A STUDY ON COMPOST PRODUCTION POSSIBILITIES FROM SOLID WASTE OF THE CITY OF BURSA

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By

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ABSTRACT

A STUDY ON COMPOST PRODUCTION
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This study summarizes research findings upon compost production possibilities from the solid waste of city of Bursa. It was carried out in three consecutive stages: a) Characterization of Bursa solid waste with monthly runs for one year, b) Pilot compostability studies for eight monthly runs, c) Quality analysis of produced compost with respect to marketability.

It is observed that: a) A compost ready for maturation can be obtained from solid waste of city of Bursa using closed-controlled-aerobic system within 5-7 days, b) Quality of compost produced can be accepted as a proper soil conditioner as compared to world Health Organization standards.

Key words: Solid Waste, Compost, Pilot Composting Study, Solid Waste Characterization, Other Unclassified Remaining Portion of Solid Waste, Solid Waste Humidity, Thermophilic and Mesophilic Operating Range.

ÖZET

BURSA ŞEHRİ ÇÖPLERİNDEN KOMPOST ÜRETİLME İMKANLARI ÜZERİNE BİR ÇALIŞMA

GÖKSU, Rıfat
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Bu çalışmada Bursa şehri çöplerinden kompost üretilme imkanları araştırılmıştır. Çalışma birbirini takip eden üç aşamada gerçekleştirilmiştir; a) Bursa çöpünün yapısını belirlemek amacıyla bir yıl boyunca her ay yapılan analizler, b) Ayda bir kere olmak üzere sekiz ay süresince gerçekleştirilen pilot kompostlama çalışması, c) Üretilen kompostun kalitesinin belirlenmesi.

Çalışma sonucunda varılan neticeler şunlardır: a) Bursa şehri çöplerinden olgunlaştırmaya hazır kompost, kapalı-kontrollü-havalandırmalı sistem kullanılarak 5-7 günde elde edilebilmektedir, b) Elde edilen ürünün kalitesi, Dünya Sağlık Teşkilatınca kabul edilen toprak şartlandırıcısı kalite sınırları içerisinde kalmıştır.

Anahtar Kelimeler: Katı Atık, Kompost, Pilot Kompostlama Çalışması, Katı Atık Karakterizasyonu, Katı Atığın Diğer Tasniflenemeyen Bakiye Grubu, Katı Atık Nem Miktarı, Termofilik ve Mezofilik İşletme Koşulları.

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1. INTRODUCTION

1.1 GENERAL

Population of the world and, in parallel to that, waste generation rates increase rapidly which in turn results in certain pollution problems because of uncontrollable dumping of wastes to receiving bodies such as water and soil. Therefore, solid waste disposal problem is one of the most challenging environmental engineering problem to be solved. Solid wastes can be defined as all wastes arising from human and animal activities that are normally solid and discarded as useless or unwanted. Solid waste generation rates have been increasing throughout the world due to increase in standard of living and it requires either a treatment operation or controlled disposal based upon sound planning, which must be the result of technical and scientific feasibility studies. Municipalities face with serious problems such as odor, leachate insect and rodent problems, and aesthetical problems, etc. due to uncontrolled tipping operations.

Municipality of Bursa wanted to seek a solution to the disposal problem of the city's solid waste problem through a research contract with Middle East Technical University. The present population yields approximately 400-700 tons/day solid waste depending upon the season and this rate is going to rise with the expected population increase and higher standard of living in future.

This thesis has been conducted within the scope of an applied project (Solid waste problem of Bursa municipality) in which composting possibilities of the solid waste of city of Bursa has been studied in detail.

1.2 SOLID WASTE DISPOSAL METHODS

There are variety of solid waste disposal methods namely as sanitary land filling, controlled tipping, incineration, composting, pulping, pyrolysis, underground burning, compacting, discharge to household sewers, etc. Among these alternatives of solid waste disposal, composting seemed to be an alternative to be studied in detail because the city of Bursa is in the middle of a fertile plain where agriculture is extensively practiced and compost produced can be utilized since composts are defined as significant sources of nitrogen, phosphate and potash and organic soil supplement (1).Further, local authorities have indicated that the compost produced may find a market since the stabilized waste of the already present land-disposal area have been taken away by the farmers to be utilized as fertilizer and soil conditioner.

1.3 THE OBJECT AND SCOPE OF THE THESIS

The evaluation of compost production possibilities from solid waste of city of Bursa was the main object of this thesis. In order to achieve this goal, it was carried out in three consecutive stages:

1.3.1 The Study on the Suitability of the Solid Waste for Compost Production

During this stage, physical and chemical analysis were carried out to assess the properties of waste. Initial moisture content, (C/N) ratio and (C/P) ratio were determined to see that they were within allowable ranges.

1.3.2 The Pilot Work Determining the Time Required to Obtain a Compost Ready For Maturation

A Pilot plant was manufactured in the workshop of Mechanical Engineering Department of Middle East Technical University and it was operated within the unit operations and processes Laboratory of the department of Environmental Engineering. By using this pilot plant, process control variables were monitored and the time required for obtaining a compost ready for maturation was determined.

1.3.3 The Evaluation of the General Properties of the Obtained Compost with Respect to Marketability

The finished compost should have certain properties in order to find customer as a soil conditioner. These properties were determined by measuring the parameters which were given by World Health Organization (WHO) and their magnitudes were checked if they satisfy the criteria as a proper soil conditioner.

2. LITERATURE REVIEW ON COMPOSTING

2.1 DEFINITION

Generally speaking, composting can be defined as the biological decomposition of the putrescible organic materials of solid wastes under controlled conditions. More specifically, different definitions can be given such as, it is the decomposition of heteregeneous organic matter by a mixed microbial population in a moist, warm, aerobic environment (2); or it is the process of converting putrescible human, plant and animal residues to more stable organic materials for use as fertilizers and soil conditioners (3); or it is the process in which aerobic biological decomposition takes place so that some of the organic material is decomposed to carbon dioxide and water while stabilized products, principally humic substances, are synthesized (4). As it can be understood from different definitions, basically composting includes biological breakdown or decomposition of organic materials of solid waste by the help of microorganisms under certain environmental conditions. Composting also occurs in nature as a breakdown process of plant residues by microorganisms, as a slow process. However, by using certain techniques municipial solid wastes can be converted to compost very rapidly which can be used as soil conditioner and also through this disposal method, a considerable amount of land can be saved, since very small amount of solid waste remains to be landfilled.

2.2 TYPE OF COMPOSTING SYSTEMS

The classification of composting systems can be according to; the existence or absence of oxygen; the temperature range in which bacteria operates; and the technology that is being adapted.

2.2.1 The Classification with respect to Existence of Oxygen

If the system is aerated it is called aerobic, otherwise anaerobic. The aerobic system is free of foul odors and operation requires less time. On the other hand, rate of anaerobic process is much slower and odorous intermediate products are produced. Although anaerobic composting has found some recent applications due to biogas production possibility as a by-product, but since it requires large area with long detention times and high investment, aerobic process is much more widely applied method. Aerobic composting is characterized by rapid decomposition normally completed within 1-7 days with a production of high temperature during process, and as it was mentioned earlier with no production of offensive odors (1).

Working temperature range of microorganisms during composting is more or less related to the absence or existence of oxygen during process. Basically, there are two types of microorganisms named as mesophilic and thermophilic bacteria respectively. The temperature range of mesophilic bacteria is stated as 35-45^{o}C whereas thermophilic bacteria operates in the range of 45-55-70^{o}C during decomposition. Composting process starts from ambient temperature of about 15-25^{o}C, then naturally reaching to 40-45^{o}C temperature covering mesophilic range and at this point all of the microbial population are killed except for thermophilic bacteria which will carry out the process at 55-70^{o}C temperature in which most pathogenic organisms can survive for more than several minutes. So, hygienic conditions are satisfied after thermophilic phase.

However, one can say that modern composting systems combine mesophilic and thermophilic ranges and they are aerobic systems.

2.2.2 Technologywise Classification

In this classification it can be stated out that the system can be open or windrow type; or an enclosed unit. In the windrow type systems, the long-low heaps of organic matter are formed and let to decompose in time. This is so called "original" composting process due to the fact that is was started started to be applied this century. The process is very slow and often takes four to six months to complete (6). To maintain aerobic conditions, the heaps must be turned over from time to time, but this damages the temperature rise so that its rise is not sufficient to kill pathogenic organisms. High area requirement is valid for windrow type composting as well as the anaerobic process.

Closed systems are also called as mechanical plants or digesters in which certain system variables, e.g. oxygen, temperature, etc. can be controlled. In these systems, the duration of composting is very low and as a result of this the area requirement is much less. There are several types of mechanical plants in the application, such as vertical movement type or horizontal systems in which organic fraction of wastes are decomposed during their voyage in horizontal or vertical direction. These systems have ability to control airflow, temperature and degree of agitation and to monitor degree of agitation using compertmentealized digesters (2).

2.3 THE PROCESS STEPS IN A COMPOSTING PLANT

Certain sequential steps must exist in any composting plant regardless of its type. These are namely as; sorting, grinding, composting and storage or so called maturation.

Sorting step involves removal of tin-cans, miscellaneous metallic substances, glass and ceramic ware and excess paper. This step is carried out either mechanically by technological devices or manually.

During grinding, the particle size is reduced to 2,5-5.0 cm. in order to increase biological activity on wastes because of the fact that wastes having small sizes increase the biological activity of bacteria on them (6).

The third step, i.e. composting phase, is actual operational phase of bacterial decomposition during which waste organic matter is decomposed into humic substances and harmless material. This step can be considered as the heart of whole process because the conditions within this step (detention time, humidity, oxygen, etc.) directly affect the system. In fact composting process, as it can be understood from its name, depends on this step. This is the main reason that the operational parameters such as detention time, have been studied in detail within the scope of this thesis.

The final step is the storage in which composted material is let to get mature before marketing. Its another name is curing stage and it directly affects the area requirement.

Figure 1 shows typical process steps in a full-scale plant.

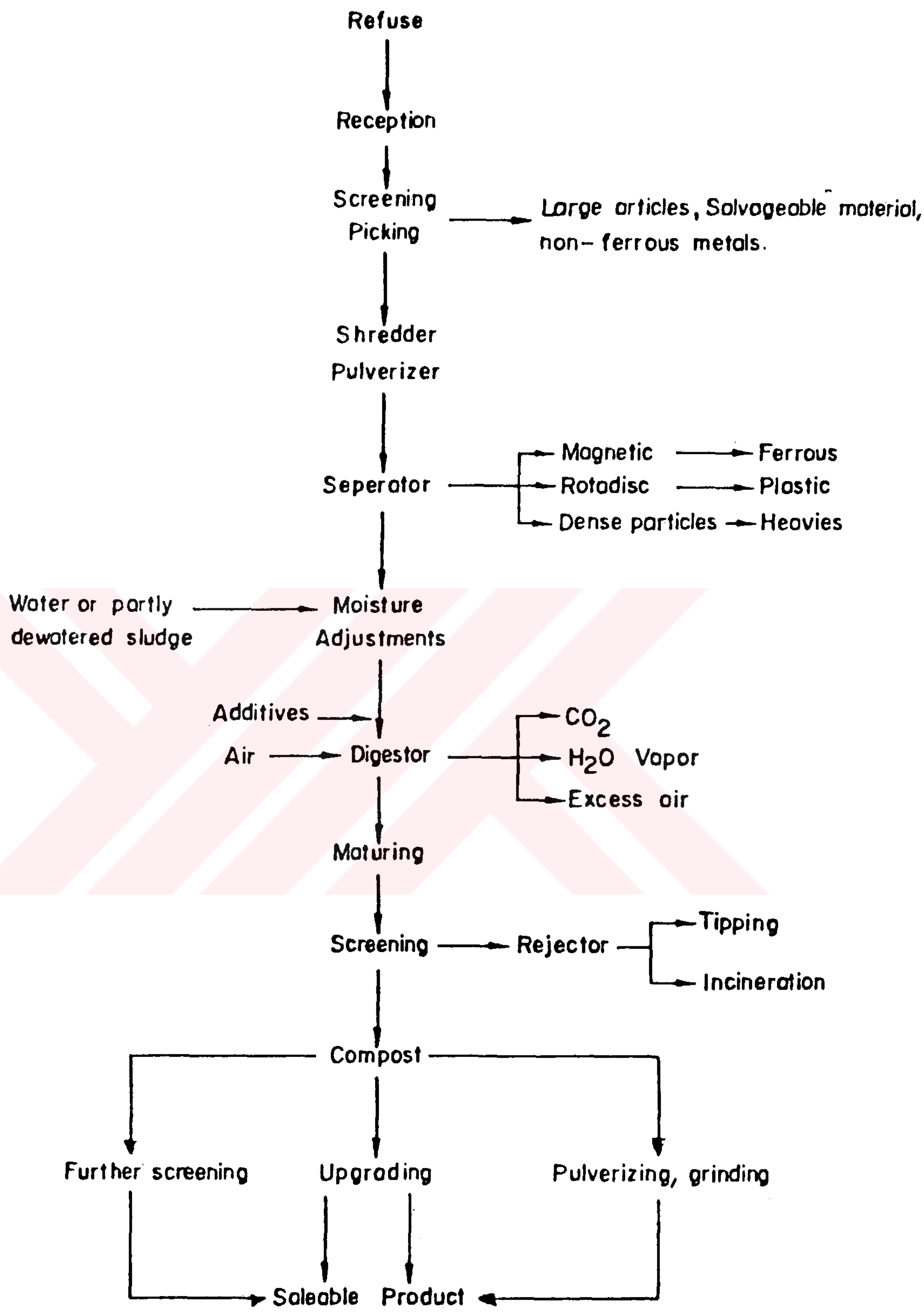

Figure I Typical process steps in a full scale plant.(4)

