consisting of 40 kg bagasse and 160 kg of filtercake were put into the composter. The drum was turned on a daily basis for the first 4 weeks and every 3 days for the remaining 3 weeks.

5.3 **Phase III –Pilot trials**

Phase III involved running pilot trials of 12 tons of waste on the premises of the RoseBelle Sugar Estate. Based on the findings of Phases 1 and 2, around 12000 kgs of bagasse and filtercake were mixed and arranged in 3 piles in such a way so as to optimize the process parameters such as moisture, C/N ratio and volume. The complete report is in Annex 2.

The characteristics of the mixtures were as follows:

		Pile 1	Pile 2	Pile 3
Weight (kgs)	Bagasse	1000	1000*	1000**
	Filter Cake	2200	3000	3000
	Weed	600		
Volume (m3)		17.3	14.5	14.5
Moisture content (%)		66.4	74.2	65.8
Volatile Solids (%)		66.5	69.9	68.37
C/N ratio		42	35	48

Table 1: Characteristics of mixtures

*: stored moist bagasse

**: fresh bagasse

They were stacked in 3 piles which were arranged in long parallel rows or windrows on a site, next to the mills on the premises of the RoseBelle sugar estate. The height of the windrows ranged from 6 ft to 8 ft with widths of 12-15 ft. They were placed upon an asphalt pad for ease of operation. Composting was being carried out aerobically. The windrows were aerated by turning the material twice a week for the first 3 weeks and once weekly for the rest of the process. Piles were composted for 6 weeks from January to March 1995.

5.4 Phase IV – large scale trials

Based on the outcome of the pilotscale trials, largescale trials involving 20-30 tons of raw materials were carried out at RoseBelle sugar estate. The windrow technique was utilized with the same design as for the pilot trials. The parameters monitored were temperature, moisture content, volatile solids and pH. The complete report is in Annex 3.

5.5 Phase V – Forced Aeration

To optimize the composting process, process control strategies were applied to the composting process. This phase consisted primarily of the setting up of the automatic control of the composting unit to provide aeration in terms of temperature and time. A prototype had been set up in the laboratory at the University of Mauritius to gather enough data.

The aeration system is an important feature of all modern composting systems. The ability to control aeration is one of the key points of process control and is an important consideration in process selection.

The main needs of a control system are:

- to ensure an adequate supply of air – for microbial and cooling needs, and
- to optimise the rate of biodegradation – by maintaining an elevated temperature.

There are a number of control strategies, which have been used in practice over the world and the most common one is the **Feedback Control Based on Temperature** whereby thermocouples inserted into the composting mixture. can generate a control signal used to modulate air now rate or blower on-time to maintain a set point temperature. Temperature is the controlled variable and aeration rates the manipulated variable. Other control strategies are detailed in the Report No 4 (Annex 4)

Composting trials were carried out in an experimental reactor which was in fact a horizontal plastic cylinder 12 cm in diameter and 90 cm in length, with a volume of approximately 0.2 m^3. An opening at the top of the drum allowed substrate to be loaded and unloaded and samples for analysis were taken from this same opening. There were 3 holes of aeration of 5.0 cm diameter on top of the drum and 1 other hole at the bottom.

Figure 1 shows the drum in which all the composting trials were performed.

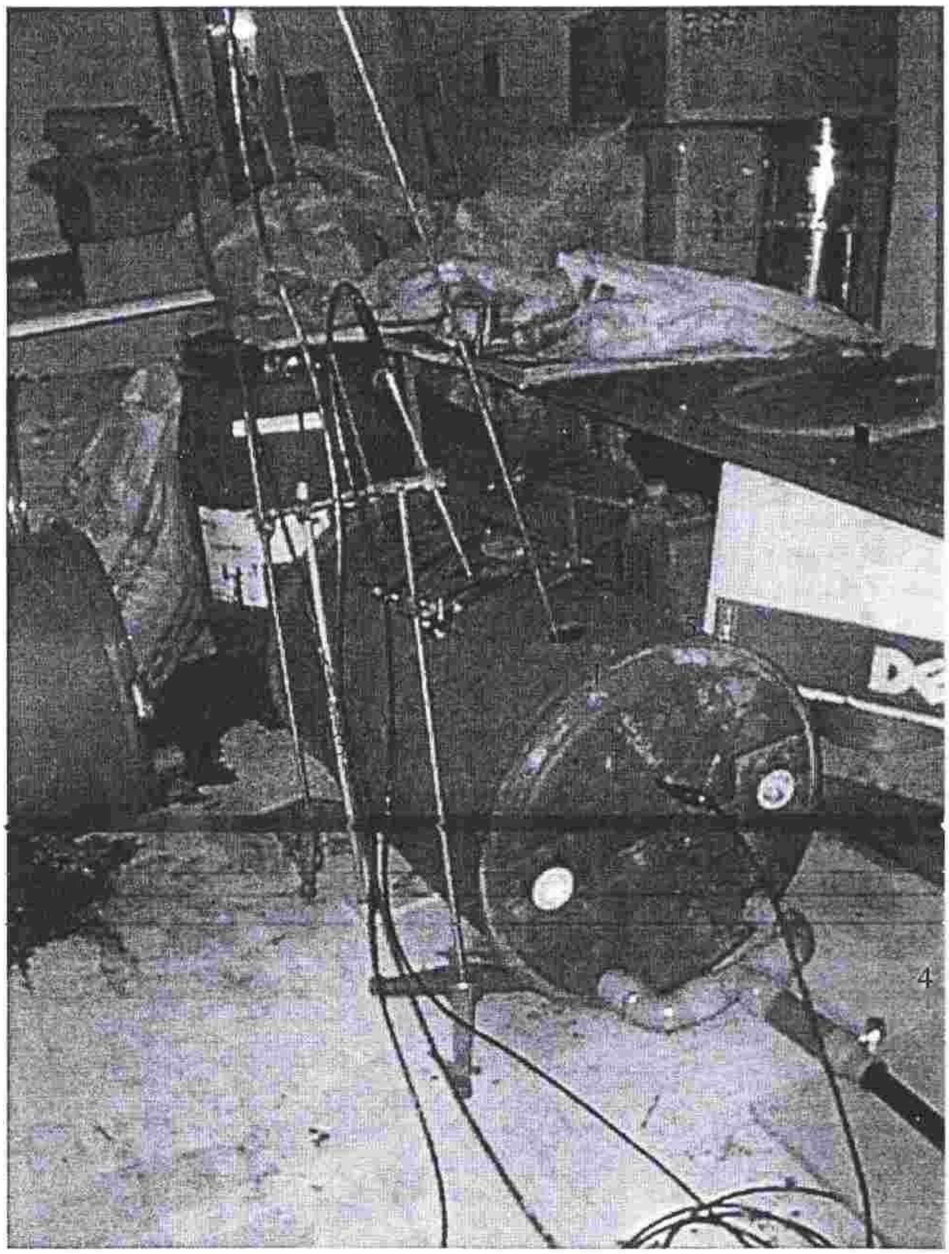


Figure 1.0: Automated Drum

l-reactor/drum
2-stain!ess steel thennocouplc
3-stand
4-aeration pipe connected to blower
5-aeration holes
o-sampling point / opening

Two aeration tubes of 5.0 cm diameter connected the drum to a fan. The fan was blowing air at a rate of 0.09 m'min' and was regulated by a timer to work at fixed intervals according to the type of demand. This timer formed part of the Compost Captain Master Composter, which is a composting instrumentation, and process control unit (See Figure 2 for Captain Composter connections). *A* trial was performed by setting the timer in such a way that the fan would blow air every 5 minutes after each 1 *Yi* hour. Temperature inside the reactor was detected by 3 probes placed in the 3 aeration holes on top of the drum.

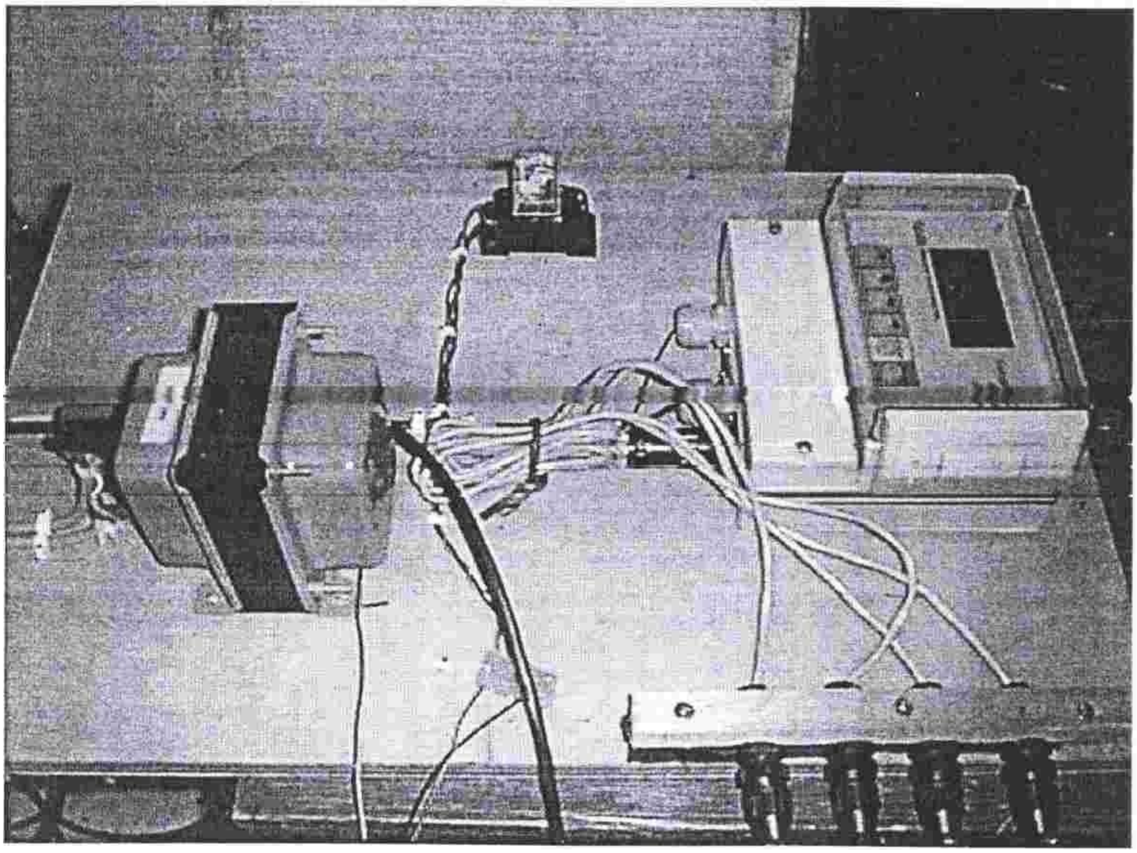


Figure 2: Captain Composter Connections

The solid fraction of the feedstock comprised a mixture of bagasse and broiler litter at a 1:2 dry mass ratio. This ratio was chosen because it gave an optimum C: N ratio. lO kg of bagasse was first soaked in 5 kg of water for optimum penetration and then it was mixed with 40 kg filtcrcake to form the starting material with about 60 % moisture and a *2511* C/N ratio. The mixture occupied 0.18 m^3 when placed into the reactor (that is the reactor was full). The resulting mixture had an initial volatile solid content of 89.11 % and a moisture content of 60 %.

5.6 MONITORING OF PARAMETERS

Optimal composting depends on the proper monitoring of process factors such as temperature, moisture content, pH, particle size, C/N ratio, structural strength and aeration rate. These factors vary on type of composting process adopted.

The composting made in the five phases included measurement of temperature, moisture content, bulk density, carbon content, respiration rate, nitrogen content and volatile solids. They were monitored on a weekly phases basis, except for nitrogen which was measured at the start and end of trials. For 2 and 3 the temperatures were recorded daily. The methods of analysis used were standard methods and are described below. For the determination of Moisture Content, Bulk Density and Volatile Solids, the techniques used were similar to those outlined in section 4.1.

6.0 ANALYSIS and FINDINGS

6.1 Phase 1: Characterisation of sugarcane byproducts

The two sugarcane byproducts bagasse and filter cake were characterized and the following results obtained:

	Moisture Content (%ww)	Volatile Solids (%dw)	TKN (%dw)	Bulk Density (kg/m³)
Filtercake	73%	57%	1.25%	330
Bagasse	45%	97%	0.25%	114

Table 2: Characteristics of bagasse and filter cake

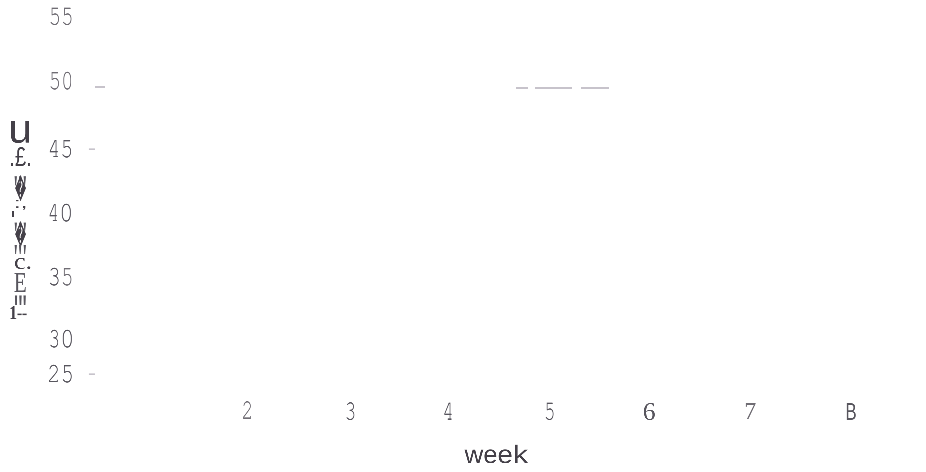
Based on the physical and chemical characteristics, mixing ratios of 3:1 scum bagasse on a wet basis to optimise parameters such as C/N ratio and moisture content were determined as per table below.

	Bagasse	Scum
Dry weight(kg)	[illegible]	[illegible]
C(%dw)	53.8	40
N(%dw)	0.27	1.25
N (kg)	0.06912	0.68
C(kg)	13.7728	21.76
C/N ratio	199.2593	32
Moisture	36	66
weight	40	160
Bulk density	114	520
volume(m3)	0.350877	0.307692

Table 3: Characteristics of mixture to be composted

6.2 Phase 2: Small Scale trials in the laboratory scale composter

The temperature profiles for the center of the pile in the smallscale composter were as shown in figure 3.0. During the first week of composting, the temperature rose from 27°C to attain a maximum of 50°C at week 4 and then dropped. This is typical of small scale systems whereby much heat is lost from the surface and temperatures higher than 55°C are seldom achieved and the mass available for degradation is quite small. The rise in temperature indicated that for this mixture, degradation was taking place as heat was being evolved.