2.4 ENVIRONMENTAL FACTORS THAT SHOULD BE SATISFIED DURING BIOLOGICAL DECOMPOSITION

Since the nature of the reactions within the compost reactor is biochemical, the environmental conditions should be suitable for the working microorganisms. The duration of the composting can be reduced, hence the capital cost can be minimized; further a good product can be obtained only after creating suitable environmental conditions for the bacteria. There are certain factors which should be considered as important for the efficiency of a composting unit;

2.4.1 (C/N) Ratio of the Waste

Carbon (C) in the waste is energy source and nitrogen (N) is the essential element for cell structure of bacteria. Therefore, (C/N) ratio which is high at the beginning of decomposition becomes lower towards the end of completion of the composting. (C/N) ratio should be within the range of 20-25/1 to 40/1 for a high-rate composting (4,6,7,8,9,10). The (C/N) ratios above 40/1 and below 20/1 are undesirable since high ratios increase composting time and low ratios cause extensive nitrogen losses (1). The main sources of (N) and (C) are vegetable-putrescible matter and paper respectively. The vegetable-putrescible matter has (C/N) ratio of 24/1 and the higher the ratio of paper to vegetable-putrescible matter, the higher the (C/N) ratio (1).

2.4.2 Moisture Content

Moisture is required for the growth and multiplication of the microorganisms within the compost unit. It should be within certain limits in order to get acceptable composting durations and to reach the thermophilic conditions. Optimum moisture content should be around 55 % (5). If moisture content is below 20 %, the biological reaction stops; if it is higher than 60 %, undesirable anaerobic conditions develope due to the fact that pores are not open for oxygen diffusion (penetration) to reach microorganisms (1).

2.4.3 Oxygen (aeration)

Aeration was reported to be essential for obtaining rapid and troublefree decomposition. When composting is carried out in stacks, turning over the material is the most commonly applied technique. In the digesters it is being achieved by blowing air at a certain rate using compressors. The supply of air should be within the range of 634-1930 lt/day/kg of volatile solids (7).

2.4.4 Temperature

Modern composting plants operate within the temperature range of mesophilic (10-40-45^{o}C) and thermophilic (40-45^{o}C to 70^{o}C). The biological process begins at ambient temperature by the activity of mesophilic bacteria which oxidizes organic carbon to carbondioxide thus liberating large amounts of heat. Therefore, the temperature of the wastes reaches to 45^{o}C within about two days. Following this stage, the process is further carried out by the thermophilic bacteria which continues to operate in the temperature range of 55-70^{o}C. Further increase in temperature beyond 55^{o}C cause a reduction in activity of microbial masses. As it can be understood, heat addition is considered as non-essential in mechanized plants.

2.4.5 pH

The literature indicates no pH control problem during composting process as long as the system is kept under aerobic conditions. However, pH is an important process evaluation (control) parameter during the decomposition phase. The raw solid waste of 3 days old is expected to have a pH in between 5-7. The pH is expected to drop below 5 within the first 3-5 days of composting operation due to organic acid formation then it begins to rise to 8-8.5 as organic acids are consumed by thermophilic bacteria for the remainder of the aerobic process. If the system is allowed to be anaerobic, the pH drops below 4.5 (1). In the aerobic systems, final product has alkalizing action on acid soils.

2.5 GENERAL PROPERTIES OF FINISHED COMPOST

Depending on the degree of biochemical degredation and final processing; compost can be classified as raw, fresh, mature or special compost. But, for all types final product must have certain properties before being accepted as a soil conditioner. Some typical values are given in Table 1 and 2 (4).

Table 1. Concentrations of Elements in Finished Compost (4)

Element	Normal Range
Major elements (in g/100 g dry basis):	
N	0.1-1.8
P (P_2O_5)	0.1-1.7 (0.2-3.8)
K (K_2O)	0.1-2.3 (0.1-2.8)
S	0.5-3.0
Alkalinity (as CaO)	(1-20)
Total salts (as KCl)	(0.5-2.0)
Minor elements (in mg/kg dry basis):	
B	60-360
Cd	15-40
Cu	90-260
Fe	8000-15000
Hg	1-5
Mn	300-1300
Mo	10
Pb	200-400
Zn	800-1200

Table 2. General Properties of Finished Compost as Marketed (4)

Property	Normal Range
Moisture (g/100 g)	30-50
Inert matter (g/100 g)	30-70
Organic content (g/100 g)	10-30
pH (of a 1:10 slurry in distilled water)	6-9
Maximum particle size (mm)	2-10

3. MATERIALS AND METHODS

3.1 COLLECTION OF SAMPLES AND PRETREATMENT APPLIED

The samples for characterization and compostability studies were collected in the following manner:

The city of Bursa was considered to have four subregions taking into account their socio-economic structures. Subregions A, B and C were the high, intermediate and low income areas while D was business center from which wastes were collected during the night. For each sampling time; 3 trucks from subregion A, 4 trucks from subregion B, 4 trucks from subregion C and finally 3 trucks from subregion D brought their loads to the sampling area. The trucks dumped the load to the sampling area once during their daily cycles.

Each group of trucks disposed their content to the sampling area so that at the end there were 4 heaps of solid wastes belonging to the different subregions. Then each heap was mixed with power-shovel to be able to get representative samples. After that one ladle of solid waste was taken from each heap and they were sorted by considering that solid waste was composed of 14 different types of material, i.e. paper, cardboard, plastics and nylon, wood, tire, textile, bones, glass, stone, fruit and vegetable residues, concrete residues and bricks, iron and tin-cans, aluminium and copper and remaining portion after sorting which was called as "OTHER UNCLASSIFIED REMAINING PORTION". Each class of material were weighed and recorded. Later, 0,5 kg samples were taken only from the portion named as "vegetable and fruit residues" and from the class called as "OTHER UNCLASSIFIED REMAINING PORTION". This sampling procedure was realized for each subregion, and for each month of a year (March 1986 - February 1987).

Also information was required about the general characteristics of average Bursa solid waste. To achieve this goal, a composite heap was formed by taking 2 ladles from heap C, 12 ladles from heap B, 3 ladles from heap A and 3 ladles from heap D. The numbers represented the weighing factors considering the expected amount of solid wastes from each subregion. This heap was also mixed and 1 ladle was taken from this heap of 20 ladles. It was sorted for classification and all sorted materials were weighed and recorded. Sampling was done as explained above. All type of materials were kept in plastics till they were transported and analyzed in the laboratory.

3.2 THE PARAMETERS TO BE DETERMINED FOR CHARACTERIZATION AND THEIR MEASUREMENT TECHNIQUES

The samples, which were collected and prepared using the method described in the previous section, were analyzed to determine their total organic carbon, moisture content, volatile solids, phosphate and pH. The measurement techniques are summarized below.

3.2.1 pH

50 gram sample was mixed with 125 ml. distilled water in a closed container, it was kept within this container for 2 hours. After that, pH was measured by electronic pH-meter with combined electrode (11).

3.2.2 Nitrogen

Nitrogen determinations were realized using Kjeldahl nitrogen measurement techniques. Kjeldahl-N is defined as the nitrogen present in ammonia plus the portion of nitrogen which can be catalytically reduced to ammonia in a concentrated sulfuric acid solution. For the analysis, about 500 mg. sample, 10 ml. H_2SO_4 and 1 gram catalyzer were added to a beaker and mixture was heated for 3-6 hours at 300^oC. After that, it was let to cool and with the addition of 30-50 ml. distilled water, it was passed to Kjeldahl flask. Up to basic conditions was prevailed, i.e. color change from white to pink, 32 % NaOH was added and distillation operation was started. At the end, content of Kjeldahl flask was distilled to the 50 ml. 0.05 N H_2SO_4 solution. Extra H_2SO_4 was back titrated with 0.05 N NaOH. Nitrogen contents of sample were calculated by using following formula (11):

$$N = \frac{(B-S)\ 0.05\ (14)}{0.5}$$ in which;

B = Amount of NaOH consumed for blank titration (ml)

S = Amount of NaOH consumed for sample titration (ml)

N = Amount of nitrogen (as mg/0.5 gr.)

3.2.3 Total Organic Carbon

In this method, sample was mixed with CrO_3 and H_2SO_4 and heated for 2 hours at 140-150^oC using a total organic carbon measurement set-up. Carbon content of the sample was broken down into CO_2 and after that this CO_2 was precipitated as Ba CO_3 by using Ba(OH_2). Part of Ba(OH_2) was used up by CO_2 coming from sample itself. Remaining part was titrated with 0.1665 N HCl and from this titration carbon content of the sample could be calculated by considering that 1 ml. of 0.1665 N HCl equivalent to 1 mg. carbon (11).

3.2.4 Moisture Content

Samples were weighed and heated for 24 hours at 105^{o}C. After that, making necessary weighing, moisture content was calculated using below formula (11):

$$W\ (\%) = \frac{a - b}{a - c} \times 100 \quad \text{in which;}$$

W = Moisture content (%)

a = Weight of sample plus container before heating (gr.)

b = Weight of sample plus container after heating (gr.)

c = Weight of container (gr.)

3.2.5 Volatile Solids

After moisture content determination, sample was again heated for 2 hours interval at 105^{o}C up to constant weight. Then, it was heated for 2 hours at 550^{o}C for volatile solids determination. Calculation was as follows (11):

$$VS = \left[\frac{\text{(Weight after constant weight)-(Final weight)}}{\text{(Initial sample weight)}} \times 100 \right]$$

3.2.6 Phosphate

For phosphate determination; initially, it was attempted to dissolve the sample in water. For this purpose, 15 ml. concentrated HNO_3 was added to 1 gr. sample. Then, it was heated up to the point that 3-5 ml. solution remained. After that, 45 ml. of certain mixture

(2 parts distilled HNO_3 plus 1 part $HClO_4$) was added to the solution and it was heated again up to release of OCl vapour. At this point, if solution was clear initial preperation was considered to be completed. If not, again 10 ml. concentrated HNO_3 was added to the solution to help the oxidation reaction. After that, it was filtered and diluted to 100 ml. Then, 1 ml. of final solution was taken and using suitable indicator it was neutralized with 6 N NaOH up to pink color appeared. If it was not clear, it was filtered and 4 ml. ammonium-molybdate and 0.5 ml. $SnCl_2$ were added. Temperature was kept constant at 25^oC and controlled. Finally, phosphate content was measured at 690 μm wavelength against to standart solution which was prepared at the same conditions (11).

3.3 THE PILOT PLANT

It is extremely difficult if not possible to theoretically estimate the composting duration in biological reactor. Literature gives a very wide range; 1-7 days for composting duration (4). The most reliable way to estimate this duration is pilot studies. To achieve this goal, a pilot plant which is illustrated in Figure 2 and which was used before for similar purposes by Whang and Meenaghan (12) was manufactured and operated as a digestor.

The pilot plant work was carried out for eight months with monthly periods starting from August 1986 and ending at March 1987 generally for average Bursa solid waste and for certain months for solid waste of different subregions. Samples were from "OTHER UNCLASSIFIED REMAINING PORTION" of sorted solid wastes. The collection and sorting procedures were already explained in

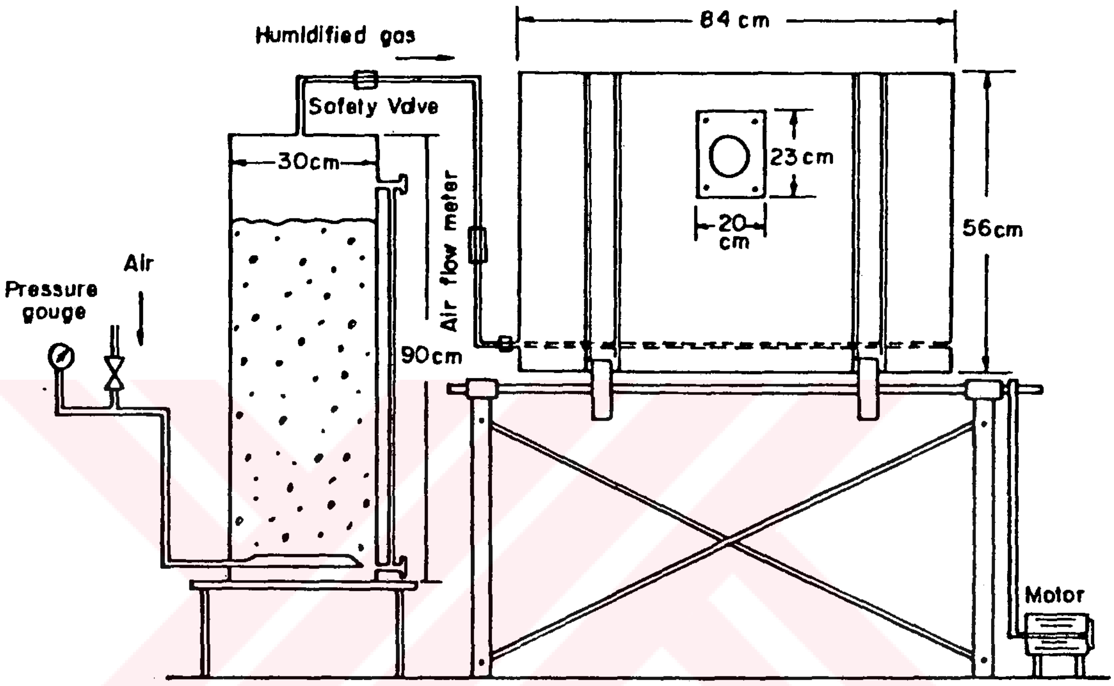

Figure. 2. Schematic representation of pilot plant.

section 3.1. Solid wastes have been loaded to the pilot plant after reducing its size to 2,5-5.0 cm. manually.

The pilot plant consists of an air supply system, a humidifier, air temperature control unit, reactor and an automatic control panel. Air (which could be humidified and/or heated if desired) was supplied to the reactor by a diffuser pipe which was attached to the bottom of the reactor. Humidification was unnecessary for most of the months since the samples had humidity level which was defined as upper level of optimum range. Further,heat supplement was only applied during winter months to bring the feed air temperature level to base temperature (summer laboratory temperature was assumed to be base temperature which was about 23-25^{o}C).

The reactor was insulated to prevent biological energy loss. The reactor was rotated by a reductor-electric motor couple to provide mixing and aeration of the reactants. Frequency of mixing using the motor is 0.90 revolution per minute. Since continous revolution was not necessary, the reactor was rotated 1-3 times in a day with 2 revolution in each time during all runs. Air flow rate was changed within the limits of 2-5 l/min. The reactor had two compartments. So, two openings were made on the top of the reactor to facilitate manual filling and emptying the reactant material. The total capacity of pilot plant was 60-80 kg. per batch. The final appearance of pilot plant was illustrated in Figure 3, i.e. supplying heated air instead of humidified air and have an automatic control panel.

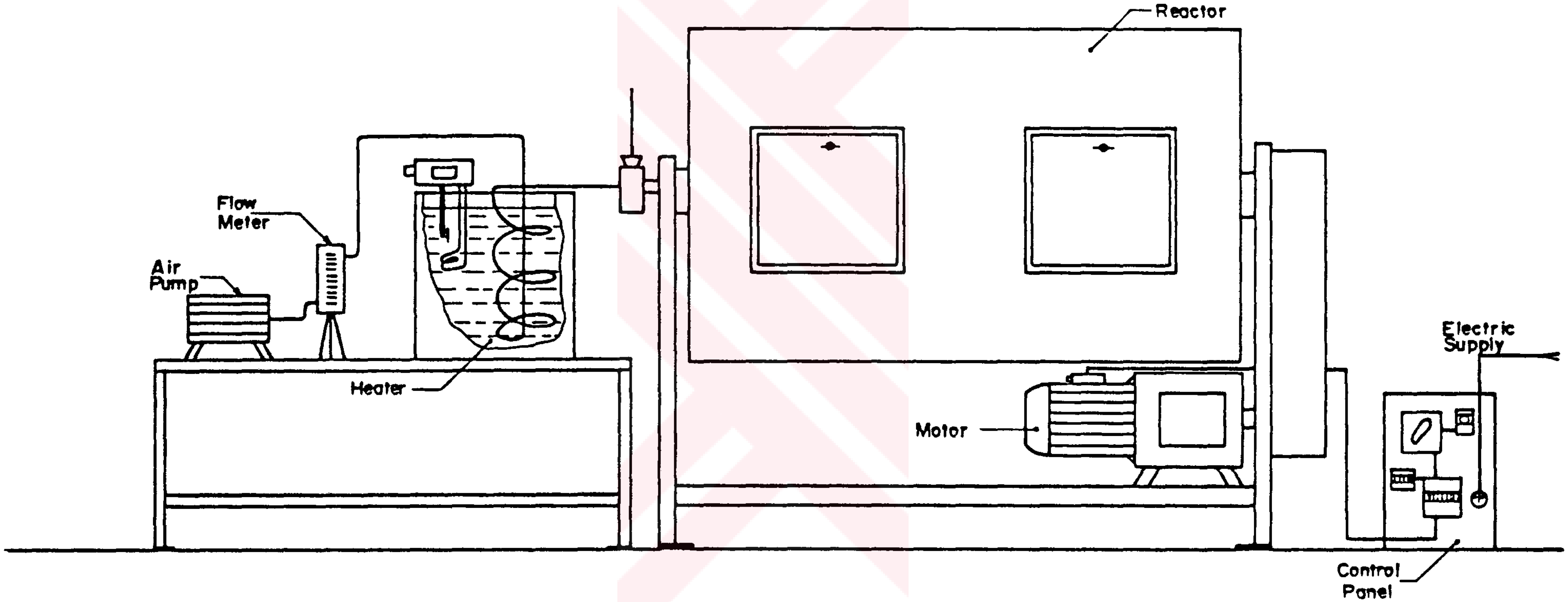

Figure.3. Modified pilot plant.

3.3.1 Parameters Measured for Monitoring Pilot Work

Several parameters have been measured daily in order to monitor the system performance. These were; humidity; temperature; O_2, CO_2 and CH_4 compositions of gas phase; total organic carbon (TOC); nitrogen (N); phosphate (P); and volatile solids (VS).

Temperature has been measured for monitoring the development of meso and thermophilic conditions. CH_4 has been measured to check if anaerobic conditions developed. CO_2 and O_2 have been measured to decide about the termination duration of aerobic stabilization. No trace of CH_4 has been detected during all runs and this showed that the system has been aerobic throughout the study. TOC and (C/N) ratio have been utilized to monitor stabilization process. Humidity has been measured to see if it was within acceptable range for composting.

Humidity, total organic carbon, nitrogen, phosphate and volatile solids measurements have been realized using the tecniques suggested by WHO which were given in detail in section 3.2 (11).

Temperature measurements have been realized by using laboratory thermometer and by inserting it into the reactor for five minutes. Gas compositions have been determined using a gas chromatography instrument. The properties of the instrument are given below:

i) Colon : 3 m x 3 mm
ii) Colon filling material : Poropak Q
iii) Carrier gas rate : 30 ml/min
iv) Carrier gas : N_2 with 99 % purity
v) Detector : Thermal conductivity

vi) Detector temperature : 25^{o}C

vii) Filament temperature : 25^{o}C

Chromotograph has been calibrated with standard gas mixture which was composed of M2 which had 10 % CO_2 and 15 % O_2 and N3 which had 1 % CH_4 and results have been recorded with Perkin-Elmer 159-1002 recorder.

4. RESULTS AND THEIR EVALUATION

4.1 CHEMICAL CHARACTERISTICS OF SOLID WASTE OF THE CITY OF BURSA

The chemical characteristics of the average Bursa solid waste are presented in Table 3 in a summary form. The analysis have been conducted on the "OTHER UNCLASSIFIED REMAINING PORTION" which is defined as the part remaining after paper, cardboard, plastics, nylon, tires, wood, bread, textile, bones, glass, iron, tin-cans, aluminium, copper have been separated.

It can be seen from Table 3 that pH values of Bursa solid waste were in the range of 5, 86-7,95 which can be considered as harmless for composting process. Humidity values remained within the acceptable limits (20 % - 56.5 %) for composting throughout the year except for the winter months (November, December, January) for which analysis have been performed on only fruit and vegetable residues fraction of "OTHER UNCLASSIFIED REMAINING PORTION" which has a moisture content of about 75 %. This different sampling procedure was due to the fact that during winter ash and other wastes were collected together and they were transferred to the dumping area. By considering this fact, analysis were realized only on vegetable-fruit residues, which was manually sorted during winter months.

Another important point was the (C/N) ratios which have been changed from 6.6/1 to 22.6/1 throughout the year. Although (C/N) ratios were below the suggested optimum level (30/1) for all months,

Table 3. Results of Chemical Analysis for "OTHER UNCLASSIFIED REMAINING PORTION" of Average Bursa Solid Waste

DATE	pH	N**	TOTAL ORGANIC CARBON (C)**	C/N	$PO_4^{\equiv}$**	HUMIDITY (%)	TOTAL SOLID (%)	TOTAL VOLATILE SOLIDS (%)
19. 3.86	7.95	14.6	194	13.2	24	40.9	59.1	35.8
25. 4.86	6.28	33.9	224	6.6	10	55.3	44.7	24.4
28. 5.86	6.72	16.9	262	16.0	14	51.1	48.9	25.1
24. 6.86	7.26	5.3	120	22.6	24	20.2	79.8	16.9
23. 7.86	6.36	12.7	151	12.0	64	55.6	44.4	16.9
26. 8.86	6.36	24.8	205	7.6	62	52.5	47.5	23.0
24. 9.86	6.70	25.3	187	7.4	70	54.8	45.2	16.6
29.10.86	6.91	18.5	193	10.4	42	56.5	43.5	18.6
27.11.86*	5.86	34.7	225	7.3	52	78.0	22.0	15.6
6. 1.87*	6.43	26.0	248	9.5	115	75.9	24.1	17.5
29. 1.87*	6.78	13.0	294	22.6	80	77.0	23.0	17.1
27. 2.87	7.00	22.9	205	9.0	45	61.3	38.7	16.0

*Because of the waste collection practice in "BURSA" which includes the collection of both organics and ashes of solid fuel, together, only organic portion has been selected and analysed for these months.