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6.3 **Phase 3: Pilot trials at RoseBelle sugar estate**

The temperature monitoring is shown in the figure below. For the monitoring of the other parameters, please refer to Progress Report No 3 in Annex 3 where all details are given.

Temperature

Composting started as soon as the wastes were mixed and placed in piles and the temperature rose beyond 35°C showing that the most common microorganisms at work were the thermophilic bacteria. The later rapidly decomposed the organic material to produce carbon dioxide, water and heat. The temperatures stabilized at around 60°C for about three weeks and after days 27 and 29, there was an abrupt rise in temperature for both piles. This might be explained by the fact that both piles were turned on day 25. The high temperatures maintained throughout the 30 days were sufficient to achieve pathogen reduction since a temperature of 60°C for a minimum of 5 days is necessary to destroy pathogens.

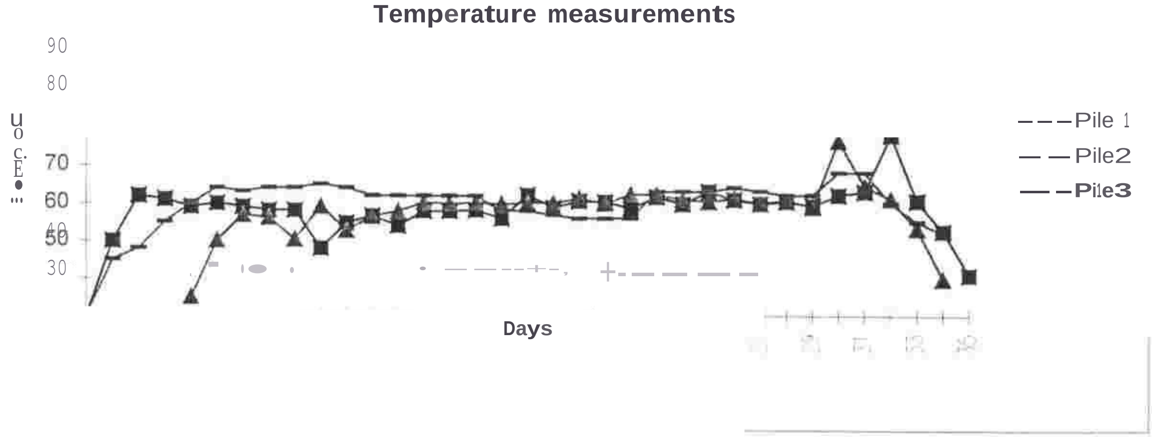


Figure 4 : Temperature measurement for pilot trials

The conclusions for the three trials were as follows:

- It was observed for pile 1 that no weeds or weed seed could be seen to grow in the pile. The high temperatures attained must have inhibited the growth of the weeds.

- **The high** temperatures **reached after** only **2-3 days of** composting **showed that these** raw materials would compost well.

- The moisture content was not limiting in any of the three piles.

- Starting from 12 tons of raw materials, around 6 tons of finished product was obtained. The efficiency is around 50%.

- The respiration rate tests showed that after 6 weeks, the piles were stabilized

6.4 Phase 4 – Largescale trials at RoseBclle sugar estate

The findings while composting 60 tons ofbagasse and filtercake were as follows:

- The temperature profiles (figure 5) followed typical temperature profiles of large scale composting systems whereby the temperature rose up to around 70°C in the first week, remained steady for about 2-3 weeks and then dropped.
- The moisture contents (figure 6) decreased during the first four weeks and at week 6. rainwater compensated for the decrease in moisture in the pile due to

microbial metabolism. The final dry matter contents averaged 35% total solids over the different trials.

- The composts were stabilised after around IO weeks. The respiration rate dropped to less than 6 mgO_2/gvs.hr after IO weeks (figure 7). The respiration rate indicates the amount of oxygen needed by the microorganisms to degrade the waste. If other parameters such as moisture and oxygen availability are not considered to be limiting, then the respiration rate can be taken as a measure of stability[3].
- Overall mass balances indicated an efficiency of around 50-60%.
- Addition of nitrogen supplements in the form of urea was found to be favourable to the composting process.
- Adequate mixing of wastes is difficult with a front end loader.

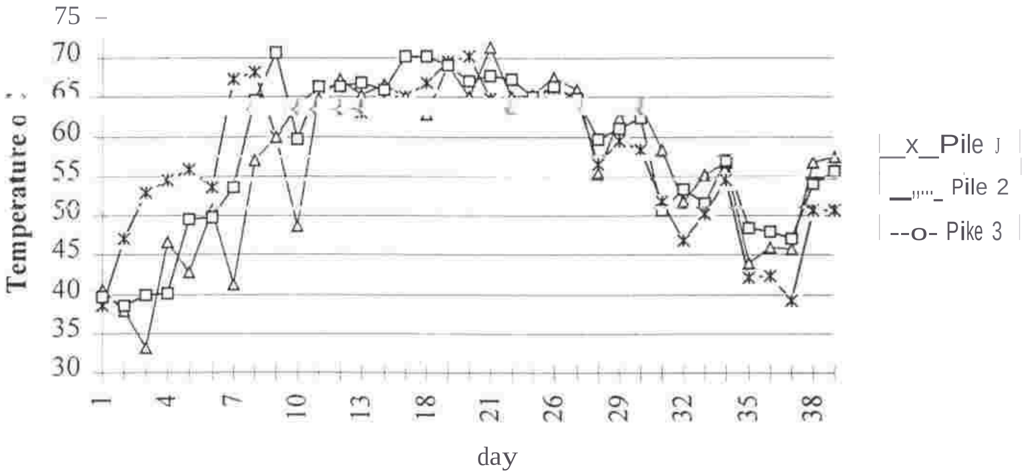


Figure 5 : Temperature profiles of piles

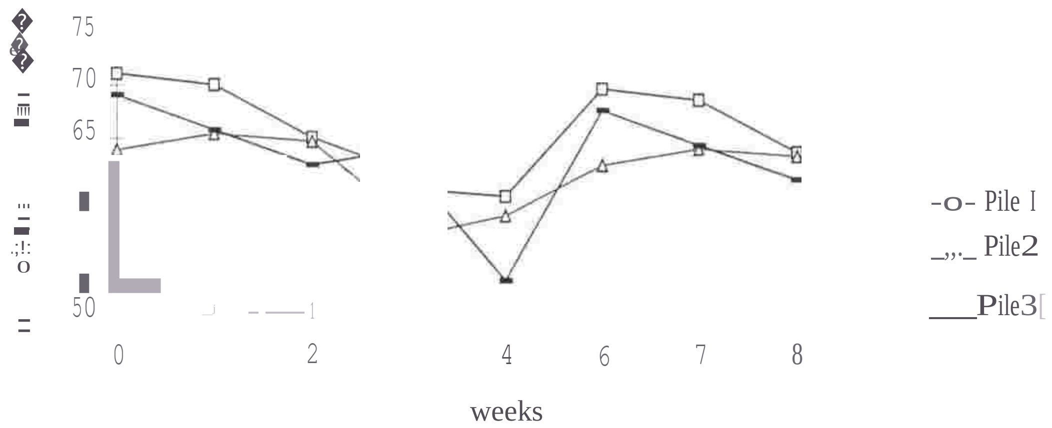


Figure 6 : Moisture content variations for piles

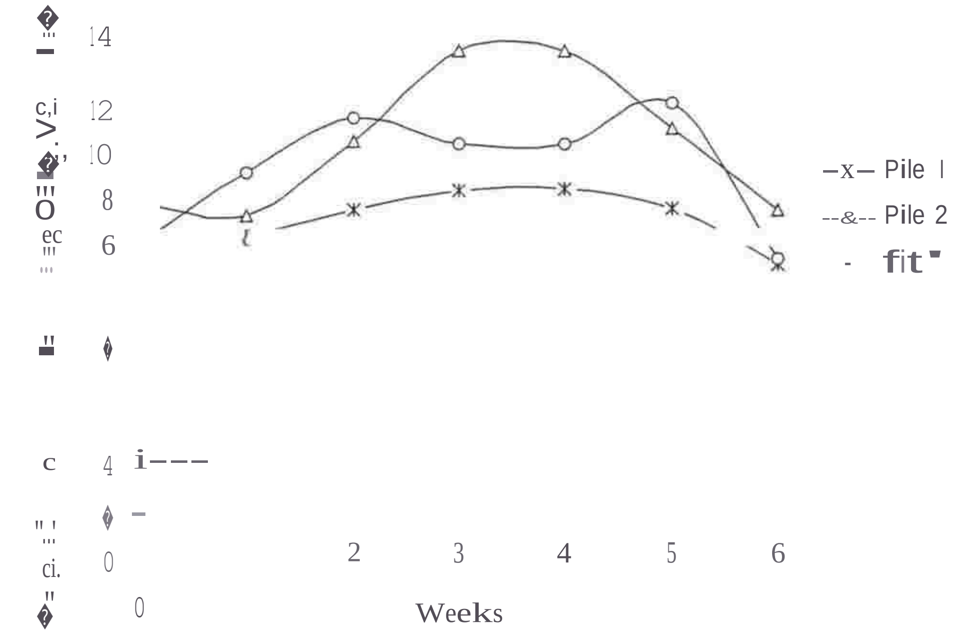
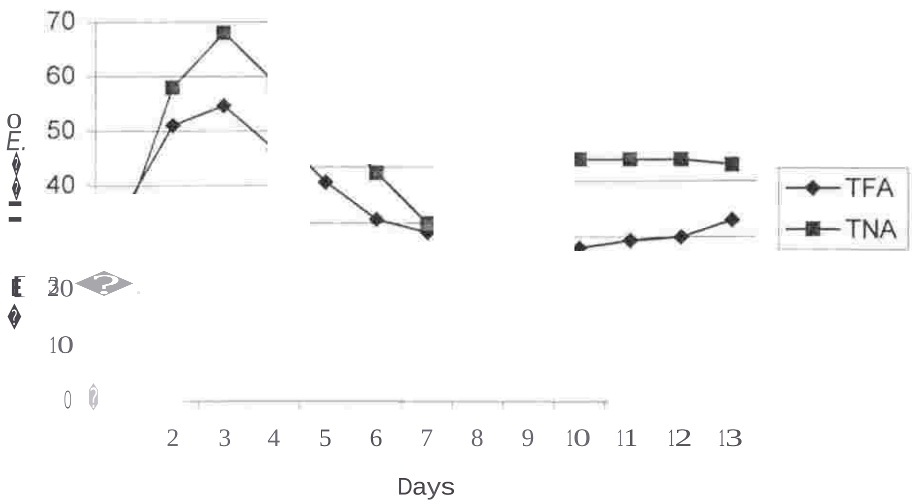


Figure 7: Respiration rate of different piles

6.5 Phase V : Forced aeration

The temperature and Volatile Solids were used as indicator to compare the forced aeration and natural aeration methods. The results were as follows:



Fi:;ure 8: Temperature evolution during natural and forced aeration

Volatile Solids

	Beginning	End	Net change in VS % (based on constant ash)
Natural Aeration	84.35	76.01	40%
Forced aeration	84.35	74.05	53.7 %

Table 4: Volatile Solids changes

In general, the natural aeration method gave higher temperatures that the fcrced aeration method. This might be due to the fact that in the forced aeration method, the airflow rate was too high and was removing too much heat from the compost pile. When looking at the amount decomposed for the forced aeration (53.7%) as compared to natural aeration

(40%), it was seen that the forced aeration method gave slightly better decomposition of material, showing that the high temperatures encountered in the natural aeration technique, specially during days 3 and 4 where temperatures higher than 6C1'C were observed, constituted a limiting factor and contributed negatively to the microorganisms.

6.6 Findings

This study has shown that the active aeration gave better results than passive aeration and that the compost captain controller unit could effectively set the aeration rate based on the temperature feedback.

However, it has to be noted that the forced aeration technique is much more expensive that the natural aeration method since it would involve the purchasing of Control Unit, Blowers, Pipes and the regular supply of electricity. Also, for small scale systems the benefits of forced aeration in the compost process could not be clearly seen apart from the fact that the compost mixtures did not have to be turned as in the previous units.

1.U Application or Composts

Composts were applied to sugarcane fields(around *2.5* hectares) at the rate of 5 tonnes per hectare during plantation. Together with fertilizers, composts were added in each line (row) of cane plantation. Control for the experiment was provided by a neighbouring 2.5 hectare plot where all plantation and agronomic conditions were maintained similar but for the compost addition.

7.1 Findings of Year *1*

Preliminary results showed that the application of 5 tones per hectare of compost improved both the chemical and physical properties of the cane. Amongst other parameters, the number and height of cane stalks improved substantially. The number of cane stalks per hectare increased from 87,654 to 116,049 and the mean height of cane stalk from 2.31 rn to 2.68 m (table). These results have been obtained for the first harvest of the cane plantation 7 year plant cycle. It was noted that in both trials, germination was good except that the plot treated with compost gave rise to more rigorous and bigger stalks.

Tonnes	With Compost	Without Compost
Mean Cane Yield in tonnes/ha	129.4	103.5
Richesse as at 3.6.97	12.71	12.68
Richesse as at 5.8.97	14.08	16.37

Table 5: Mean Cane Yield for Year 1

7.2 Findings of Year 2

Tonnes	With Compost	Without Compost
Mean Cane Yield in tonnes/ha	110.9	82.3
Richesse as at 9.6.98	12.93	12.87
Richesse as at 3[illegible]8	14.'18	16.21

Table 6: Mean Cane Yield for Year 2

As seen, the mean cane yield is much greater for the plot of treated cane with compost. However, it is to be noted that the richesse of nontreated cane was better than the treated cane. This was because for the treated plot, vegetative growth predominated on sugar accumulation. However, the yield gap between treated and nontreated plots was so important that it largely compensated for the difference in richesse.

7.3 Findings of Year 3

	With Compost	Without Compost
Mean Cane Yield in tonnes /ha	80.6	69.2

Table 7: Mean Cane Yield for Year 3

The mean cane yield was better than the plot with compost as compared to the plot without compost for the richesse. The same was obtained as for year 2.