** The units of N, total organic carbon and PO_4 are mg/g dry weight.

compostability studies gave encouraging results which will be discussed in following section.

4.2 THE MONTHLY RUN RESULTS FROM PILOT PLANT COMPOSTING STUDIES

The study covered the time period between August 1986 to March 1987 with monthly runs and promising results have been obtained from pilot studies. The runs for August 1986, September 1986, October 1986, February 1987 and March 1987 have been realized on solid waste collected without any ash and on the "OTHER UNCLASSIFIED REMAINING PORTION". The other runs, i.e. November 1986, December 1986 and January 1987, have been carried out on the fruit and vegetable residues fraction of "OTHER UNCLASSIFIED REMAINING PORTION". The following sections explain the results of the eight monthly runs.

4.2.1 August 1986

For August 1986, a sample of 70 kg. weight has been loaded to the two compartments of the reactor. The pilot unit operating parameters have been kept as follows:

Mixing frequency : 3/day
The number of rotation in each mixing : 2
The flow rate of compressed air : 5 l/min
Temperature of compressed air : 26^{o}C
Temperature of ambient air in laboratory : 26^{o}C
Air humidification : Applied

The thermophilic phase has been reached at the end of the 2nd day and at the end of the 4th day temperature has risen to 68^{o}C (Figure 4). The thermophilic phase was complete when the temperature level has fallen to 45^{o}C at the end of the 8th day. The fall in temperature has continued within 8th day, and after that it reached to ambient air temperature of the laboratory. At the end of the 4th day, during which highest temperature was measured; carbondioxide concentration has reached to its maximum level (35 %) as it was naturally expected. Complete stabilization was at the end of 16th day during which CO_2 concentration has reached to undetectable level (Figure 5). TOC (Figure 6) and (C/N) ratio (Figure 7) have shown a similar trend as CO_2 concentration. (C/N) ratio was 14/1 at the beginning, and it has been dropped to 8/1 within 16 days. Results of all analyses for August 1986 is also presented here in Table 4.

4.2.2 September 1986

For this month, two types of samples, each of was 35 kg. and which was taken from the "OTHER UNCLASSIFIED REMAINING PORTION", of high and low income regions of Bursa solid waste have been loaded to the first and second compartments of the pilot unit respectively. The pilot unit operating parameters have been kept as follows:

Mixing frequency : 3/day

The number of rotation in each mixing : 2

The flow rate of compressed air : 5 l/min

Temperature of compressed air : 25^{o}C

Temperature of ambient air in laboratory : 25^{o}C

Air humidification : Applied

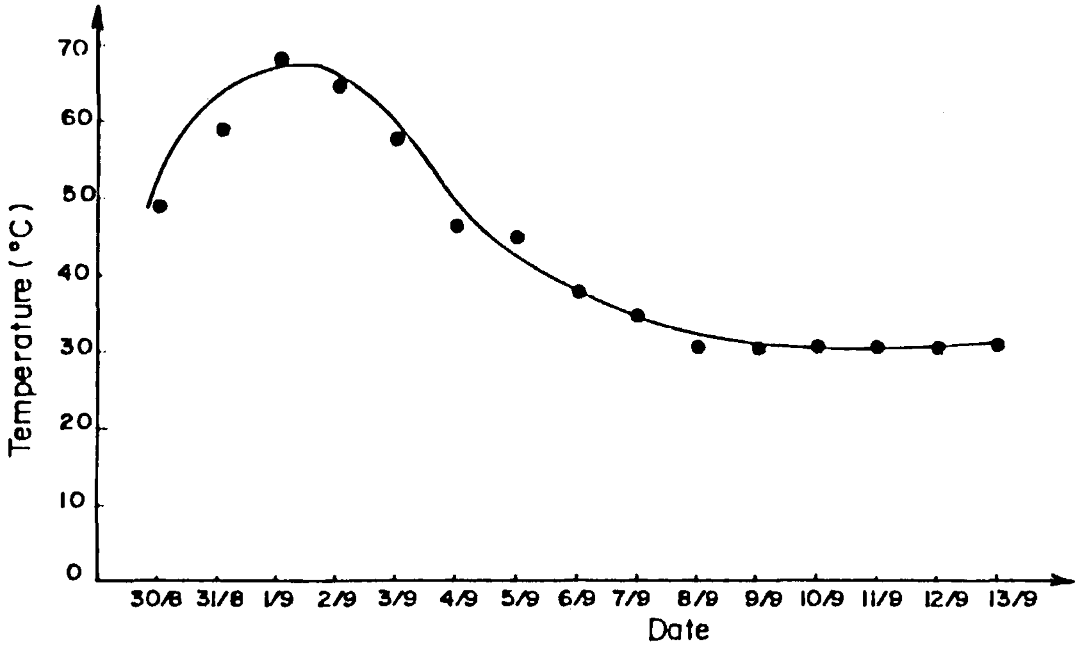

Figure.4.Change of temperature with respect to time.
(August 1986)

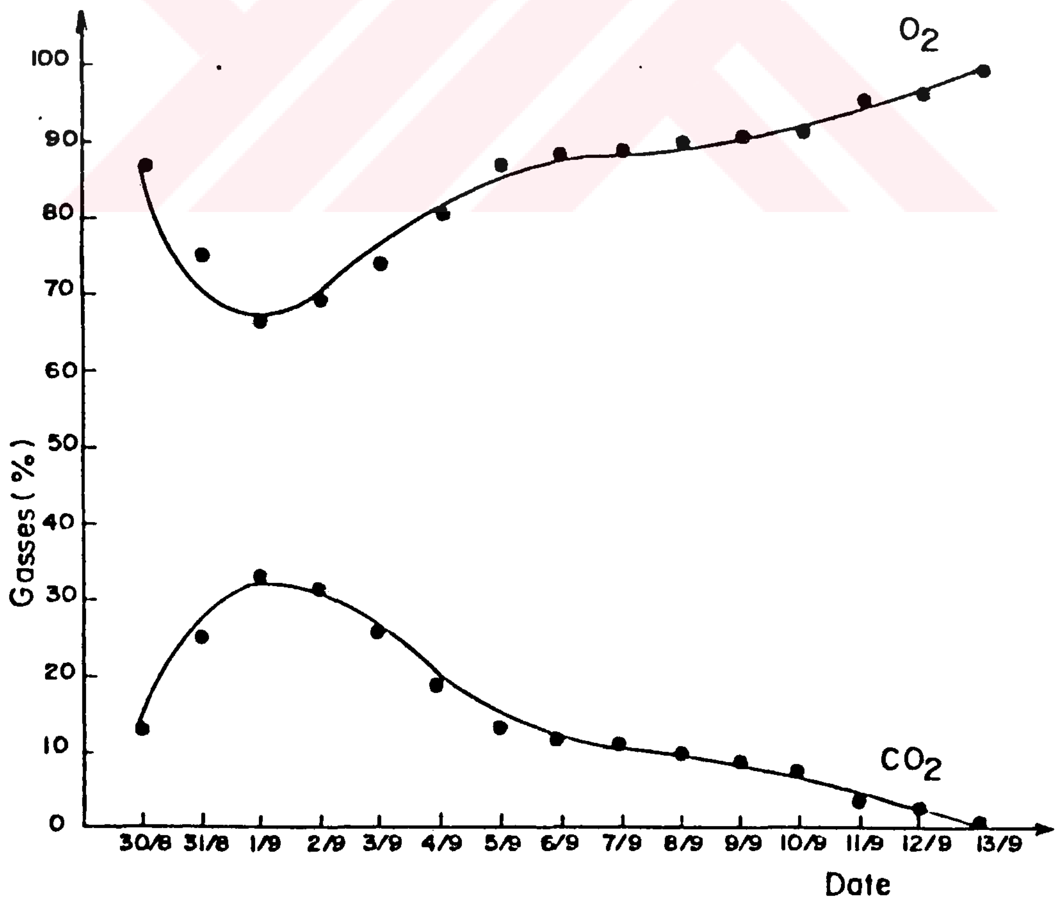

Figure.5.Change of gas composition with respect to time.
(August 1986)

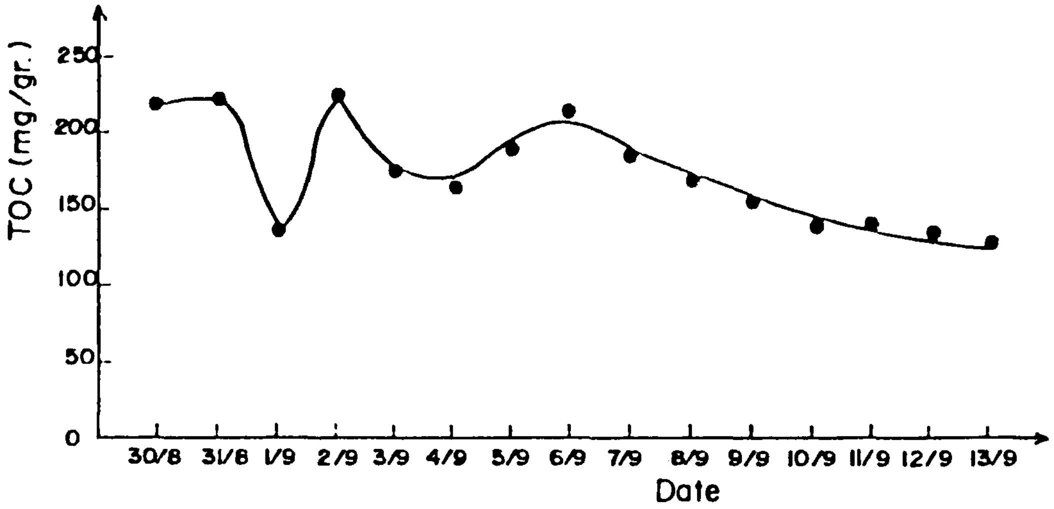

Figure:6. Change of TOC with respect to time. (August 1986)

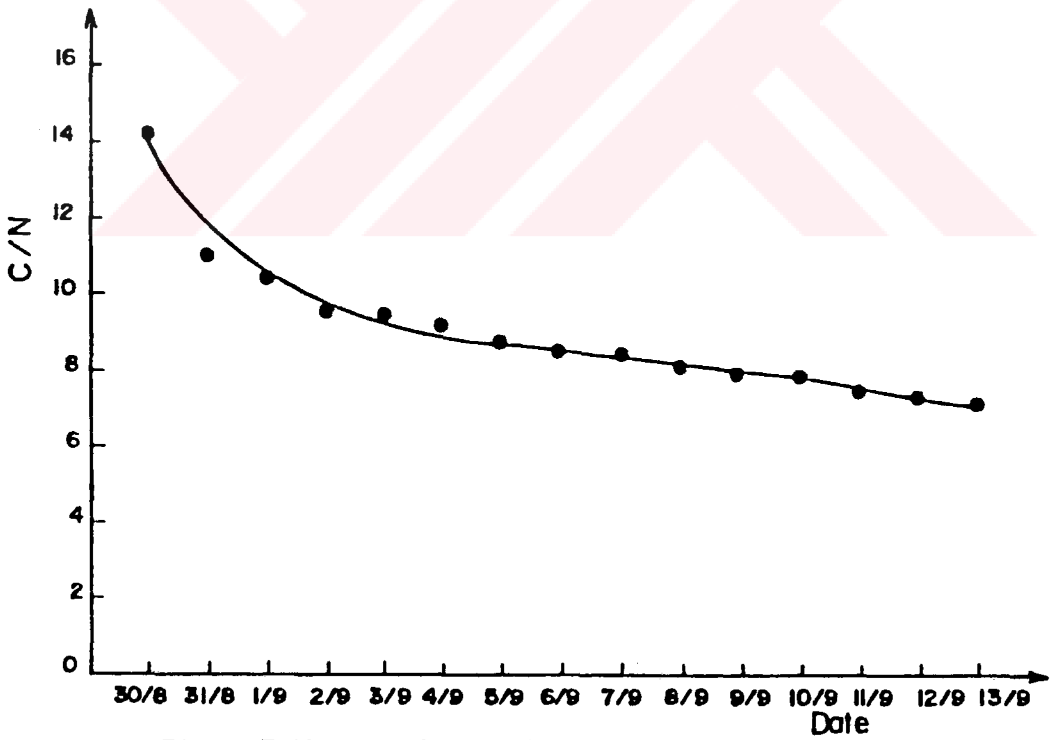

Figure.7.Change of (C/N) ratio with respect to time.
(August 1986)

Table 4. Results of Analysis for August 1986 Run

DATE	HUMIDITY (%)	TEMPERATURE (^oC)	GASSES(%)		TOC (mg/gr) (C)	N (mg/gr)	$PO_4^{\equiv}$ (mg/gr) (P)	C/N	C/P
			O_2	CO_2					
30.8.86	53	49	87	13	218	15.4	55	14.2	3.97
31.8.86	50	59	75	25	220	20.2	60	10.9	3.67
1.9.86	57	68	67	33	139	13.2	49	10.5	2.83
2.9.86	56	65	69	31	226	23.5	84	9.6	2.69
3.9.86	57	58	74	26	175	18.5	78	9.5	2.24
4.9.86	62	47	81	19	165	17.9	75	9.2	2.2
5.9.86	58	45	87	13	191	21.9	89	8.7	2.1
6.9.86	47	38	88	12	212	24.8	85	8.5	2.5
7.9.86	51	35	89	11	185	22.0	80.4	8.4	2.3
8.9.86	48	31	90	10	169	20.7	76.8	8.1	2.2
9.9.86	57	31	91	9	157	19.8	79	7.9	1.9
10.9.86	57	31	92	8	142	18.2	78	7.8	1.8
11.9.86	48	31	96	4	139	18.5	79	7.5	1.76
12.9.86	57	31	97	3	131	17.8	77	7.3	1.7
13.9.86	50	31	100	-	125	17.6	75	7.1	1.67

The mesophilic range was reached at the end of 2nd day. The CO_2 concentration has reached to its maximum level (23 %) and temperature has risen to 49°C (which was also the maximum level for this run) at the end of the 6th day. Due to high humidity which was about 69 %, the temperature rise was not satisfactory to reach thermophilic range and it began to fall after 6th day. So, earobic stabilization only covered the mesophilic range and it was complete within 11 days. Results of the analysis; temperature, gas composition TOC, and (C/N) ratio measurements with respect to time are presented here as Table 5 and figures 8,9,10,11,12,13,14 and 15 respectively.

The results of this run also showed that, different socio-economic group's solid wastes gave more or less the same results with respect to compostability.

4.2.3 October 1986

For October 1986, 70 kg. of sample which was taken from the "OTHER UNCLASSIFIED REMAINING PORTION" of the average Bursa solid waste has been loaded to the two compartments of the reactors. The pilot unit operating parameters were as follows:

Mixing frequency : 3

The number of rotation in each mixing : 2

The flow rate of compressed air : 5 l/min

Temperature of compressed air : 19°C

Temperature of ambient air in laboratory : 19°C

Air humidification : Applied

At the end of the 3rd day, the mesophilic range has terminated and temperature reached to thermophilic range as 52°C which can also

Table 5. Results of Analysis for September 1986 Run

DATE	HUMIDITY(%)		TEMPERATURE (^oC)		GASSES (%)				TOC(mg/gr) (C)		N (mg/gr)		$PO_4^{\equiv}$(mg/gr) (P)		C/N		C/P	
					I		II											
	I*	II*	I	II	O_2	CO_2	O_2	CO_2	I	II	I	II	I	II	I	II	I	II
25. 9.86	70	67	35	36	93	7	97	3	240	210	29.68	24.64	70	68	8.1	8.5	3.4	3.1
26. 9.86	63	65	45	45	89	11	88	12	206	191	29.68	25.76	84	65	6.9	7.4	2.4	2.9
27. 9.86	69	63	46	46	81	19	85	15	193	160	25.48	23.32	81	77	7.6	6.8	1.7	2.1
28. 9.86	70	67	47	47	79	21	81	19	158	166	27.88	21.80	92	81	5.9	7.6	1.7	2.1
29. 9.86	75	64	49	49	77	23	78	22	174	151	23.24	22.91	78	69	6.4	6.6	2.2	2.1
30. 9.86	65	62	46	46	84	16	86	14	145	128	25.72	23.00	79	66	4.9	5.5	1.8	1.9
1.10.86	68	69	40	39	87	13	89	11	141	121	23.00	20.90	71	62	6.1	5.8	2.0	1.9
2.10.86	64	67	35	33	94	6	92.5	7.5	135	118	21.20	18.50	68	60	6.4	6.4	2.0	2.0
3.10.86	67	60	30	30	97	3	100	-	129	115	19.00	18.00	67	62	6.8	6.3	1.9	1.8
4.10.86	60	61	26	26	100	-	100	-	121	107	20.60	17.60	65	59	5.8	6.1	1.9	1.8

*I High Income Area

**II Low Income Area

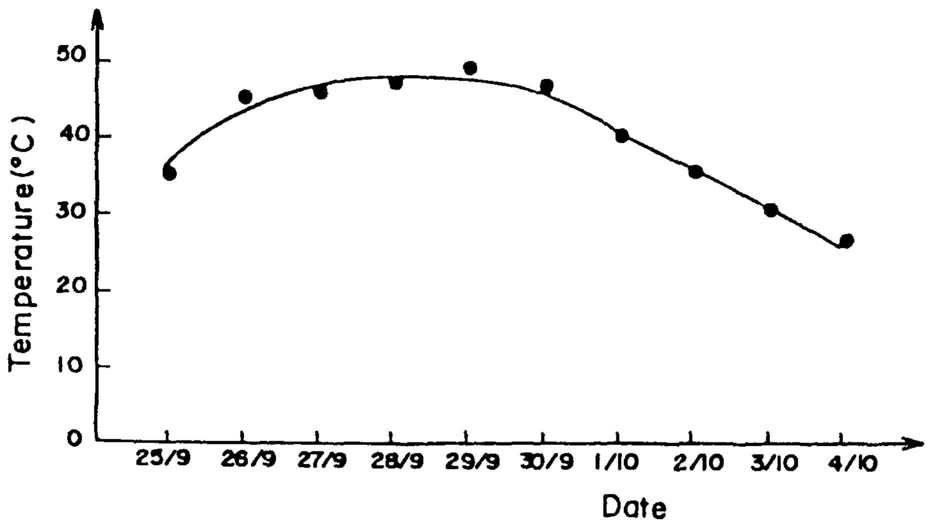

Figure.8 For 1st Comparment, change of temperature with respect to time. (September 1986)

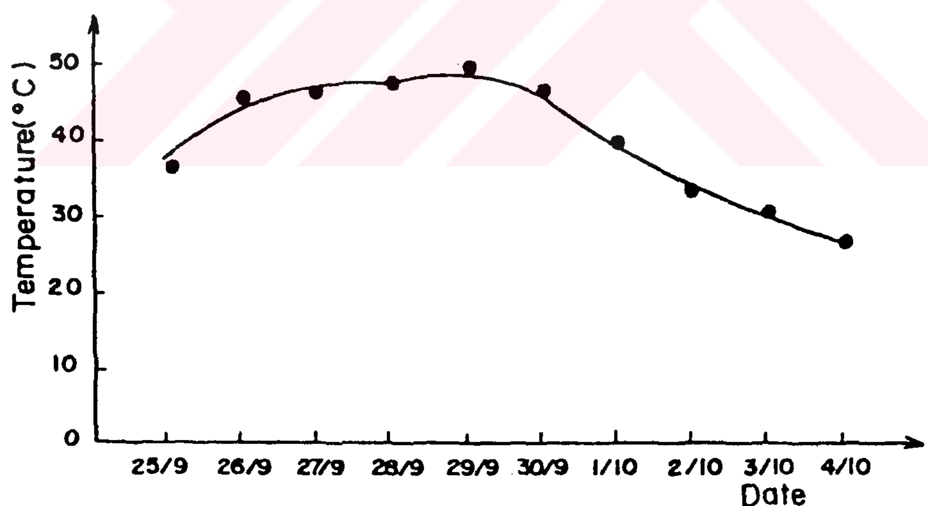

Figure.9 For 2nd Compartment, change of temperature with respect to time. (September 1986)

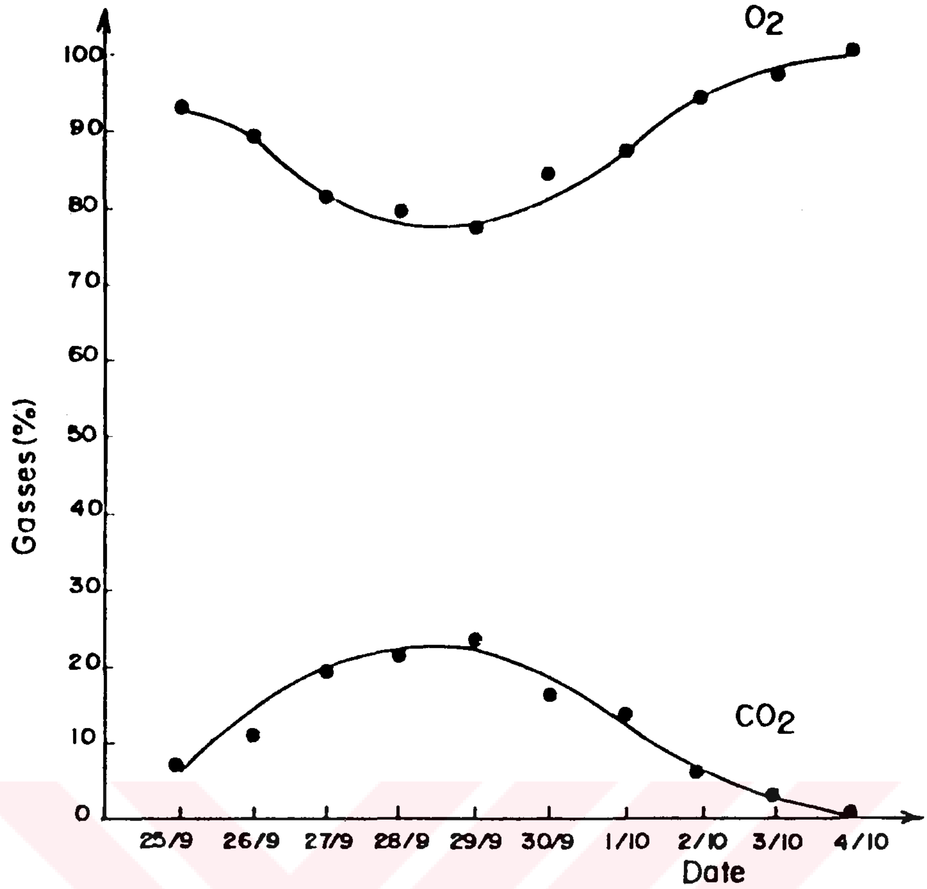

Figure 10. For 1st comparment change of gas composition with respect to time. (September 1986)