8.0 GENERAL CONCLUSIONS

From this study, the following conclusions can be drawn :

- The mixing ratio 3: l bagasse, filtercake gives good results in terms of compost startup and composts produced. The final composts were well stabilized and were of good quality.
- Successful composting has been carried out on both laboratory scale and large scale composting. It is to be noted that the data gathered during smallscale composting were used to develop the largescale composting process.
- Staff at RBelle sugar estate have been successfully trained since they have the know how of conducting largescale experiments
- Main reasons for exploring the forced aeration method were
    - It speeds up the composting process. The duration for the high rate composting is aecreasea rrorn six weeks to J weexs,
    - The substrates need net be pretreated
    - There is no need for mechanical turning using front end loaders which diminish the costs of labour and equipment .
    - It is a computerized stand alone system whereby the temperature is automatically regulated through the intake of air. It does not need precise monitoring of parameters once the system is set up.

This study showed that with Captain composter, it was possible to control the aeration with the temperature feedback. However, on such a scale. it was difficult to see the benefits of forced aeration as temperature was not much better and the increase in degradation was quite small.

Also the costs of forced aeration have to be weighed against the improvements in degradation rates in the composting system.For the sugar factory facilities were available (tractor) to regularly turn the waste and space for composting was not a cririCal issue. The windrow method utilizing natural aeration was more appropriate.

The additional expenses likely to be encountered with forced aeration were not justified.

- Field application of composts showed good germination growth and gave better yields in cane (around 25% increase in yield the first year, 26% the second year and 14.1 % the third year). In some cases, the richesse was slightly less, in the case of treated plot with compost. But this is largely compensated by the high increase in yield. Furthermore, it has been seen that one application of compost led to increase in yields over at least three years showing the prolonged benefits of composts.
- This study has been one of the first in Mauritius to demonstrate largescale composting of agricultural wastes and the benefits of applying compost on cane. It has shown promising results in that increase in yields are obtained with application of composts with prolonged benefits over at least three years. Also, these composts can be produced on site with the sugarcane byproducts forming part of an integrated cycle. More bagasse and filtercake will be produced as a result of compost application and these raw materials can then be transformed into additional compost which has the potential to increase the yields further.

Further work has to be done to investigate the (a)Enrichment of the compost with other materials and (b) Conduct field studies to investigate the variety of substitution effect of chemical fertilisers with compost.

ANNEXES

ANNEX I

MRC RESEARCH PROJECT
Preliminary report No 1

COMPOSTING OF SOLID ORGANIC WASTE IN SUB TROPICAL REGIONS

Small scale trials

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Reduit,
Mauritius

December 1995

INTRODUCTION

In Mauritius, high soil temperatures lead to rapid loss of organic matter, thus decreasing its productivity. Organic waste materials could be recycled to these soils to maintain their nutrient balance and act as soil conditioners. However, the majority of solid wastes produced i.e poultry waste, municipal waste and sugarcane waste such as bagasse, vinasse and scum are not suitable for direct application. Composting appropriate mixtures of these wastes would convert them to a humus containing organic material advantageous for crop production..

This report focuses on the solid waste problem in Mauritius and evaluates composting as a potential treatment for solid waste, through smallscale trials.

1.0 SOLID WASTE MANAGEMENT IN MAURITIUS

1.1 Waste generation and its characterisation

Solid waste generation in Mauritius can be grouped into three broad categories: Household and Commercial, Agricultural and Industrial. Waste from commercial sectors grouping hotels and shops is usually collected by same agencies as for household waste. Figure I summarizes the major types of solid wastes generated on the island by sector.

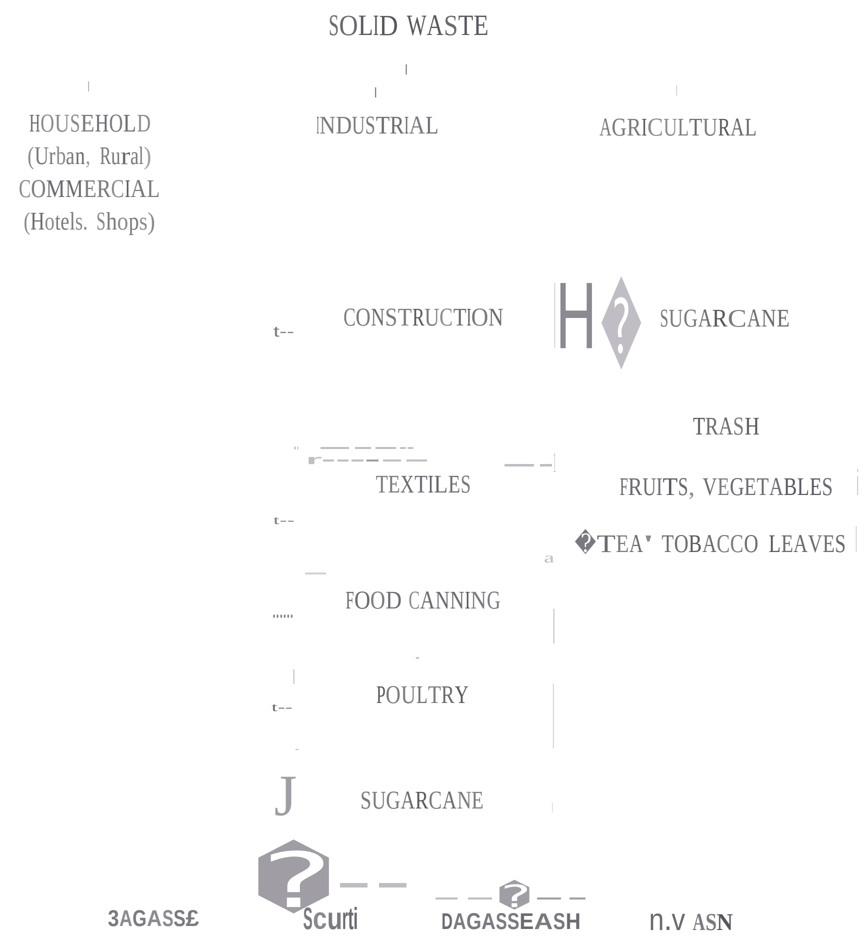


Fig 1 : Summary of main solid organic waste generated

Domestic waste

Amount:

Changes in population size, composition and regional distribution have influenced the amount of domestic waste generation to a great extent. Table 1 indicates the amount of solid waste generated in the 9 districts of Mauritius. These figures are based on a recent study conducted by Ministry of Local Government and are for waste reaching the dumping grounds.

District	Population	Approximate tonnage daily	Kg capita^{-1}.day^{-1}
PortLouis	140000	75	0.535
BBassin/Rhill	100000	55	0.55
Q.Bornes	67000	50	0.746
Vacoas-Phoenix	57000	60	1.052

Curepipe	66000	90	1.36
Pamplemousses	186000	58	0.31
Moka Flacq	248000	40	0.16
Gport/Savanne	162000	80	0.50
Black River	45000	35	0.78
Total		541	

Table 1 :Amount of domestic waste

Composition :

A large proportion of the domestic waste consists of yard refuse (grass, shrubs, hedge trimmings) , paper and food wastes. A study carried out at the University of Mauritius [1] showed that the waste contained a relatively high proportion (65-90%) of biodegradable material.

Figure 2 shows the typical composition of MSW in Mauritius.

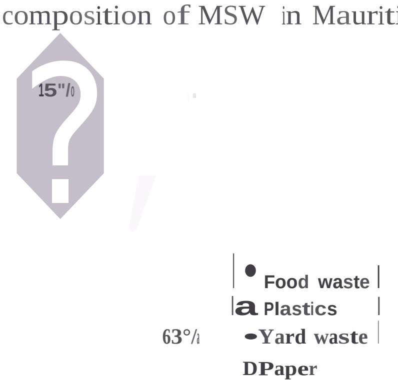


Fig 2 : Domestic waste composition

Industrial waste

There is no detailed data on types and quantities of solid waste generated by the industrial sector. However, certain estimates can be worked out based on the activities of the various industries in the country. For example for the poultry industry during year 1993, it can be estimated that some 900 kg.day^{-1} of poultry waste was generated based on an annual production of 17000 tons of poultry.

Table 2 indicates daily estimates of solid organic waste produced by various industrial sectors based on recent studies [2) and surveys.

Industry	Types of Waste produced	Quantity in tons.day^{-1} (wet basis)
Sugar Cane	Bagasse	4700
	Scum	640
	Fly ash	150

	Bagasse ash	45
Textile	Cuttings	33
Construction	Basalt waste	17
Poultry	Poultry waste	0.9
Others	Food canning waste	0.5
	Breweries	0.5

Table 2: Waste Produced by Industrial Sector

Agricultural wastes

Mauritius has always been an agricultural country which is dominated mainly by the sugar cane industry. Consequently, the agricultural waste consists *mainly* of sugarcane trash (5500 tons.day''), tea and tobacco leaves. These wastes are usually recycled to the land.

1.2 Waste disposal

The solid waste generated on the island was, until recently, dumped in several uncontrolled tipping sites. Since 1991, the authorities have interdicted the use of these [illegible] deals with issues such as solid waste collection, disposal and treatment, not covered by past legislation,

Based on recommendations from several consultants and the *National Environmental Action Plan*, a sanitary landfill strategy has been adopted as the main method of waste disposal for the future. It is expected that by 1996, 2 landfill sites will be operational and 6 transfer stations in the surrounding zones will be setup, each of which will accept on an average 75 tonnes of waste daily.

1.3 Choice of solid waste treatment method

Since the wastes have a high organic content, composting as a treatment method would be highly suitable as the wastes would be easily reduced to an endproduct which could be used both as nutrient supply and soil conditioner. The value of compost lies not only in its NPK content but also in substantial quantities of humus which are essential for maintenance of soil organic matter and fertility levels in tropical and subtropical regions such as Mauritius.

1.4 Relevance of composting in the Mauritian context

The relevance of composting in the Mauritian context is as follows :

- Help to get rid of the organic portion of solid wastes in an environmentally friendly way.
- Provide humus to the soil, specially in subtropical regions where high soil temperatures lead to rapid loss of organic matter, thus decreasing its productivity.
- The endproduct could be used to replace chemical fertilizers in the production of organic sugar, the demand of which is gradually increasing on the European market.

2.0 OVERVIEW OF COMPOSTING

2.1 The Composting process

Composting is generally defined as an exothermic process of biological oxidation in which organic matter is decomposed by a mixed population of micro organisms in a warm, moist aerobic environment. The microorganisms require oxygen, moisture, a source of carbon and macro nutrients such as N, P, K usually found in the waste material. In the process, the organisms reproduce themselves and eventually die.

2.2 Methods of composting

One of the oldest forms of composting has heen the windrow system. *The material* to *be* composted *is* stacked in piles that **car? be** arraaged **in lang parallel** rcws er windrows.

Nowadays, there are numerous ways of composting starting from the simple heap system to the highly mechanized ones equipped with control strategies. A variety of techniques can be used to classify compost systems. They can be grouped according to degree of aeration *(aerobic,anaerobic)*, temperature *(mesophilic, thermophilic)*, technological approach *(open, enclosed)*, operational mode *(batch, continuous)*, raw materials *(municipal refuse, sludge, refuse/sludge)* and operating methods *(conventional, nonconventional)*.

2.3 Monitoring of parameters

Optimal composting depends on the proper monitoring of process factors such as temperature, moisture content, pH, particle size, C/N ratio, structural strength and aeration rate. These factors vary on type of composting process adopted.

The process parameters [3] recommended for composting are given in Table 3 :

Parameter	Value
C/N ratio of feed	25 to 35:1

Particle size	10 mm for agitated systems and forced aeration 50 mm for long heaps and natural aeration
Initial moisture content	50 to 60% (higher values when using bulking agents)
Air flow	0.6 to 1.8 m^3 air/day/kg volatile solids during thermophilic stage, or maintain oxygen level at 10 to 18%
Temperature	55 to 60°C held for 3 days
Agitation	No agitation to periodic turning in simple systems. Short bursts of vigorous agitation in mechanized systems
pH control	Normally none necessary
Heap size	Any length, 1.5 m high and 2.5 m wide for heaps using natural aeration. With forced aeration, heap size depends on need to avoid overheating and maintain air flow.

Table 3 :Parameters for composting process

3 NATURAL AERATION TRIALS

A bench scale aerobic composting system using a drum composter of 0.7 m3 has been developed that has permitted the natural composting process to occur in the laboratory.

In the first stage, the laboratory cornposter has been used to assess the chemical and physical properties of raw materials, determine appropriate bulking agent and the optimum mixing ratio to allow efficient composting

3.1 Compost drum

The drum was made of mild steel, the inner surface of which was coated with bitumen to prevent corrosion. It was mounted on wheels and placed in the lab. The dimensions are as follows : length 1500 mm, diameter 700 mm and volume 0.577 m^3 The drum was turned on a daily basis for the first 4 weeks and every 3 days for the remaining 3 weeks.

3.2 Characterisation of raw materials

Three trials were carried out consisting of different combinations of solid organic waste. The characteristics of the materials used and mixtures are summarized in Table 4.

(a). Markel waste and bacasse *firinl* 11

Mixture l consists of 3 i kg of market waste and 26 kg of bagasse, The major component in the solid waste produced in the market *is* vegetable waste (around 95%). 5% consisted of rocks, paper and plastics which were removed by hand and the remaining was chopped. The average particle size was around 3 cm.
Bagasse is the fibrous material left after juice has been extracted. Its composition is as follows : moisture content : 48-52%, fibre (cellulose, lignin, pentosans): 43-52% and soluble solids : 2-6%.

(b) Chicken waste and scum *(trial 2)*

Mixture2 consists of 67 kg of chicken waste and 50 kg of scum. The raw material was composed mainly of chicken manure and wood shavings (the latter being the bedding material). Filter mud is added to raise the initial moisture content of chicken waste and wood shavings (around 31 %). Filter mud or scum is the cake formed after impurities in sugarcane juice are removed by filtration.

(c) Market waste and sawdust *(trial 3)*

A trial consisting of market waste and saw dust was done to examine the possibilty of substituting bagasse by saw dust which is more readily available. Mixture3 is made up of 40 kg of market waste and 60 kg of sawdust.

	Waste	Weight (kg)	Moisture content (%)	Bulk density (kg/m")	Nitrogen content (%)	C/N ratio
TRIAL 1	Market waste	31	80	250	2	23
	Bagasse	26	50	114	0.27	*
	Mixture!	57	65	157	*	*
TRIAL 2	Chicken waste	67	31	331	3.11	16
	Scum	50	73	520	1.25	25
	Mixture 2	117	60	485	*	*
TRIAL3	Market waste	40	90	250	2	23
	Sawdust	60	44	260	0.1	554
	Mixture3	100	62	251	0.3	181

* : not available.

Table 4 : Characteristics of trials 1, 2 and 3.