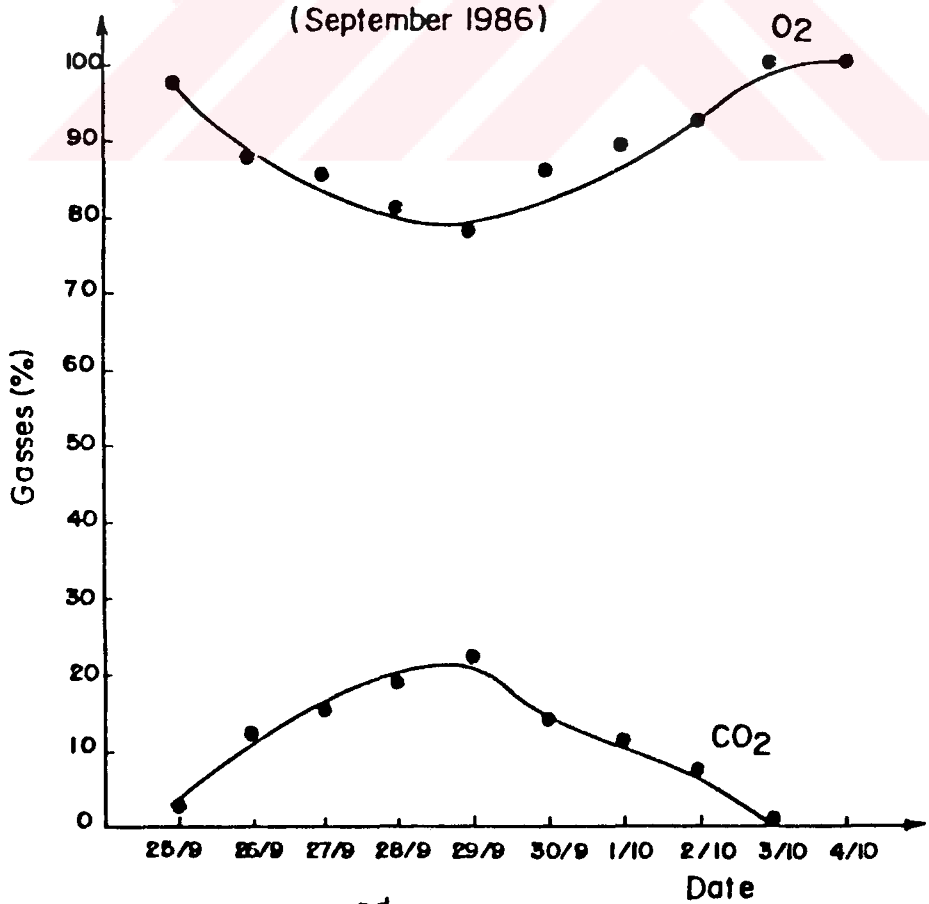

Figure:11 For 2nd Compartment change of gas composition with respect to time. (September 1986)

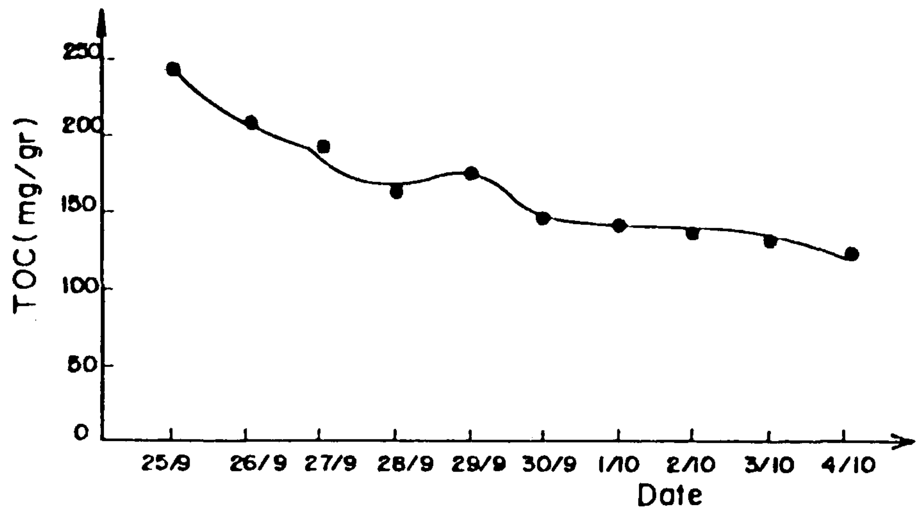

Figure 12. For 1st Compartment, change of TOC with respect to time. (September 1986)

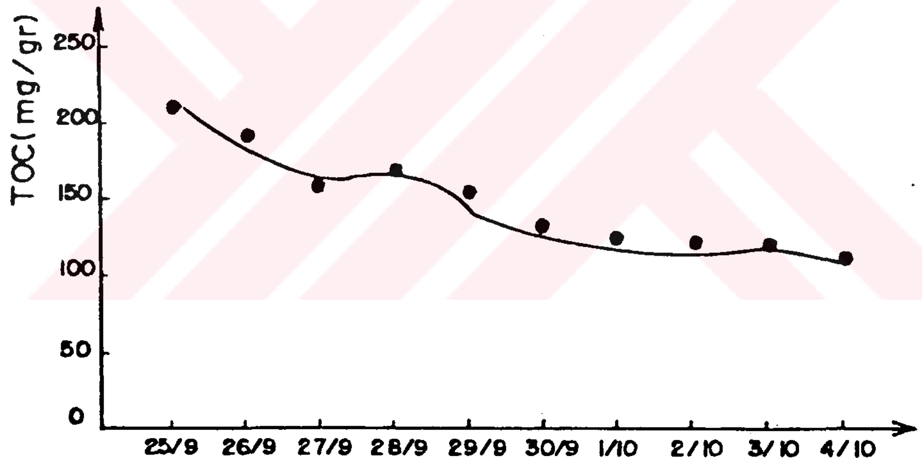

Figure 13 For 2nd Compartment, change of TOC with respect to time. (September 1986)

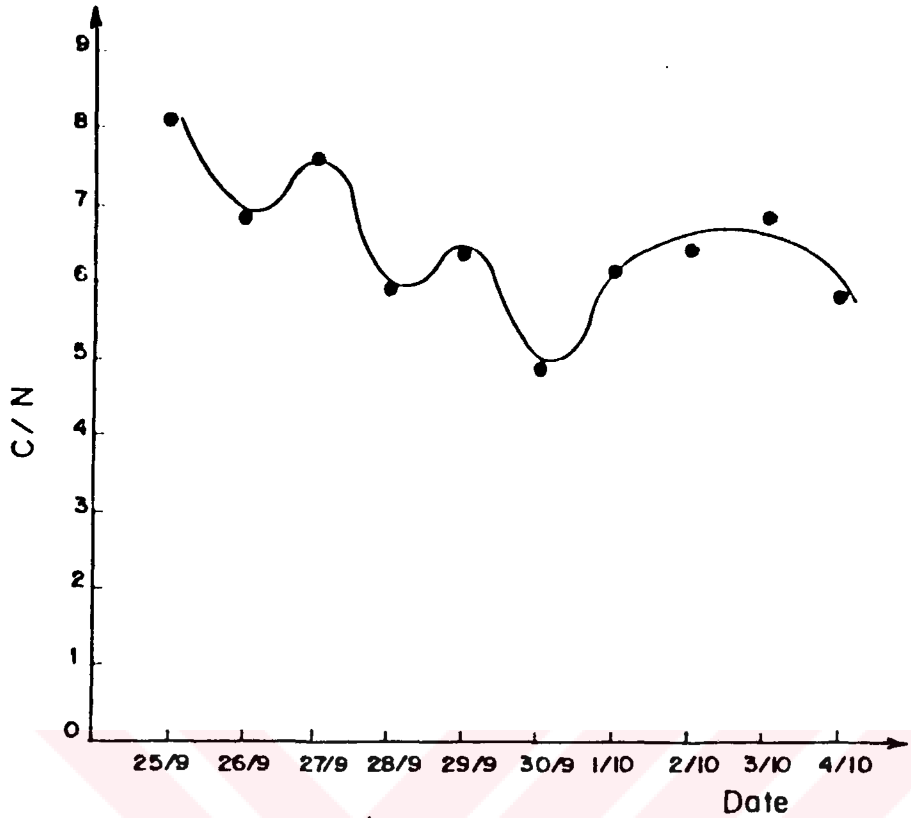

Figure.14. For 1st Compartment, change of (C/N) ratio with respect to time. (September 1986)

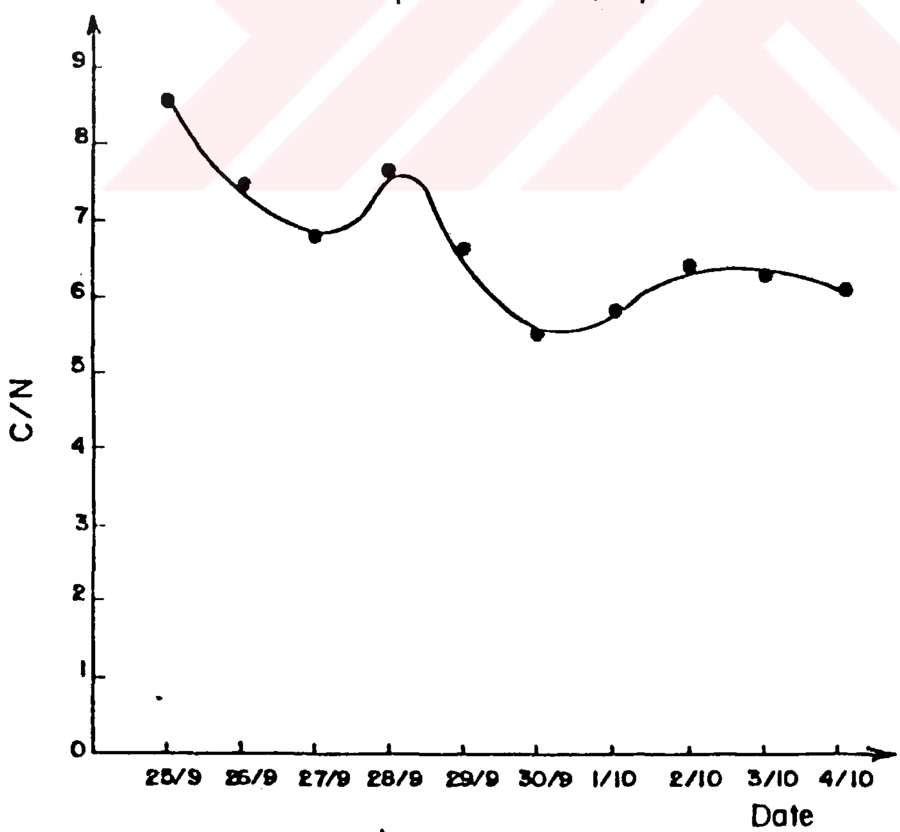

Figure.15 For 2nd Compartment, change of (C/N) ratio with respect to time. (September 1986)

be seen from Figure 16. It has reached to 68^{o}C at the end of the 4th day and then it began to fall. At the end of the 7th day, it dropped to 38^{o}C and complete stabilization was realized at the end of the 9th day at which temperature was 19^{o}C, i.e. ambient air temperature, and in parallel to this observation CO_2 concentration has reached to an undetectable level. At the end of the 4th day, the CO_2 concentration has reached to its maximum level as 38 % (Figure 17) as it was expected because of the fact that the highest temperature has been observed during this time. TOC (Figure 18) and (C/N) ratio (Figure 19) observations with respect to time showed similar trends with earlier months. They were higher at the beginning, and then they decreased slowly showing non-linear trend. Results of all analysis are presented in Table 6.

4.2.4 November 1986

Bursa waste collection system collects both garbage and ash together during winter months, i.e. November, December, January, February and March during which ash is produced as a result of fossil fuel incineration. Since it was realized that ash should not enter the compost plant, pilot unit has been loaded only with fruit and vegetable residues fraction of the "OTHER UNCLASSIFIED REMAINING PORTION" during this month. That part that has been loaded contained high moisture ratio (73 %).