3.3 Results and discussion

The physical and chemical analysis of the mixture included measurement of temperature, moisture content, bulk density, carbon content, respiration rate, nitrogen content and volatile solids. They were monitored on a weekly basis, except for nitrogen which was measured at the start and end of trials. The temperatures were recorded daily. The methods of analvcis [illegible]

T

Temperature

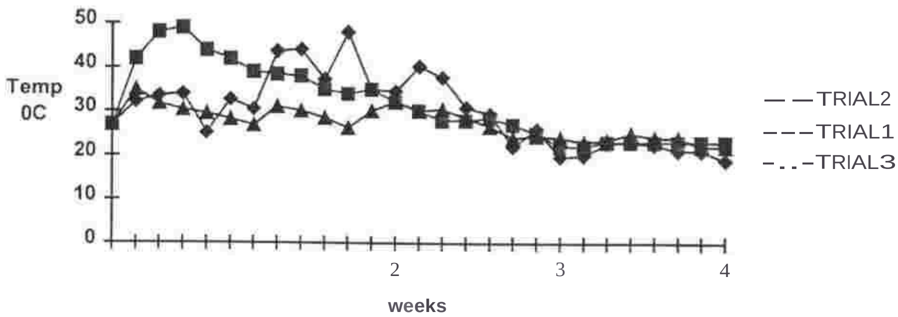


Fig 3: Temperature profile.

In the drum composting experiments, the general trends observed were as follows : The temperature rose very rapidly in the first three days to achieve a maximum of 50 °C and then dropped gradually over 3 -4 weeks to reach ambient temperature.

This panern can be explained by the fact that the drum being metallic, the heat losses from the compost to the surroundings increased when the temperature gradient increased.

Also, the quantity of degradable material contained in the drum is not sufficient to sustain microbial activity since a maximum of 80 -90 kg of waste could be composted at one time.

Moisture content

Day No	7	14	21	28	35	42
Trial 1(%)	59	61	63	63	64	65
Trial 2(%)	55	56	60	59	62	63
Trial 3(%)	53	57	60	60	62	64

Table 5:Moisture content variation.

Table 5 shows the results for moisture content. Despite the fact that the optimum range of moisture is often given as 50-65% in practice, a high initial moisture content of 62–68% was used in these experiments since bagasse is a rigid material.
During the composting process, moisture is usually released as one of the end products of microbial metabolism. In the three trials, the moisture content tended to increase in all cases. This may be due to the high humidity of the climate (av. 80%) and also due to the cylindrical structure of the drum. Any excess moisture when condensed tended to drop to [illegible]

Bulk density

Day No	7	14	21	28	35	42
Trial l(kg/m,)	200	214	221	243	257	257
Trial 2(kg/m^3)	485	485	500	521	571	571
Trial 3(kg/m^3)	267	296	296	311	311	311

Table 6: Bulk density variation.

Table 6 shows the variation in bulk density with time.The bulk density increased in all trials. This was due to the particles being broken down to smaller size by the microorganisms during the composting process. When the mixture was first introduced, the particle size was around 30 mm compared to the 2 mm at the end of the process.

Volatile solids

Day No	7	14	21	28	35	42
Trial I (% d.w)*	87.9	87.7	86.8	85.0	82.6	82.5

Trial 2 (% d.w)	83	81	78	77	76	76
Trial 3 (% d.w)	98.93	98.87	98.75	98.7	98.64	98.5

Table 7: Volatile solids variation.

(% d. w)* : percent dry weight

Table 7 indicates the volatile solids content for the three trials.The volatile solids content decreased by an average of 35% in trials 1 & 2, on a mass basis. Experimental results at start might be misleading due to the heterogenuous nature of mixture.

Day No	7	**14**	**21**	**28**	**35**	**42**
Trial 1	6.6	6.6	7.3	**7.3**	7.4	7.4
Trial 2	6.1	6.2	6.3	6.7	6.7	6.7
Trial 3	6.3	6.4	6.4	6.6	6.7	6.7

Table 8: pH profile.

Table 8 gives the variation in pH. A pH ranging from 6 to 8 is usually considered ideal in [illegible] around 7.

C/N ratio

C/N ratio	Start	End
Trial 1	71:1	41:1
Trial 2	17:1	15:1
Trial 3	181:1	*

*: not available

Table 9: C/N ratio at start and end of trials.

Table 9 gives the C/N ratio at start and end of the three trials.In the experiments, an accurate calculation of C/N ratio was difficult because some of the carbon substrate is not easily available. specially the bagasse is in the form of highly resistant lignin which takes litlle part in the composting process and is only decomposed over a long period of time when the compost is added to the soil.

Respiration rate

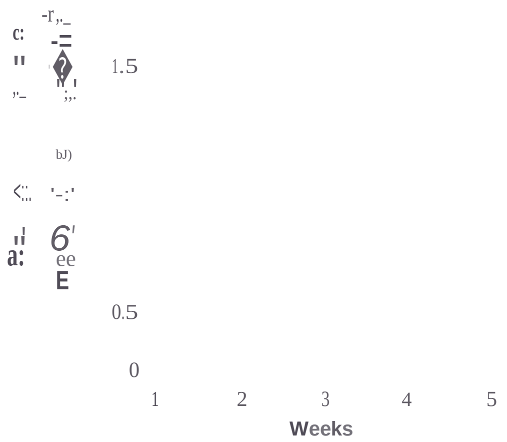


Fig 4: Respiration rate - Trial

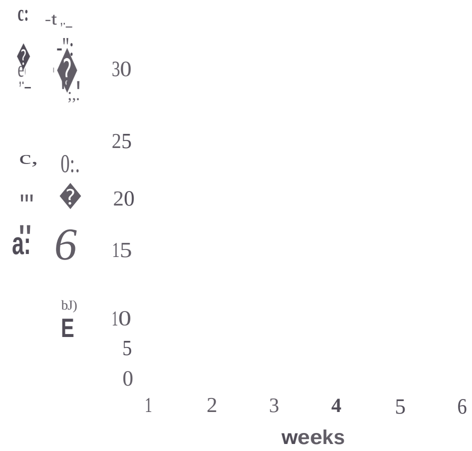


Fig 5: Respiration rate - Trial 3

Figures 4 and 5 refer to the respiration rates for trials 1 and 3. The oxygen consumption appears to increase to a maximum and then decreases with time.

Being a natural aeration process, the rate of air diffusion into the compost mass is not uniform and since samples were taken in a random way, the oxygen uptake rates might not be homogeneous.

CONCLUSION

The temperature patterns and breakdown **rates indicate that the** raw materials would compost well, Also, the **finai** composts **were humus iike in texture, uniform** in **particle** size with no objectionable odors.

FUTURE PLAN OF WORK

Large scale windrows of industrial waste will be set up and the process parameters will be monitored so as to achieve composting in minimum time. The product would be tried for organic sugar production in collaboration with one of the sugar estates.

As a first trial, 3 windrows of 4 tons of sugar cane waste each will be composted using natural aeration. The three piles will consist of mixtures of bagasse and scum (pile 1), bagasse, scum and fresh grass (pile 2) and bagasse, scum and a suitable nitrogeneous source (pile 3).

To optimise composting process, experiments where parameters would be monitored and varied would be carried out. The stability of the compost, a critical characteristic when used for sugar cane plantations would also be closely followed.

Methods such as aerated static pile systems and other process control stategies will be investigated to optimise the large scale composting process.

Finally, an economic feasibility of composting would be carried out.

References :

1. Bunjun ., 1983. *Treatment of waste* . Brech final year project, University of Mauritius

2. State of the Environment in Mauritius, (1991). Report prepared for presentation at UN Conference on Environment and Development. Rio de Janeiro, Brazil, June 1992.

3. Dalzell, H. W., Biddlestone, A.J., Gray, K. R. & Thurairajan, K., Soil Management• *Compost Production and Use in Tropical and Sub Tropical Environments.* Soils Bulletin 56. Food and Agriculture Organisation, United Nations, Rome, Italy, 1987.

Annex 1 : Methods of Analysis

Parameter	**Method**
Temperature	The temperatures were taken at 6 different points in the mixture [illegible] temperatures were taken daily during the project
[illegible]re	The moisture content was determined using the dry 'Neight method. The initiai mixture is weighed and then put in the oven at 105°C for 24 hrs and the weight of final mixture is determined. The % loss in weight gives the moisture content.
Bulk density	The bulk density was determined by filling a bucket of known volume (bucket filled with water and weight is determined) with the sample and weighing it. The bucket was shaken to allow the sample to settle down.
Volatile solids	The VS is determined by taking a known weight of the previously dried mixture at 105°C, burning it in a crucible to remove smoke and placing it in a furnace at 550 °C for 2 hrs. The final weight is determined. The % loss in weight gives the volatile solids content.
pH	5 g of compost are dissolved in water and continuously stirred. A portable pH meter is then used to measure the value.
Carbon content	The amount of carbon is obtained by using the empirical formula % C = (100 - ash)/ 1.8 where % Ash = 100 - VS

Nitrogen content	The total kjeldahl nitrogen was determined by using a special digesdahl apparatus. The sample is first digested with concentrated sulphuric acid and heated at 850°C, and then treated with hydrogen peroxide. The amount of nitrogen is the determined by using Nessler's method.
Respiration rate	The shredded compost is mixed with water and placed in a BOD bottle. This BOD meter is connected to a chart recorder and airpump. The sample is aerated for a certain time and then the rate of oxygen consumption is determined during 30 minutes and then sample is reasserted. Around 5 -6 tests are performed for the same sample and the SOUR (Specific oxygen uptake rate) is the maximum rate obtained for that sample.

$$SOUR = \frac{\text{oxygen uptake rate} * \text{volume}}{\text{sample mass} \cdot \text{fraction dry solids} \cdot \text{fraction vs}}$$

ANNEX 2

MRC RESEARCH PROJECT
Preliminary report No 3

COMPOSTING OF SOLID ORGANIC WASTE IN SUB TROPICAL REGIONS

Pilot Scale Trials

Prof J. Baguant, R. Mohce

University of Mauritius

Reduit,
Mauritius
April 1997

INTRODUCTION

Successful utilization of organic materials produced during sugar cane processing will not only drastically reduce amounts of material destined for disposal, but also create useful predicts.

Composting to biologically stabilize these wastes into a humus material similar to soil organic matter could prove to be a viable process. The final composted product is less bulky than that of raw waste and because of the reduced volume, it will cost less to haul and apply. Also the heat produced by the compost process destroys pathogens.

Numerous options exist for organic materials management, ranging from simple on site composting to capital intensive mixed waste compost facilities.

The aim of this project is to assess the composting potential of 2 sugarcane byproducts, bagasse and scum through pilot scale trials and also study the possibility of using weeds as amendment. Adequate procedures for largescale composting will then be developed.

1.0 METHOD

Li Raw materials

The raw materials used for this preliminary trial were scum and bagasse. The characteristics of filter cake used have been determined in the laboratory and are as follows : Moisture : 73%, Volatile solids content: 57%, total kjeldahl nitrogen was 1.25% (on a dry weight basis), C/N ratio 16 and bulk density was 330 kg/m3.

Tests were done in the laboratory on two types of bagasse, fresh and stored moist bagasse. The moisture content for fresh bagasse was around 44% and that for moist bagasse : 72%.

Around 12000 kgs of these materials were mixed and arranged in 3 piles in such a way so as to optimize the process parameters such as moisture, C/N ratio and volume.
The characteristics of the mixtures were as follows :

		Pile 1	Pile 2	Pile 3
Weight (kgs)	Bagasse	1000	1000*	1000**
	Scum	2200	3000	3000

Weed	600		
Volume (m3)	17.3	14.5	14.5
Moisture content(%)	66.4	74.2	65.8
Volatile Solids (%)	66.5	69.9	68.37
C/N ratio	42	35	48

* : stored moist bagasse
**: fresh bagasse

They were stacked in 3 piles which were arranged in long parallel rows or windrows. The height of the windrows ranged from 6 ft to 8 ft with widths of 1215 ft. They were placed upon an asphalt pad for ease of operation.

Composting is being carried out aerobically.The windrows were aerated by turning the material twice a week for the first 3 weeks and once weekly for the rest of the process.

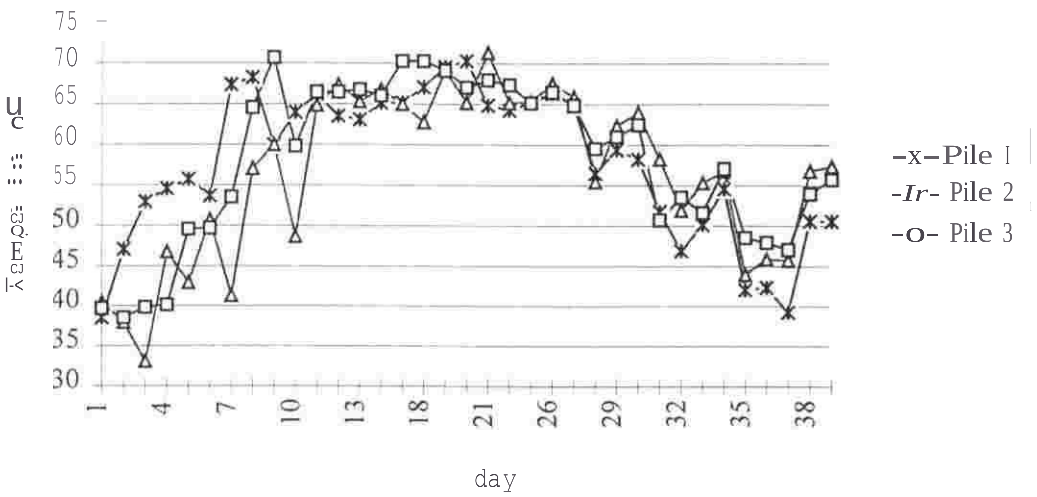
1.2 Monitoring of parameters :

Piles were composted for 6 weeks from January to March 1995. Single sarnpes (30 gm weight) were removed every week for moisture, ash and pH deierminaiion. iniernai temperatures at 3 different sites in each pile were monitored on a daily basis. To determine the stability of the compost pile, the respiration rate of mixtures were also measured.