Aerobic stabilization was observed as mesophilic as a natural consequence of high humidity and terminated within 9 days. The final product contained high moisture ratio (80 %) which can't be accepted as a good compost property. It is felt that this product should

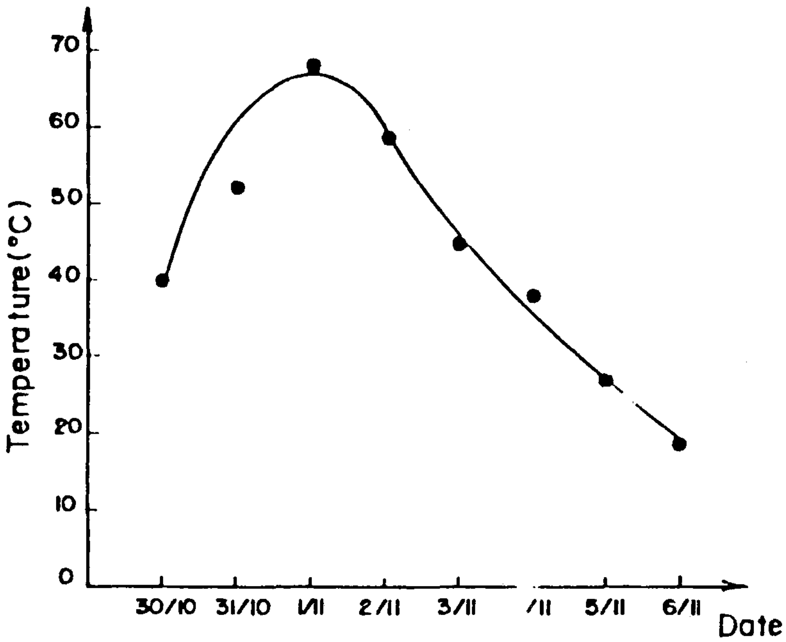

Figure.16. Change of ter perature with respect to time. (October 1986)

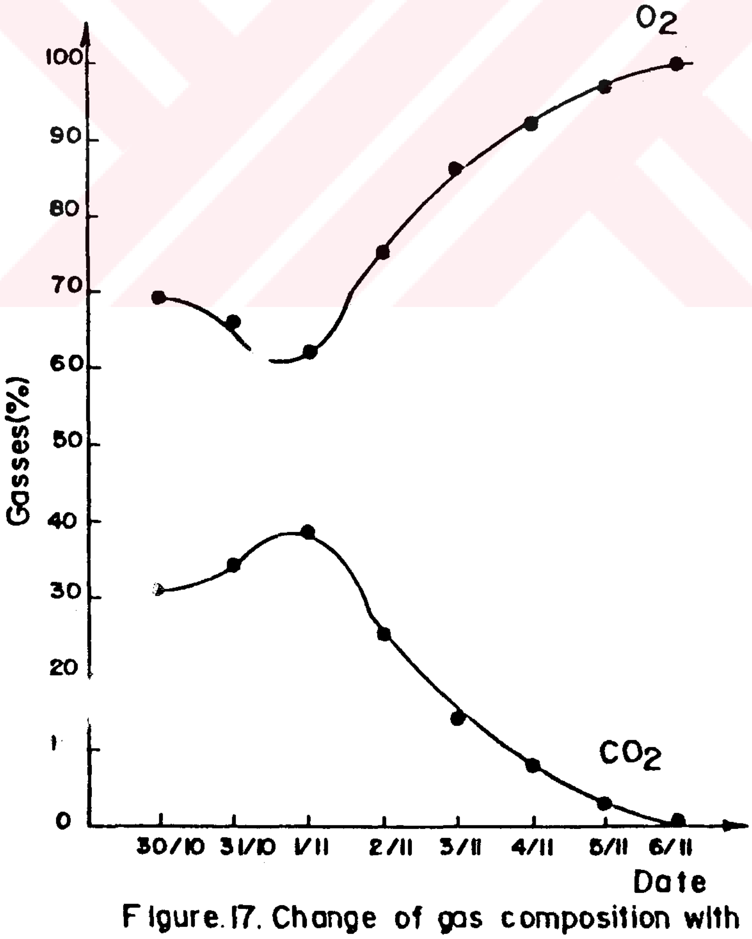

Figure.17. Change of gas composition with respect to time. (October 1986)

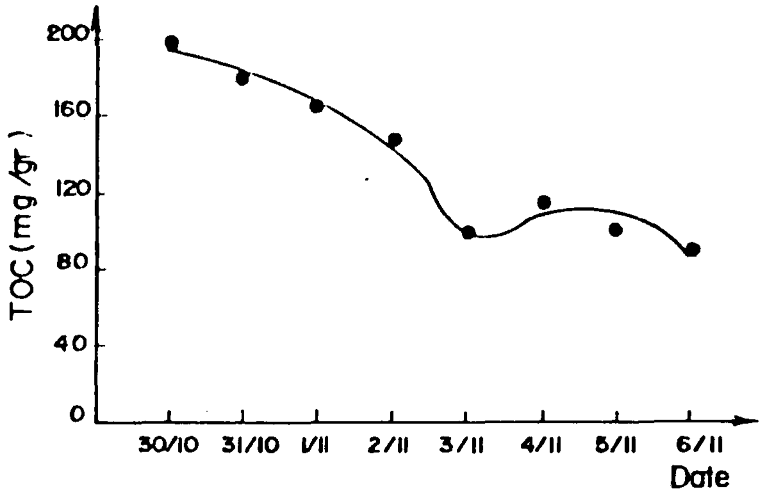

Figure.18.Change of TOC with respect to time.
(October 1986)

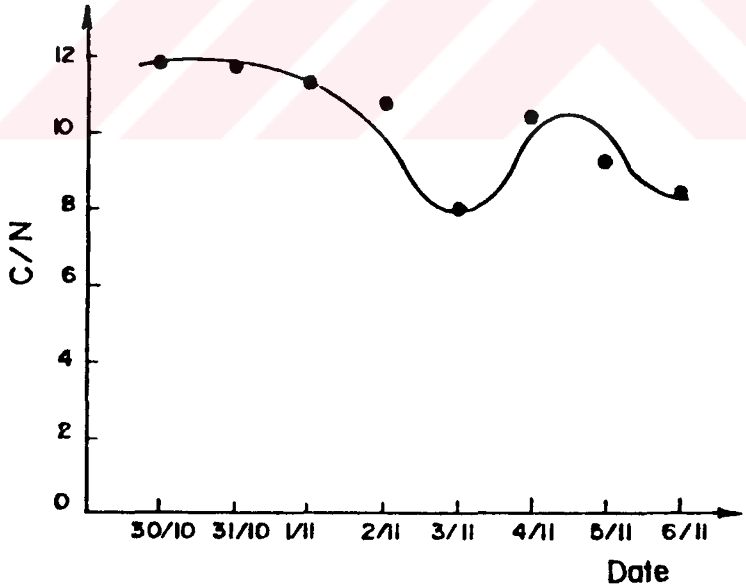

Figure.19.Change of (C/N) ratio with respect to time.(October 1986)

Table 6. Results of Analysis for October 1986 Run

DATE	HUMIDITY (%)	TEMPERATURE (°C)	GASSES (%)		TOC (mg/gr) (C)	N (mg/gr)	$PO_4^{\equiv}$ (mg/gr) (P)	C/N	C/P
			O_2	CO_2					
30.10.86	43	40	69	31	198	16.8	38	11.8	5.2
31.10.86	59	52	66	34	181	15.4	120	11.7	1.5
1.11.86	60	68	62	38	165	14.5	75	11.3	2.2
2.11.86	59	59	75	25	147	13.7	47	10.7	3.1
3.11.86	59	45	86	14	98	12.3	86	7.9	1.1
4.11.86	55	38	92	8	116	11.1	55	10.4	2.1
5.11.86	57	27	97	3	100	10.9	43	9.2	2.3
6.11.86	58	19	100	-	88	10.6	62	8.3	1.4

undergo a dehumidification and sterilization stage before being accepted as a compost. The results of analysis, temperature, gas composition, TOC and (C/N) ratio observations with respect to time are given in Table 7 and Figures 20,21,22 and 23.

In this run, due to high humidity content humidification part of the pilot plant was by-passed in the 2nd day of run, dry air was started to be compressed into the reactor. The operating conditions were:

Mixing frequency : 3/day

The number of rotation in each mixing : 2

The flow rate of compressed air : 5 l/min

The temperature of compressed air : 19^{o}C

Temperature of ambient air in laboratory : 19^{o}C

Air humidification: Not applied.

4.2.5 December 1986

For December 1986, the problem of combined collection of ash and garbage was still present.That encountered to make a run only on fruit and vegetable residues of the "OTHER UNCLASSIFIED REMAINING PORTION". Aerobic stabilization experienced was within the mesophilic range and it was complete within 10 days. The highest temperature attained was 43^{o}C at the end of the 5th day during which CO_2 concentration has reached to its maximum level (46 %). The operating parameters for this month were as follows:

Table 7. Results of Analysis for November 1986 Run

DATE	HUMIDITY (%)	TEMPERATURE (^oC)	GASSES (%)		TOC (mg/gr) (C)	N (mg/gr)	$PO_4^{\equiv}$ (mg/gr) (P)	C/N	C/P
			O_2	CO_2					
28.11.86	73	35	82	18	286	35.7	75	8.01	3.81
29.11.86	73	43	79	21	264	24.1	60	10.96	4.40
30.11.86	78	46	64	36	248	15.4	57	16.10	4.35
1.12.86	78	43	73	27	225	45.2	78	4.98	2.88
2.12.86	80	40	78	22	202	14.8	88	13.68	2.29
3.12.86	82	35	88	12	187	15.2	77	12.30	2.43
4.12.86	81	25	91	9	153	18.7	72	8.18	2.12
5.12.86	80	20	1.0	-	100	16.5	68	7.03	1.71

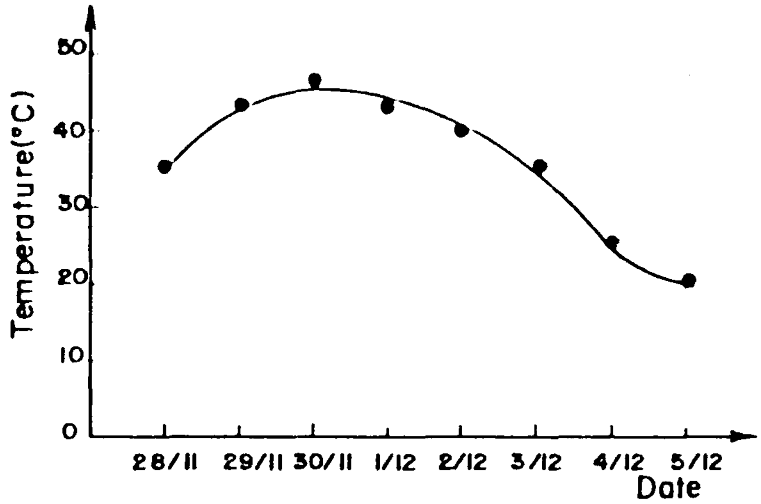

Figure.20.Change of temperature with respect to time. (November 1986)

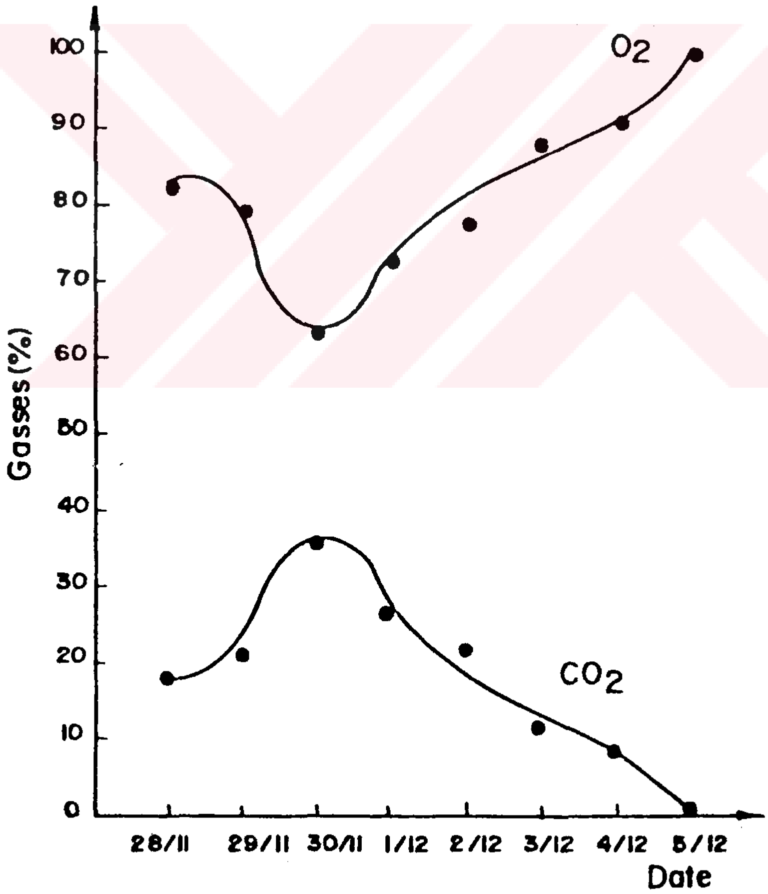

Figure.21.Change of gas composition with respect to time. (November 1986)