2.0 RESULTS :

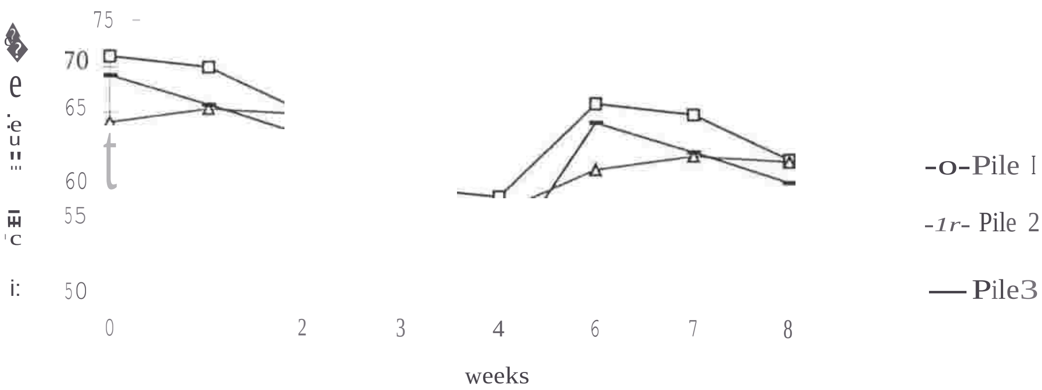
2.1 Temperature :

When composting begins 2 or 3 days after the wastes are mixed and placed in piles, thermophilic bacteria, the most common microorganisms at work in the 35oC - 50oC range rapidly decompose the organic material to produce carbon dioxide, water and heat. The temperature thus continues to rise and then stabilizes at around 65oC for almost 1 week before falling. This is sufficient to achieve pathogen reduction since a temperature of 60oC for a minimum of 5 days is necessary to destroy pathogens.



2.2 Moisture Content:

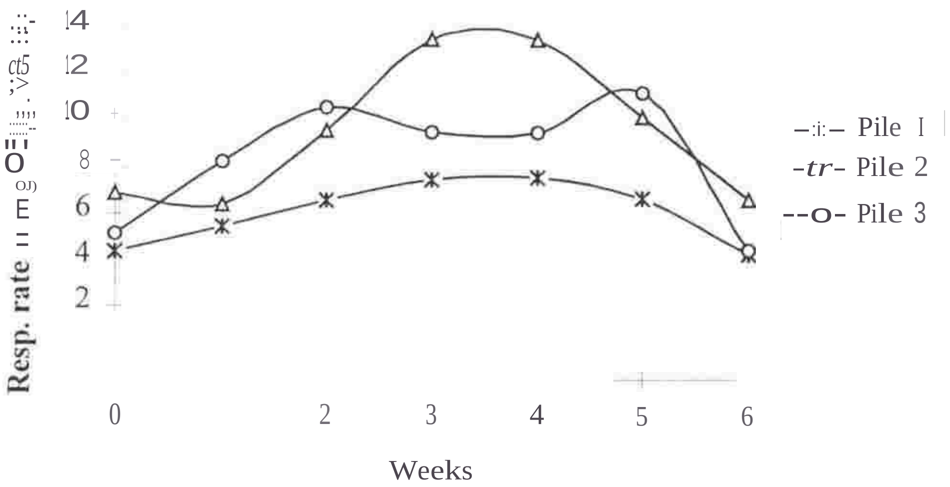
The ideal moisture content is usually in the range of 6065%. In all trials, the moisture content decreased to below 60% after 4 weeks of composting so that [illegible]



2.3 Respiration rate:

Respiration rate is used as an indicator for stability of compost. The oxygen consumption at a particular instant in a composting cycle depends not only on temperature, but on degree of agitation, feed material composition and whether heap is warming up or cooling down.

The respiration rate of mixtures rose from 4 mgO_2/(g VS.hr) to stabilize around 12 mgO_2/(g VS.hr) after 4 weeks of composting, indicating that microorganisms are still active in the piles. It then started falling gradually.



2.4 pH:

A pH of 6-8 is considered ideal. As composting progresses, the pH for the three piles decrease since carbondioxide when combined with water produce carbonic acid which would lower the pH of the final product. The variation in pH for the three piles were as follows:

Week	0	1	2	3	4	5	6	7
Pile 1	8.9	7.8	7.5	7.7	7.9	7.8	8	7.5
Pile 2	8.5	7.9	8	8	8.3	7.9	8.2	7.8
Pile 3	8.4	7.9	7.5	7.9	7.6	8.1	8	7.8

2.5 N, P, K value:

The N, P, K determination for pile 1 was done and the values are as follows:

	Week 1	Week 7

N(% dry weight)	0.92	1.49
P(% dry weight)	0.66	0.87
K(% dry weight)	0.16	0.23

2.6 Stability of composts :

The final composts were dark in color, had an earthy smell and it was quite difficult to recognize the original ingredients although bits of bagasse could be seen.

Based on the respiration rate and temperature evolution, the final compostswere stabilized and ready to be spread on cane fields as soil amendment. However, if the composts were to be used for horticultural practices or in seed starting mixtures, it would have to be cured for another 4 weeks.

CONCLUSION

- It was observed for pile 1 that no weeds or weed seed could be seen to grow in the pile. The high temperatures attained must have inhibited the growth of the weeds.

- The high temperatures reached after only 1015 days of composting showed that these raw materials would compost well.

- Starting from 12 tons of raw materials, around 6 tons of finished product was obtained. The efficiency is around 50%.

FUTURE WORK

Largescale windrows consisting of around 150 tons of sugarcane waste would be composted. Additives such as chicken waste and urea would be used to improve C/N ratio and speed up composting process. The rate of decomposition, the final product quality and monitoring of process parameters would be determined.

Finally, the possibility of using aerated static piles would be investigated.The material would be placed in windrows fitted with perforated piles through which air would be blown.This would eliminate the need for frequent turning.

ANNEX 3

MRC RESEARCH PROJECT
Report No 4

COMPOSTING OF SOLID ORGANIC WASTE IN SUB TROPICAL REGIONS

Pilot Scale Trials and Use of Compost

R. Mohee

University of Mauritius
in collaboration with
Rose Belle Sugar Estate

Mauritius

August 1998

Introduction

This project was initiated in 1995 to assess the potential of composting the byproducts of the sugarcane industry namely bagasse and filtercake. Preliminary work was carried out to characterise wastes available in the sugar factories and to assess the feasibility of composting as a treatment method for byproducts of sugarcane production. In this context, a bench scale composter was developed in the laboratory at the university where several composting mixtures of bagasse, scum and chicken waste were investigated.

Preliminary trials carried out at the University of Mauritius using the laboratory scale composter determined the following factors:

- Chemical and Physical characteristics of substrates
- Mixing ratio of the two substrates
- Need for additional amendments and bulking agents.

The findings for the trials using the laboratory composter and characterisation of wastes have been described in previous reports[1, 2]

Preliminary trlats

Based on the outcome of the experiments on a laboratory scale basis, pilotscale trials involving 20-30 tons of raw materials were carried out. The findings were as follows :

- The temperature profiles (figure 1) followed typical temperature profiles of large scale composting systems whereby the temperatures rose up to around 70°C in the first week, remained steady for about 2-3 weeks and then dropped.
- The moisture contents (figure 2) decreased during the first four weeks and at week 6, rainwater compensated for the decrease in moisture in the pile due to microbial metabolism. The final dry matter contents averaged 35% total solids over the different trials.
- The composts were stabilised after around 10 weeks. The respiration rate dropped to less than 6 mgO_2/gvs.hr after 10 weeks (figure 3). The respiration rate indicates the amount of oxygen needed by the microorganisms to degrade the waste. If other parameters such as moisture and oxygen availability are not

considered to be limiting, then the respiration rate can be taken as a measure of stability"

- Overall mass balances indicated an efficiency of around 50-60%.
- Addition of nitrogen supplements in the form of urea was found to be favourable to the composting process.
- Adequate mixing of wastes is difficult with a front end loader.

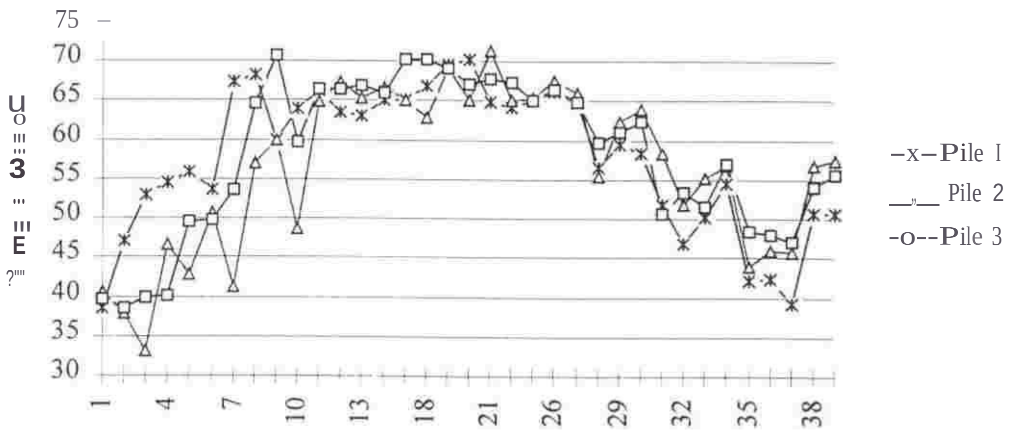


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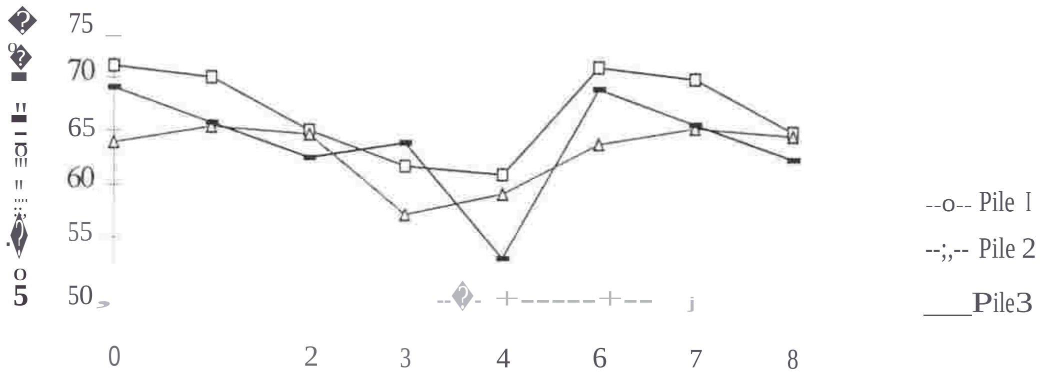
Fig.on, i : Temperature profiies of piies



weeks

Figure 2 : Moisture content variations for piles

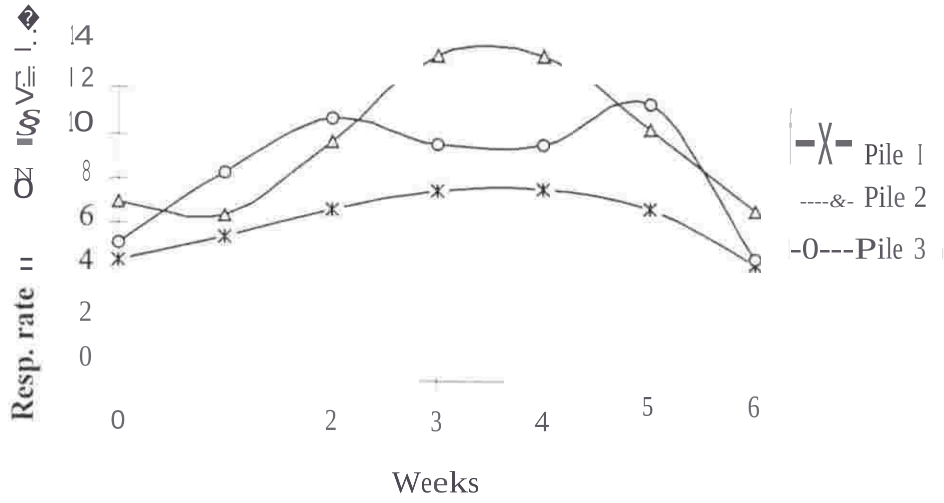


Figure 3 : Respiration rate of different piles

Application of composts

l-omposts were applied to sugarcane tields(around 2.5 hectares) at the rate of 5 tonnes per hectare during plantation. Together with fertilizers, composts were added in each line (row) of cane plantation. Control for the experiment was provided by a neighbouring 2.5 hectare plot where all plantation and agronomic conditions were maintained similar but for the compost addition.

Findings of Year I

Preliminary results show that the application of 5 tonnes per hectare of compost improved both the chemical and physical properties of the cane. Amonsgt other parameters, the number and height of cane stalks improved substantially. The number of cane stalks per hectare increased from 87,654 to 116,049 and the mean height of cane stalk from 2.31 m to 2.68 m. These results have been obtained for the first harvest of the cane plantation 7 year plant cycle.

Future Work - Phase 2/Forced Aeration

To optimise the composting process, process control strategies would be applied to the composting process. A control system with aeration based on temperature feedback could be setup to maintain biologically favourable temperatures. Thermistors could be installed in the pile and a temperature controller with an adjustable temperature set point will receive signals from the pile. The blower will then be actuated and the airflow rate will be modified. Pipes will be laid underneath the composting pile and a blower will be switched on/off with the controller system.

After discussing with Rose Belle Sugar Estate, because of financial problems, it was decided that a prototype involving forced aeration techniques be set up at the University of Mauritius to identify control parameters. The findings of the prototype study will then be used as basis for large-scale forced aeration composting. The prototype set up will be from July 1998 - December 1998. Details of the blower control system are given in figure 4

Advantages of forced aeration composting compared to windrow technology :

- It speeds up the composting process. The duration for the high rate composting is decreased form six weeks to 3 weeks.
- The substrates need not be pretreated
- There is no need for mechanical turning using front end loaders which diminish the costs of labour and equipment .
- It is a computerized stand alone system whereby the temperature is automatically regulated through the intake of air. It does not need precise monitoring of parameters once the system is set up.

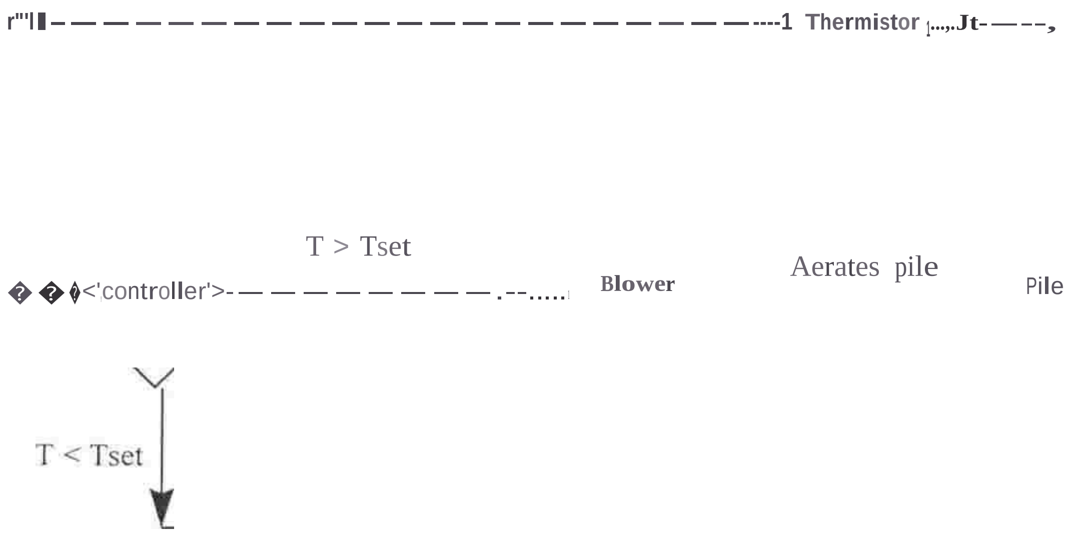


Figure 4 : Schematic of temperature feedback blower control system

References :

1. Mohee R. and J. Baguant. [illegible] Composting of solid organic waste in subtropical regions. Small Scale trials. Preliminary report 1. Submitted to Mauritius Research Council in December 1995.

2. Mohee R. and J. Baguant. 1997. Composting of solid organic waste in subtropical regions. Pilot Scale trials. Preliminary report 3. Submitted to Mauritius Research Council in April 1997.

3. Lasaridi K. E and Stentiford E. I. (1996). Respirometric Techniques in the context of Compost Stability Assessment: Principles and Practice. In M. de Bertoldi, P.Sequi, B.Lemmes, T.Papi (eds). The Science of Composting, Part I. Chapman & Hall, Glasgow.pp 274-285.

ANNEX 4

MRC RESEARCH PROJECT

COMPOSTING OF SOLID ORGANIC WASTE IN SUB TROPICAL REGIONS

PHASE 2 – FORCED AERATION

Status Report

Dr (Mrs) R. Mohee

University of Mauritius

Reduit,
Mauritius

March 2000

Table of Contents

Acknowledgement

We would like to express our thanks to the MRC for funding this project. Also, we would like to thank Mr I. Rohomom, the research assistant, Miss H. Ramsurn who conducted the small scale experiment as well as the technical staff of the Sugar Tech Lab, Mr Bheekun, Mr Sowruth and Mr Tokhai. Our thanks also go to the CIS Department, Mr Roshnee and Mr Govinda from the CITS Department for helping us with the automatic control equipment.

Acknowledgement

We would like to express our thanks to the MRC for funding this project. Also, we would like to thank Mr I. Rohomom, the research assistant, Miss H. Ramsum who conducted the small scale experiment as well as the technical staff of the Sugar Tech Lab, Mr Bheekun, Mr Sowruth and Mr Tokhai. Our thanks also go to the CIS Department, Mr Roshnee and Mr Govinda from the CITS Department for helping us with the automatic control equipment.

SUMMARY

The final phase of this study, financed by the Mauritius Research Council (MRC), is based on the automatic control of aeration in composting. Composting is the controlled degradation of the organic fraction of certain wastes with the main objective of producing soil conditioners (fertilisers) for agriculture. The main requirements in composting besides temperature and moisture control is the monitoring of aeration, i.e oxygen supply. Aeration in composting is carried out manually or mechanically. Manual aeration is the regular turning of the compost pile so that air can penetrate it and mechanical aeration is the turning of the pile with a tractor or other type of machine.

The aim of this research is to control the aeration automatically by using Stainless Steel Pile Temperature Probes and Oxygen Pile Probes in order to activate a single-phase blower. The temperature probe senses the temperature of the compost, matches it against a set temperature, so that the blower will be on above the set temperature. Similarly, the oxygen probe will sense the oxygen content of the pile, matches it against a set point value, so that the blower is on below that set point.

In the previous phases, it has been seen that composting of sugarcane byproducts such as bagasse and scum can be achieved successfully.

Phase 1	Determination of optimum parameters
Phase 2	Composting and application of composting
Phase 3	Forced aeration method

Phase 3, that is this phase consists primarily of the setting up of the automatic control of the composting unit to provide aeration in terms of temperature and time. This part has been validated with a mixture of bagasse and broiler litter as data with passive aeration already existed for bagasse/broiler litter mixture for small scale systems and can be used for comparison purposes.

From this study, it has been seen that aeration can effectively be controlled with the compost captain controller unit based on temperature feedback and that active aeration promotes more efficient composting as compared to passive aeration.

A user manual for the compost captain controller unit has also been written (Appendix 2.0).

1. INTRODUCTION

Composting is an exothermic, aerobic, microbial process of stabilization of organic material. During composting, microorganisms such as bacteria and fungi break down complex organic compounds into simpler substances and produce carbon dioxide, water, minerals and stabilized organic matter (compost). Determined environmental factors like moisture, temperature, oxygen, are the requirement for the microbial metabolism, and the function of the process technique for composting is to optimize and to keep these factors

Air is required during aerobic composting for three purposes :

1. supplying oxygen for biological decomposition (stoichiometric demand),
2. removing moisture from the composting mass (drying demand), and
3. removing heat to control process temperatures (heat removal demand).

Air is supplied to naturally aerated compost piles by convection induced by the buoyancy of heated air (also called the chimney effect) or by wind currents. The amount of air supplied by these mechanisms is affected by the size, shape and orientation of the compost pile. Another mechanism of aeration used in naturally aerated piles is mechanical turning to replace the interstital compost gas with fresh air. The effectiveness of aeration via turning is related to the turning frequency. Neither of these mechanisms can however provide the level of aeration supplied by forced aeration. Since insufficient aeration can lead to anaerobic conditions and strong noxious odours, understanding the effectiveness of these aeration mechanisms and ways they can be optimized is important. Aeration rate is a key factor during composting and influences the rate of organic matter decomposition, the production of odour compounds and the quality of compost products

2. CONTROLLING THE AERATION RATE

The aeration system is an important feature of all modern composting systems. The ability to control aeration is one of the key points of process control and is an important consideration in process selection.

The main needs of a control system are :

- to ensure an adequate supply of air – for microbial and cooling needs, and
- to optimise the rate of biodegradation – by maintaining an elevated temperature.

There are a number of control strategies, which have been used in practice. These can be summarised as follows:

1. **Uncontrolled** – Windrow aeration by natural ventilation is an example of this approach. However, this is not applicable to aerated pile or reactor systems.
2. **Manual** – Throttling valves can be used to manually control the aeration rate. This is a common practice where lateral ducts are tied to a manifold, which in turn is connected to a central blower system. Throttling valves can also be used with a single blower/manifold system. Flow through each lateral or single blower is manually adjusted by throttling the valve throughout the composting cycle.
3. **On/Off Sequencing by Timer** – With a singie biower design, the average rate of air supply can be controlled by regulating the blower "on-time" by means of a timer control. This approach is often used with a static pile system and some reactor systems. Timer control can be used in conjunction with throttling valves to allow adjustment of both on-time and flow rate.
4. **Feedback Control Based on O_2 or CO_2 Content** – Oxygen or carbon dioxide probes inserted into the composting mixture or the exhaust gas ducts can generate a control signal used to modulate air supply and maintain a set point O_2 or CO_2 content. O_2 or CO_2 is the *controlled* variable and aeration rate the *manipulated* variable. This control strategy is only useable with dry substrates and where temperature control is not used because the aeration supply is then near the stoichiometric demand. With wet substrates or where temperature control is used, the aeration demands for moisture and heat removal are so high that the O_2 content often differs slightly from that of ambient air (21 % by volume).

5. Feedback Control Based on Temperature– Thermocouples inserted into the composting mixture can generate a control signal used to modulate air flow rate or blower on-time to maintain a set point temperature. Temperature is the controlled variable and aeration rate the manipulated variable. This controlled approach is used in many static pile and most reactor systems and is considered well proven.
6. Air Flow Rate Control – If the daily quantity of feed material remains reasonably constant, it is possible for the operator to control air flow rate to a fixed value by either manual adjustment of fan dampers or by a set point flow rate control loop. This approach is used in some reactor systems where conditions are not expected to change rapidly.

3. MATERIALS AND METHODS

3.1 Apparatus

3.1.1 The Drum

Composting trials were carried out in an experimental reactor which was in fact a horizontal plastic cylinder 112 cm in diameter and 90 cm in length, with a volume of approximately 0.2 m^3. An opening at the top of the drum allowed substrate to be loaded and unloaded and samples for analysis (See Section 4.3) were taken from this same opening. There are 3 holes of aeration of 5.0 cm diameter on top of the drum and 1 other hole at the bottom.

Figure 3.1 shows the drum in which all the composting trials were performed.

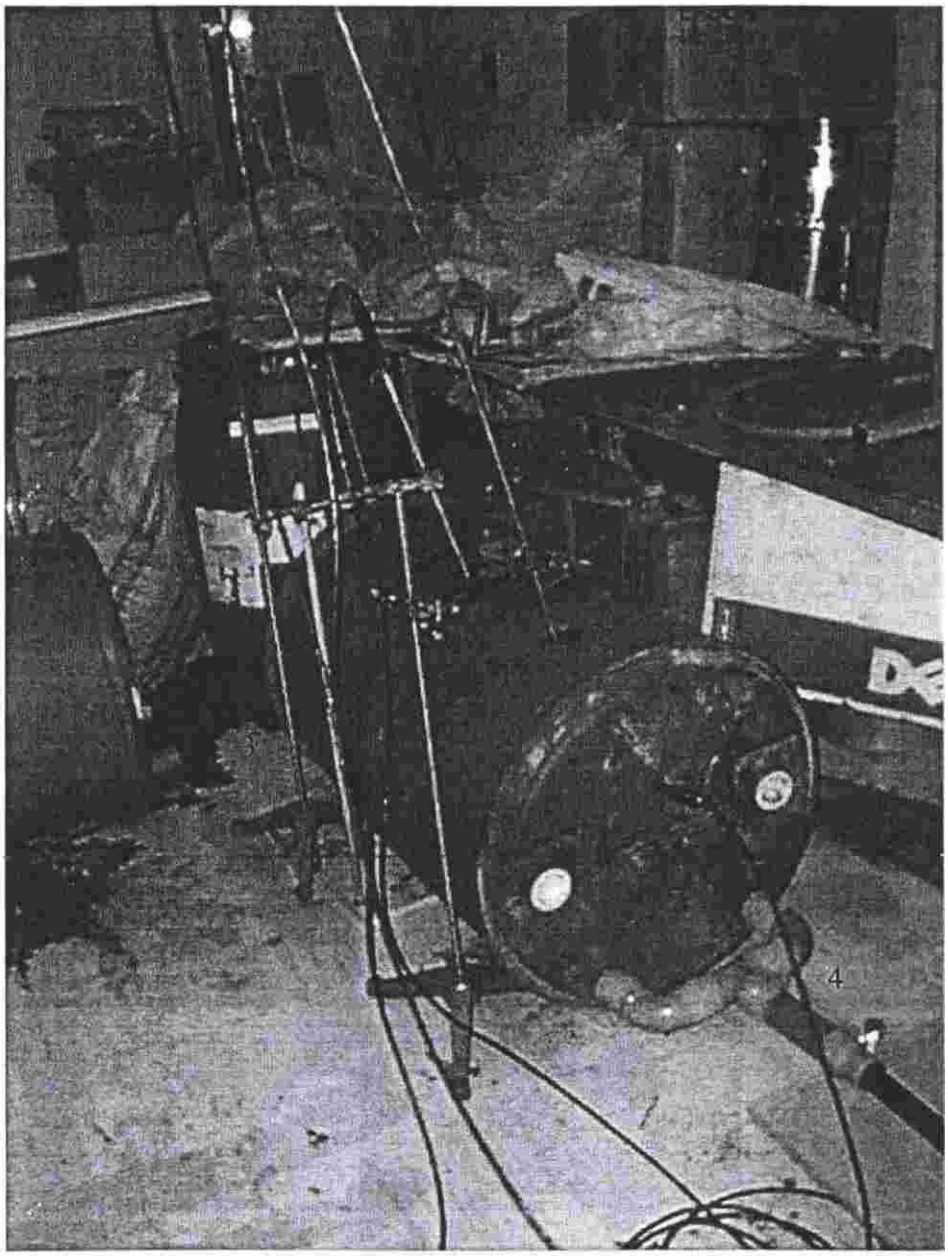


Figure 3.1 : The reactor (Drum) used for composting Bagasse and Broiler Litter

l -reacter.drum

"stainless steel thermocouple

3-stand

4-aeration pipe connected to blower

5-acration holes

6-sanlpling point / opening

3.1.2 Compost Captain

Two aeration tubes of 5.0 cm diameter connected the drum to a fan. The fan blows air at a rate of 0.09 m³min⁻¹ and was regulated by a timer to work at fixed intervals according to the type of demand. This timer forms part of the Compost Captain Master Composter, which is a composting instrumentation, and process control unit (See Figure 3.2 for Captain Composter connections). A trial was performed by setting the timer in such a way that the fan would blow air every 5 minutes after each 1 ½ hour.

Temperature inside the reactor was detected by 3 probes placed in the 3 aeration holes on top of the drum. These probes were connected directly to the compost captain whose screen indicated the actual temperature measured by these devices. The 42" temperature probes supplied with the Compost Captain have connector end, stainless steel body, and temperature sensing tip. The connector end is attached to the sensor extension cables and then to the temperature sensor cable at the Compost Captain Master. The probes can sense temperature in the range of 4.4 °C to 93.3 °C. The temperature sensing tip reads the temperature and converts it to a 4 mA to 20 mA signal which is read by the Composter.

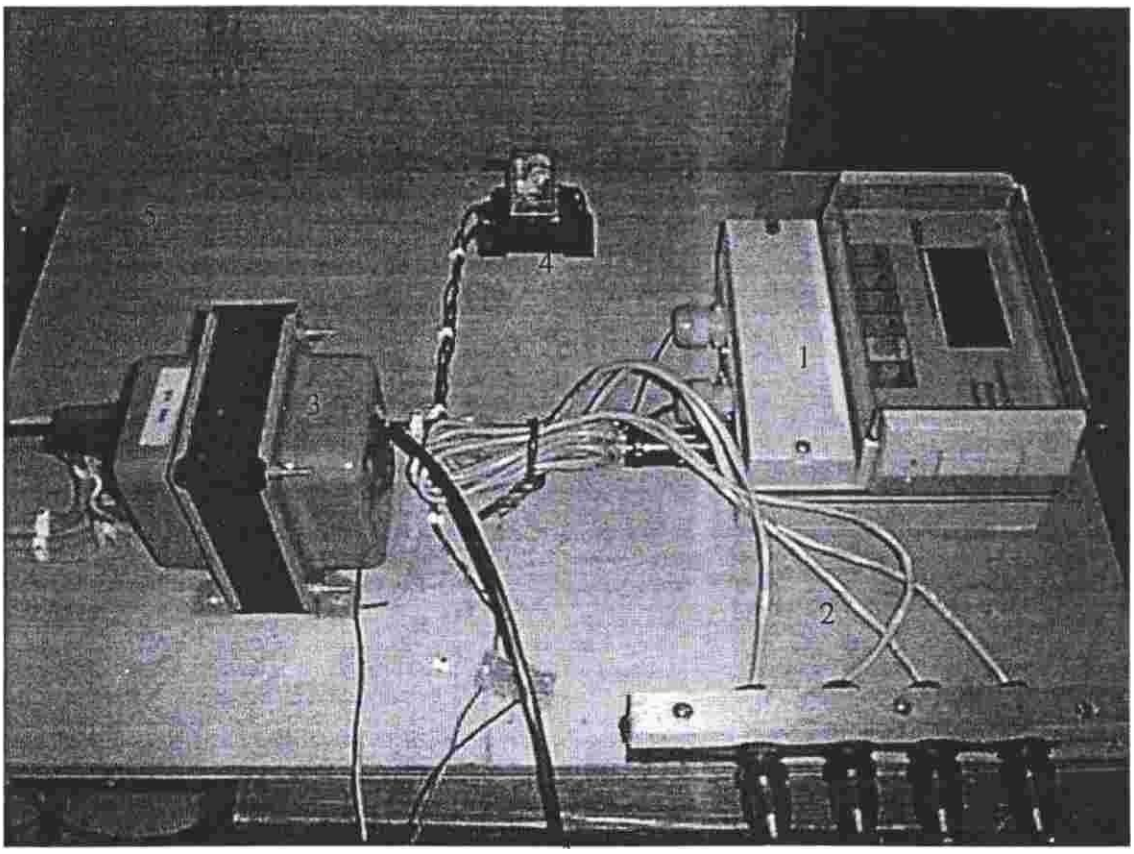


FIGURE 3.2: CAPTAIN COMPOSTER CONNECTIONS

1-**Compost Captain**
2-**Wires connecting** thermocouples t**o the Compost Captain**
3-**Transformer**
4-Relay Switch
5-Wooden Support

3.1.2.1 *THE COMPOST AERATOR SYSTEM*

The apparatus which performs the automatic aeration control in the compost pile is called The Compost Captain. It is a product from The Marcom Industries Products, USA. It consists of the basic aerator control unit, the sensors and the blower, however, the latter as purchased separately. The Compost Captain is a composting instrumentation, and process control unit which can measure process variable such as temperature, oxygen , moisture etc.

The Compost Captain also called a Composter, has two modes of operation, processing and setup. The processing mode allows the display of different processing variables using the push buttons. The setup mode allows adjustment of control set points, sensor types, control strategies, processing timers, etc.

In the processing mode, there are eight different informational displays, *current, Maximum, Minimum, Trend, Setpoint, Timers, Control Type, and Entering Setup Mode.*

The current display will show the latest sensor values for each zone.

*Maxi*11111111 will display the maximum sensor reading for each zone since the last max-min reset.

The Sctpoint display will show the control setpoint and the hysterisis.

Trend shows the short, over the last minute, and the long term, over the last thirty minutes of each sensor.

Timers will display the off timer and the on tinier value for each zone.

Control Type shows the control strategy which has been selected for each zone.

The last line displays if the zone output is on or off. By depressing and holding the Enter Key, the last line changes to the internal working timer value. This will show how much time is left until the next timer controlled transition.

Pushing the *Enter* key will place the Composter into the Setup mode. In this mode different system configuration menus can be displayed for changing by pressing the next button.

The available set up menus are *setpoint, control type, hysterisis, on tinier, off timer, data logging, clear network address, real time clock, scroll display, sensor type and exit setup.*

While in the Setup mode pushing the left arrow button will increment the display zones line for those selections which apply to individual zones, while a right arrow will decrement the display zone line. The selections which use zone lines *are Setpoint, Control type, Hysterisis, On Tinier and Sensor Type.*

The *setpoint* value will control at what point the sensor reading will activate an output using the temperature or time & temperature control type. The setpoint value is displayed in the units of the sensor, which was selected using the Setup Sensor Type, associated with that zone. The setpoint can range from the sensor minimum to the sensor maximum. Each setpoint is *zone* specific.

Control Type allows the selection of how the Composter will control each zone output. The control types available are Temperature and Time & Temparature.

The On timer associated with each zone is used with the T & T Control Type. The on timer can have a value from 10 seconds to 99 hours. Seconds are displayed with a '' after the number, minutes *are* displayed with a ' , and hours are displayed without anything after the number.

The Off tinier controls the output off time when in the T & T control. The off timer has the same adjustment range as the on tinier.

The wiring diagram is given in Appendix 1.0 and user manual in Appendix 2.0.

3.1.3 The Temperature Piles Probes

Each zone has an associated 42" Stainless Steel Pile Temperaure Probe which measures compost temperature. The probes can sense temperature in the range of 4.4° C to 93.3° C. The temperature sensing tip reads the temperature and converts it to a 4 mA to 20 rnA signal which is read by the Composter.

3.1.4 Electrical Installations of the circuit Board

Consider Figure I which shows the wiring diagram of the compost Captain and the blower. Each zone has a normal open solid state switch connected to two terminal strip positions. This switch is rated for 8 Amps 120 V AC maximum. The switch is closed when the amber zone status LED illuminates.

3.2 Composting Material

To test the automatic control of the composting unit, a preliminary trial was done on the mixture of bagasse and broiler litter since data in small scale without active aeration already existed and a comparison could easily be done. Further trials would be done with bagasse and scum as in previous large scale studies in phases I and 2.

3.2.1 Bagasse

Bagasse was analysed for its moisture, dry solids, volatile solids and ash contents. The table below gives the values obtained when bagasse was analysed prior to its use for composting.

TABLE 4.1: CHARACTERISTICS OF BAGASSE

Moisture(%)	12.88
Total Dry Solids(%)	87.12
Volatile Solids(%)	96.78
Ash(%)	3.22

3.2.2 Broiler Litter

Broiler Litter was obtained from a commercial broiler growing house in Mauritius. Sawdust was used as the litter base. The physical and chemical composition of litter varies with

- the type of birds raised,
- the number of birds per unit area,
- the kind of feed,
- the base material for the litter,
- the length of time litter was used and
- the kind of feeding.

The raw litter was analysed for its initial moisture, total dry solids, volatile solids and ash content. Each determination was run in triplicate and the table below gives the results of the analysis.

TABLE 3.2: CHARACTERISTICS OF BROILER LITTER

Moisture(%)	20.00
Total Dry Solids(%)	80.00
Volatile Solids(%)	77.34
Ash(%)	22.66

3.2.3 The mixture

The solid fraction of the feedstock comprised a mixture of bagasse and broiler litter at a 1:2.4 wet mass ratio. This ratio was chosen because it gave an optimum C:N ratio. 18 kg of bagasse was first soaked in 31 kg of water for optimum penetration and then it was mixed with 24 kg of water remaining and 43 kg Broiler Litter to form the starting material with about 60 % moisture and a 15/1 C/N ratio. The mixture occupied 0.2 m^3 when placed into the reactor (that is the reactor was full) and 37 kg was left. This means that the effective weight in the drum was 79 kg. The resulting mixture had an initial volatile solid content of 89.11 % and a moisture content of 62.29 %.

3.3 Analysis Techniques

3.3.1 Moisture Content (MC) and Total Dry Solids (TS)

Samples of 70-100 g Bagasse, Broiler Litter and Mixture were taken in triplicate and dried at constant weight in an oven at 105 °C for 24 hours and cooled in a dessicator. The difference in weight was recorded and moisture content calculated as follows:

Moisture content (Wet Weight Basis), % = Loss in weight x 100

Net wet weight

Total Dry Solids (TS), % = 100– % moisture content

3.3.2 Total Volatile solids (organic matter) and ash

A weighed sample of dried material obtained from the determination of total solids or that dried separately were ignited at 550 °C for 3 hours in a muffle furnace. The difference in weight between before and after heating gave the Volatile solids content (%) of the sample.

Volatile solids, VS,%= Loss in weight x 100

Net dry weight

Ash,%= 100 - % VS

4.0 RESULTS

4.1 Passive aeration

The Table below shows the temperatures obtained when Bagasse and Broiler Litter were composted naturally.

TABLE 4.1 : TEMPERATURE CHANGES DURING NATURAL COMPOSTING

Day number.	T_1 / °C	T_2 / °C	T_1 / °C	$T_{average}$ / °C
1	26.9	26.8	26.9	26.87
2	54.6	52.9	52.4	53.30
3	54	54.7	53.4	54.03
4	70.2	70.4	69.9	70.17
8	65.5	66.3	63.3	65.03
9	63.4	64.6	62.0	63.33
10	61.4	62.6	56.7	60.23
11	54.1	58.5	52.3	54.97
12	46.5	49.5	47.0	47.67
15	50.7	53.1	47.9	50.57
16	47.9	53.7	46.1	49.23
17	45.1	51.7	43.0	46.60
18	40.7	47.1	40.5	42.77
19	42.6	45.1	36.8	41.50

TABLE 4.2: CHARACTERISTICS OF MIXTURE DURING NATURAL AERATION COMPOSTING

Day number	Moisture (%)	Total Solids, TS(%)	Volatile Solids, VS(%)	Ash(%)
1	65.25	34.75	85.72	14.28
4	67.29	32.71	87.46	12.54
8	73.85	26.15	82.00	18.00
9	75.84	24.16	82.53	17.47
11	72.87	27.13	81.462	18.54
15	76.37	23.63	82.085	17.92
18	74.51	25.488	78.646	21.35

4.2 Active aeration

Table 4.3 shows the temperatures obtained when Bagasse and Broiler Litter were composted by using a blower with timer (forced aeration).

TABLE 4.3 : TEMPERATURE CHANGES DURING COMPOSTING FOR ACTIVE AERATION

Day number.	T1/°C	T2 /°C	T3 / °C	$T_{average}$ / °C
1	28	29	29	28.67
2	56	58	59	57.67
3	62	60	61	61
4	58	55	57	56.67
5	55	54	53	54
10	41	40	39	40
11	37	35	36	35
12	34	32	33	33
15	32	29	31	30.67

16	32	32	31	31.67
17	32	31	32	31.67

TABLE 4.4: CHARACTERISTICS OF MIXTURE FOR ACTIVE AERATION

Day number	Moisture (%)	Total Solids, TS(%)	Volatile Solids, VS(%)	Ash(%)
1	62.29	37.71	89.11	10.89
2	64.37	35.63	86.47	13.53
3	66.57	33.44	88.08	11.92
4	69.18	30.82	85.70	14.30
5	59.28	40.72	85.00	15.00
10	74.04	25.96	81.28	18.72
11	69.10	30.9	84.05	15.95
12	65.53	34.47	81.96	18.04
15	56.71	43.29	78.05	21.97
16	54.20	45.8	77.56	22.44
17	53..41	46.59	77.02	22.98

Figures 4.1, 4.2 and 4.3 show the temperature, moisture and VS changes respectively of active and passive aeration.

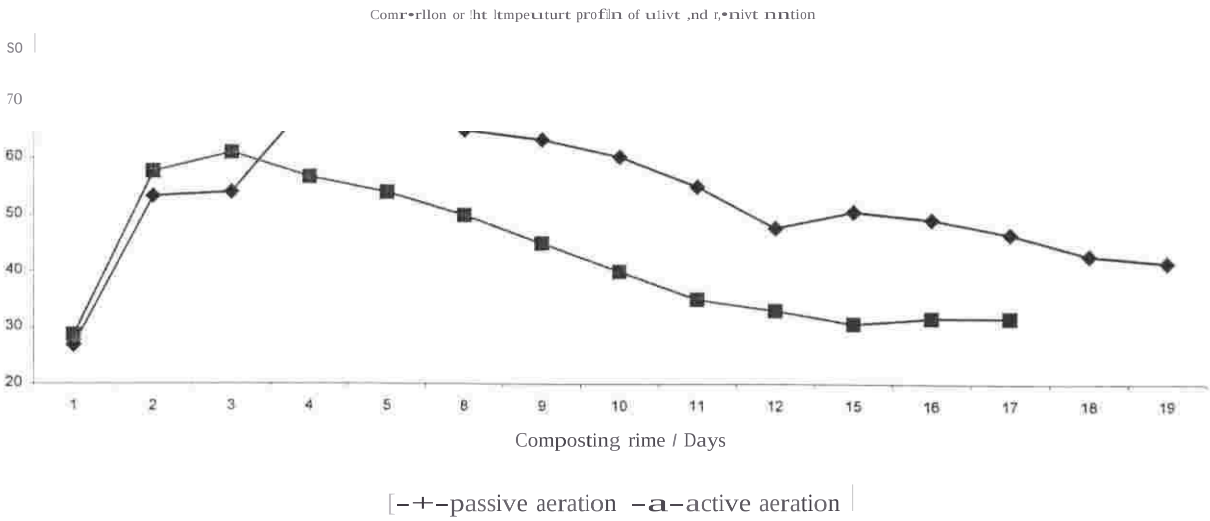


Figure 4.1 : Comparison of temperature between active and passive aeration

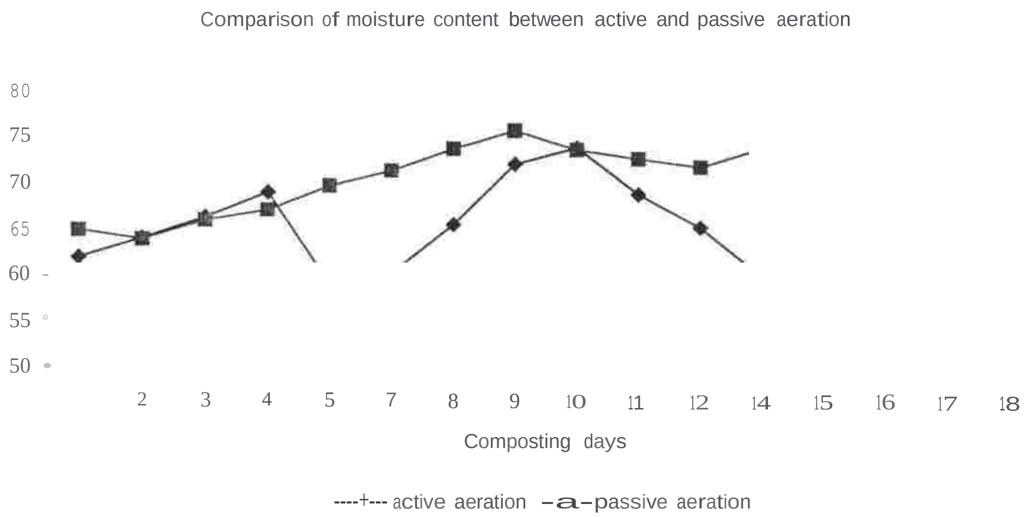


Figure 4.2: Comparison of moisture between active and passive aeration

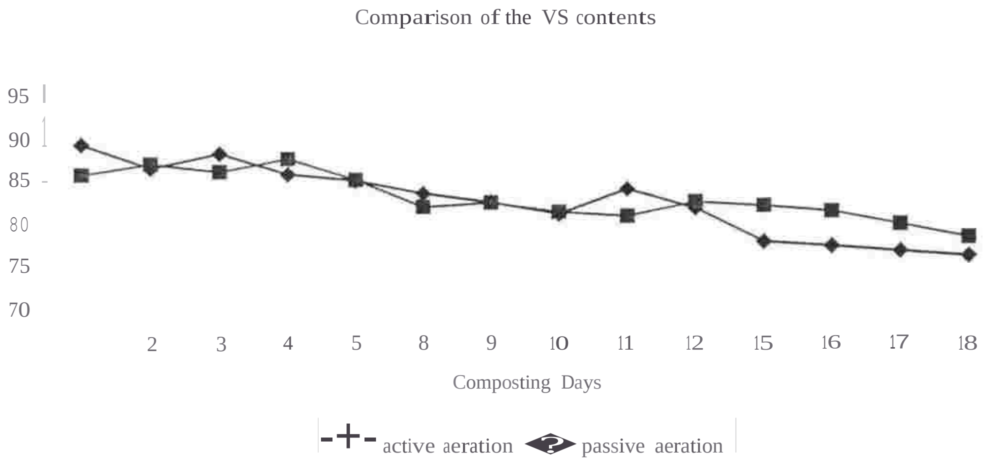


Figure 4.3 : Comparison of VS content between active and passive aeration

The net reduction in volatile solids content was greater in the case of active aeration (around 14%) as compared to passive aeration (around 8%) showing that more decomposition has taken place.

5.0 CONCLUSIONS and FUTURE WORK

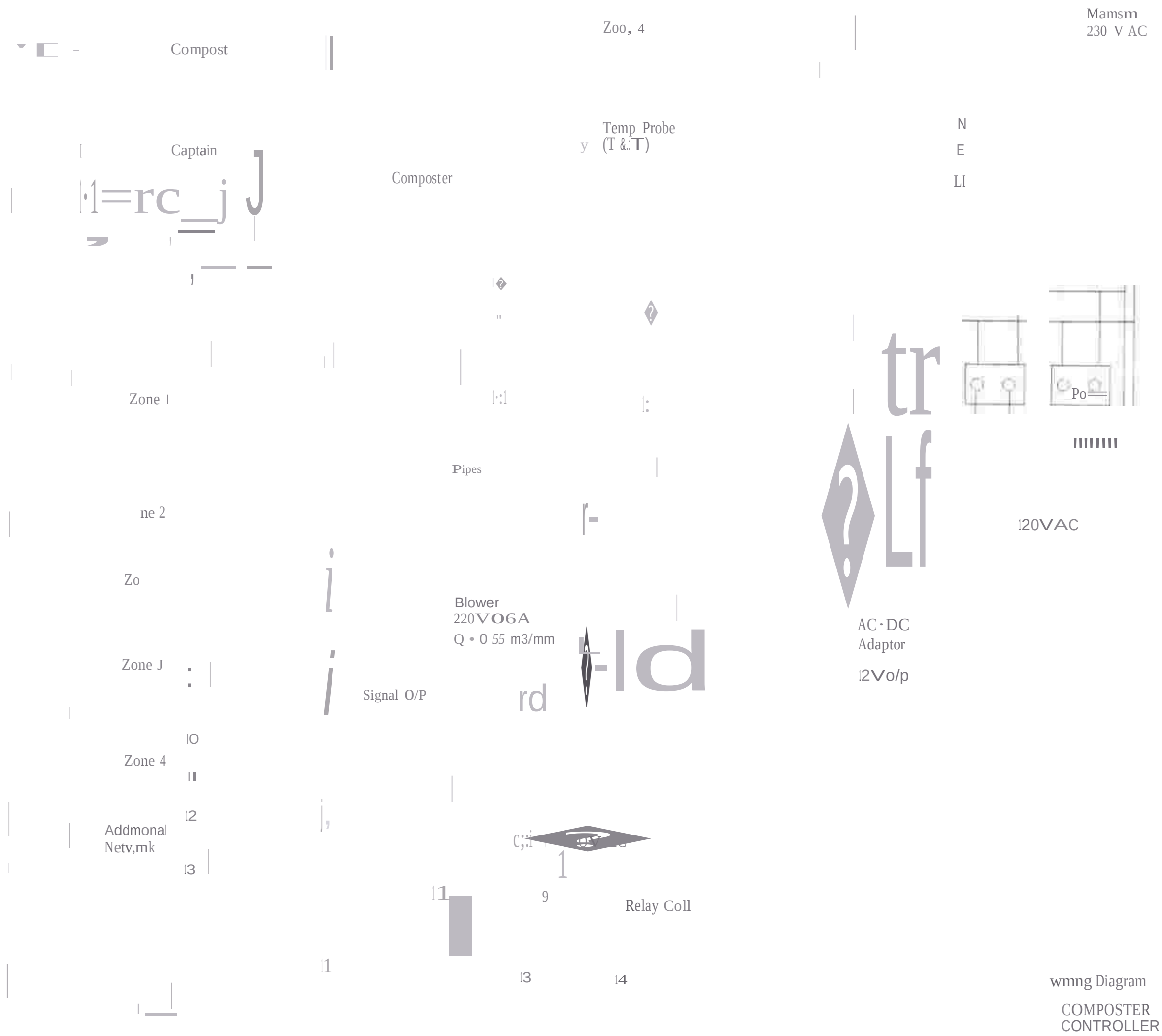
This study has shown that the active aeration gave better results than passive aeration and that the compost captain controller unit could effectively set the aeration rate based on the temperature feedback.

However, certain problems were encountered during the setup of the compost captain and were as follows:

- Being given that the control unit for composting is not available as a complete system and that the technical manual supplied was very elementary, undue time was spent in understanding the unit.
- Help was sought from the Center For Instrumentation Services, TEC, for the calibration and testing of the zones output signal level. Infact it was found that the zone output was a current level and not a mV signal.
- Time was spent in the procurement of a 110 V AC transformer as this was unavailable at the Electrical Engg. Dept., of the 110 V AV relay switch as it is rare and the installation board.
- There was significant delay from the wood workshop for the procurement of the blower wooden fixing plate.
- Data logging via a computer was actually not possible as the 9 to 25 pin DIN supplied by the supplier was defective and therefore communication between the composter and the computer was not possible. The supplier was faxed to this effect but no reply was obtained.

Future work consists in setting the compost captain controller unit to composting of mixtures of bagasse and scum so as to obtain design parameters concerning aeration rate, pipe length and blower.

APPENDIX 1.0: WIRING DIAGRAM OF COMPOST CAPTAIN


Compost
Composter
Temp Probe
Zone 2
Zone 4
Pipes
Blower
220V 0.6A
Signal O/P
Relay Coil
230 V AC
N
E
AC-DC
Adaptor
12V o/p
COMPOSTER
CONTROLLER

APPENDIX 2.0 : USER MANUAL

COMPOSTER CONTROLLER UNIT

COMPOST CAPTAIN MASTER COMPOSTER AERATION CONTROLLER UNIT

USER MANUAL

Mauritius Research Council I University of A1auritius
"Composting a/Solid l¥aste in Subtropical Regions"
User Manual to be anached withfinal project report.
December i999

Table of Contents

1 Introduction

The *Compost Captain ft1aster Composter* unit is a temperature, oxygen and moisture content controller, with data logging as the only option and Pile Temperature and Pile Oxygen Probes as sensors.

The unit monitors four zone-sensors and can control four zones output (blower) with an additional zone for networking (option not available). In this study only one zone output is used as there is only one blower.

The wiring of the composter with the compost-drum and the blower has already been made and it is assumed that no ""ire will be disconnected.

2 Power requirements

The com poster uses 12 V DC from a 240V AC adaptor (transformer)

The blower uses 230 V to 240V AC supply activated by a 110 VAV relay.

The zone output (24) is activated by a 110 V AC supply from a 240 V–110 V AC variable transformer.(in this experiment only the Z4 has been used, however, shall there be any need to activate other blowers then the remaining zones could be used).

3 Switching the Com poster ON

On putting the unit ON the following messages are obtained on the screen:

"""""""" 1996

Compost Captain

A1aster Composter

Log

Then,

Copyright 1996

Marcom Ind. Inc.

All right reserved

Revision 5.5

Then there will be eight different informational displays appearing one by one by pressing next. This is the Processing Mode.

4 Processing Mode.

Different processing information can be displayed by pressing the next key.

4.1 Current

The first display appearing will be *Current*. This will show the latest sensor value for each zones, e,.g if Z4 is at 55° C then this will be the current value.

4.2 Maximum

This will display the *maximum* sensor reading for each zone since the last max-min reset e.g if the maximum temperature reached since the unit has been on is 65° C then this will be the value as maximum.

4.3 Minimum

Like maximum, the *minimum* will display the minimum sensor reading for each zone since the last max-min reset.

4.4 Setpoint

This will show the control *setpoint* and *hysterisis* for each zone. Hysterisis can be considered to be a tolerance, e.g if zone 1 has been put to record temperature in° C, setpoint is at 63° C, hysterisis is 1, then the output of z 1 (blower is on) will be on when the temperature reaches 64° C and will be off at 62° C, as shown diagrammatically below.

63°C

OFF ON

62° 64° C

Setpoint

4.5 Trend

The *trend* shows the short term, over the last ,ninute and long term over the last 30 minutes trend for each sensor. However, this function has not been well appreciated as no change has been noted and NC being the only message obtained.

4.6 Aeration Timers

Timers will display the *OFF timer* and *ON timer* value for each control zone e.g on pressing the aeration timers, the screen may appear

ZJ	Z2	Z3	Z4	
30"	JO'	20"	20"	(OFF time} –Not shown
JO'	30"	20"	20'	(ON time} –Not shown

This is used with the *Time and Temperature ({&T)* mode. The unit will act as timer (that is will use the time criteria for control) when the temperature sensed by the zone sensor indicates that the *ten,perature is below* the setpoint. *Abo,•e tlte setpoint* the unit will use the temperature value as the temperature criteria to set the blower on or off.

The first line represents the off time, i.e the time during which the blower is OFF, for example for 21 the blower is off for 30 seconds and for zone 2 it is off for lO minutes.

The second line shows the On tirne for the blower, i.e the time the blower is ON, for example for 23 the blower will be On for 20 seconds and for 24 it will be On for 20 minutes.

4.7 Control Typo

This shows the control strategy which has been selected for each zone. The control type can be *Ternp (I')*, *Time* and *Temperature (T&T)* or other represented *by ???*.

If the zone is controlling temperature, then depending upon the experimenter he can either use *TT& T*, however, if oxygen or moisture are being monitored *???* is used.

Under each zone there will be an indication whether the state output is I or 0. If the state output is !(that is the LED is ON) then on the screen under that particular zone *ON* will appear, otherwise *OFF* will appear.

After this the controller unit will enter the *Set Up* mode. On the screen the following message will appear:

<System Set Up

Press the Enter Key"

Now pressing the Enter Key, the system will enter the Set Up mode.

5 Set Up Mode

In the setup mode, different system configuration menus can be displayed for changing by pressing the next button.

The available setup menus are, *setpoint, control type, hysterisis,, on timer, off timer, data logging interval, data logging clear, nenvorking address, real time clock, scroll display, sensor type and exit set up.*

Note: *Pressing the up arroul key will increment the variable being changed ro the next value. Pressing the down a,.,.o,v will decrement the variable. Once the variable reaches ii 's highest value, pressing the up arrolv will loop the value to it's minimum. Likewise if the lowest value is displayed, pressing the down arro,v will loop the display to the maximum.*

5.1 Setpoint

In the setpoint menu, the setpoint for each zone output can be set. Consider changing the setpoint value for zone 4, which currently has a setpoint of 60° C to 70° C. The following are adopted.

Press the left arrow key until Z4 conies at the far left end.

By pressing the Up arrow key will increment the value from 60° C to 70° C. By pressing the DOWN, this will decrement the value.

When the value has been set then the Enter is pressed to accept the value. If the Enter key is not pressed the value will not be entered.

The same procedure is adopted for each zone to change the setpoint.

The Next key is then pressed

5.2 Control Type

The control type enables the zones to be used as *Ten,perature, Time and Tentperature or ???* (as explained in the Control Type above).

The same steps as setpoint are adopted to change the zone control type.

The Next key is then pressed.

5.3 Hysterisis

As explained above (inSetpoint), hysterisis can be considered as a tolerance. Therefore, each zone has a tolerance which can be set according to need.

The Next Key is then pressed

5.4 ON time

Used in conjunction with *T& T,* the On time allows the period the blower will blow for each zone.

The Next Key is then pressed.

5.5 OFF Time

Used in conjunction with *T& T*, the OFF time allows the changing of the period of time the blower is switched off for each zone.

The Next Key is then pressed.

5.6 Logging Interval

This is the time interval between storing each sensor in the logging area. It can be set to 1,5, 15,30 minutes, 1,6, 12 or 24 hours.

The Next key is pressed. The following message is obtained

"Log Data

Press Enter to clear all data"

Pressing the enter key will clear all stored logging readings.

The Next key is pressed. The following message is obtained:

Time Clock

MMIDDIYY HH:MM

11118/99 12:50

This is the current date and time.

The Next key is then pressed.

5.7 Scroll Display

By pressing YES, the zone line will automatically increment every 15 seconds

The Next key is then pressed.

5.8 Sensor Type

This allows the unit to be used with different types sensors. Each zone can have a unique sensor type associated with it. The available types of sensors are ^{0}*F(temperature in degrees Fahrenheit),* ^{0}*C (temperature in degrees centigrade), %* O_2 *(oxygen content in percent) and dee {which will display the sensor reading as a number from decimal 0 to decimal 255)*

*Pressing **Next will exit Setup.***

6 Some Useful keys

While in the Processing Mode, depressing the Up Arrow and the Next keys at the same time will reset the internal Maximum and Minimum for each zone.