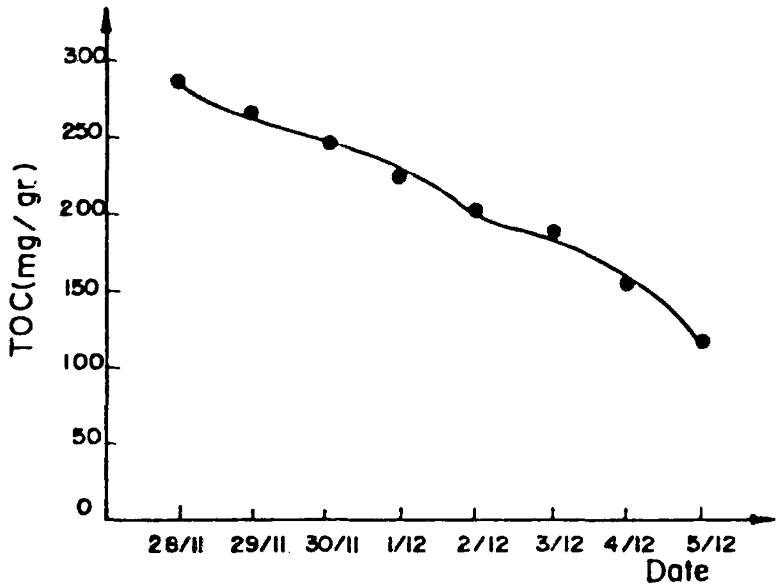

Figure.22.Change of TOC with respect to time. (November 1986)

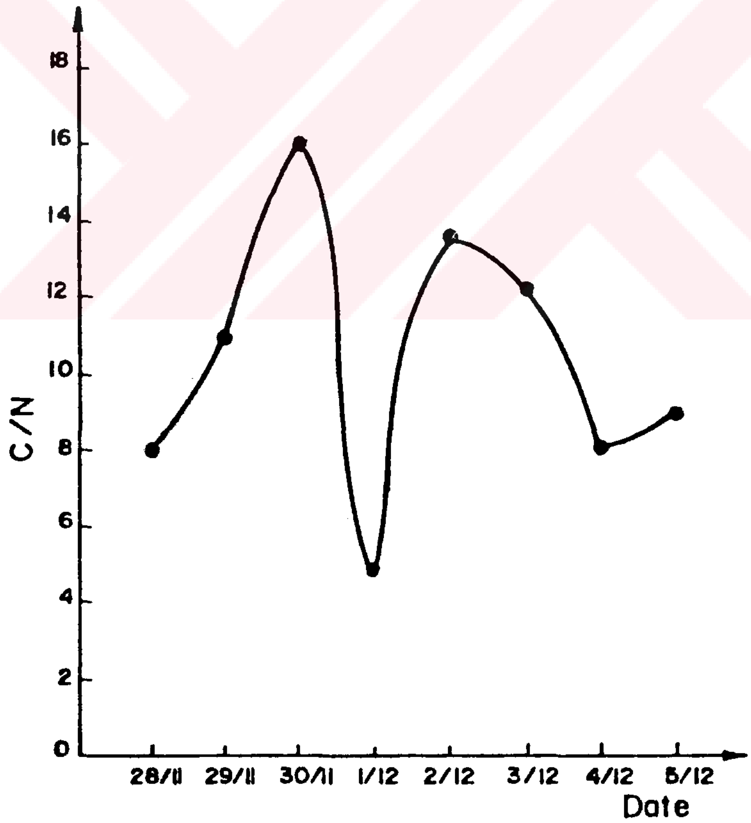

Figure.23.Change of (C/N) ratio with respect to time. (November 1986)*

*The trend obtained above do not fit the expected trend as compared to the previous runs. Certain sampling and measurement errors might have been introduced during analysis.

Mixing frequency : 1/day

The number of rotation in each mixing : 2

The flow rate of compressed air : 2 l/min

The temperature of compressed air : 16^{o}C

The temperature of ambient air in laboratory: 16^{o}C

Air humidification : Not applied

The results of analysis; temperature, gas compositions, TOC and (C/N) ratio observations with respect to time are presented in Table 8, Figures 24,25,26 and 27. The final product contained 88 % humidity which was very high and it could not be accepted as a proper compost before being dehumidified and sterilized.

4.2.6 January 1987

In this month,the practice of combined collection of ashes and garbage continued. Two types of 35 kg. weight sample have been loaded to the 1st and the 2nd compartments of the reactor as fruit and vegetable residues to the first one and fruit and vegetable residues plus excess paper to the second one respectively. By the addition of paper, it was expected to reduce humidity level of the waste which caused some undesirable results in previous runs. The humidity content of 2nd compartment (75 %) was lower when compared to the humidity level in the 1st one (80 %), but it was still above the specified upper limit.

Again, aerobic stabilization which was seen as a mesophilic phase, was complete within 9 days. The highest temperature attained was 43^{o}C for two compartments as in the December 1986 run. The final product of two compartments contained 88 % and 81 % humidity respectively

Table 8. Results of Analysis for December 1986 Run

DATE	HUMIDITY (%)	TEMPERATURE (^oC)	GASSES (%)		TOC (mg/gr) (C)	(N) (mg/gr)	$PO_4^{\equiv}$ (mg/gr) (P)	C/N	C/P	TOTAL VOLATILE SOLIDS (%)
			O_2	CO_2						
8.1.87	84	24	82	18	296	67.9	63	4.36	4./1	82.6
9.1.87	85	29	76	24	268	65.9	56	4.07	4.78	73.5
10.1.87	84	35	65	35	260	59.4	80	4.38	3.25	79.1
11.1.87	85	43	54	46	208	52.3	70	3.98	2.97	73.9
12.1.87	85	40	79	21	190	50.9	86	3.73	2.21	69.7
13.1.87	85	30	92	8	184	48.9	50	3.76	3.68	58.7
14.1.87	88	23	95	5	164	53.2	48	3.08	3.42	65.5
15.1.87	88	18	97	3	146	54.0	46	2.70	3.17	69.4
16.1.87	88	18	100	-	98	56.1	40	1.75	2.45	61.5

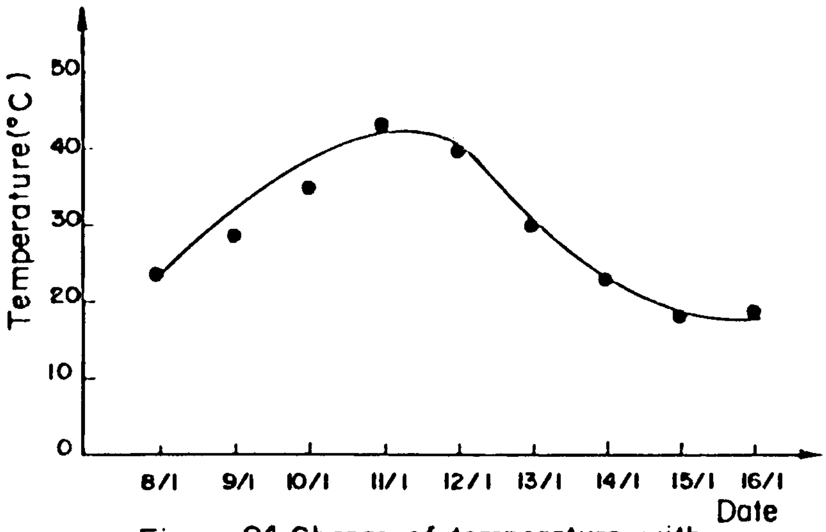

Figure. 24. Change of temperature with respect to time. (December 1986)

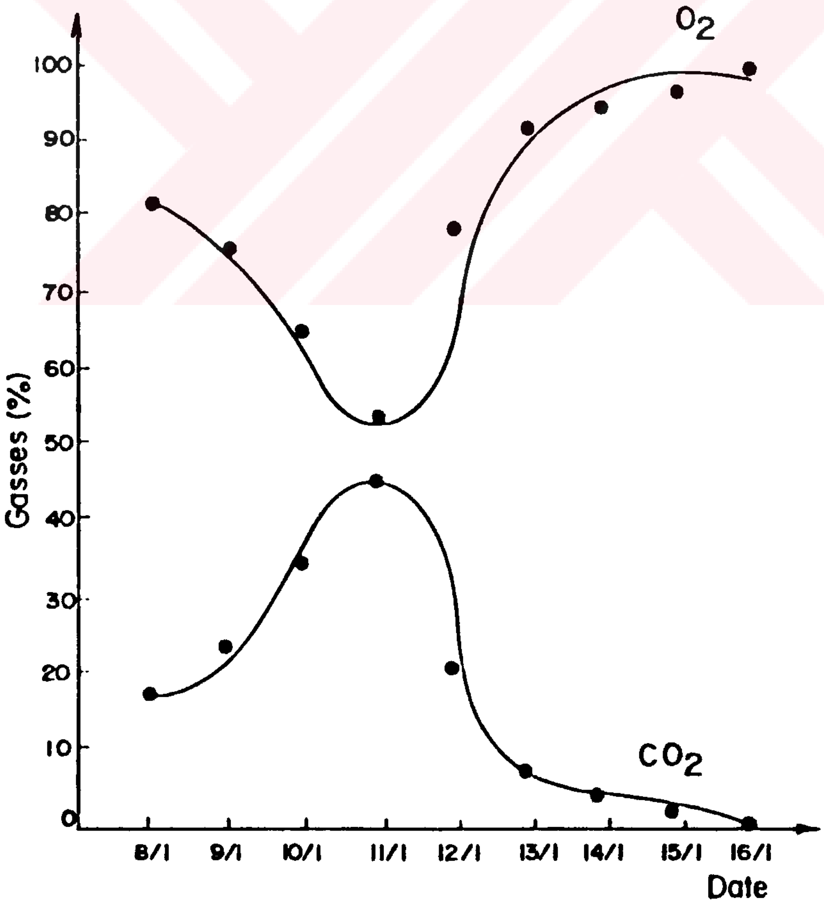

Figure. 25. Change of gas composition with respect to time. (December 1986)

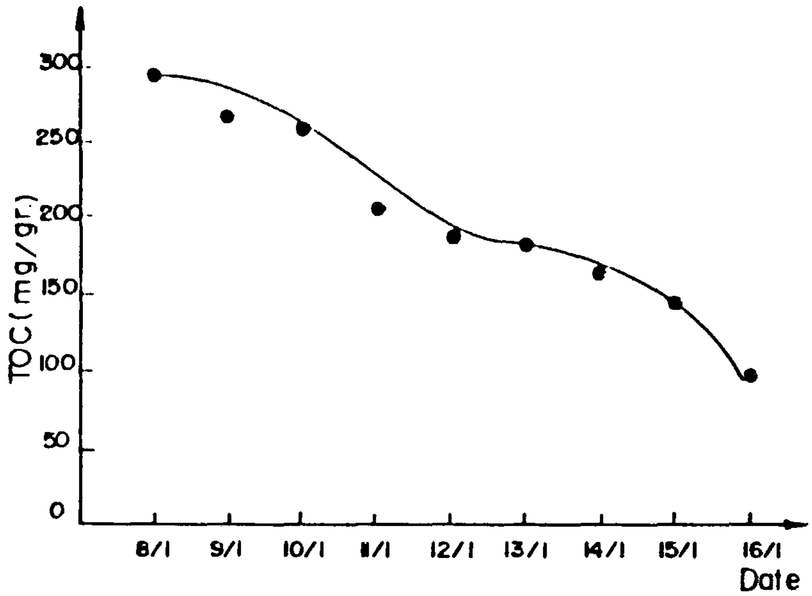

Figure.26. Change of TOC with respect to time.
(December 1986)

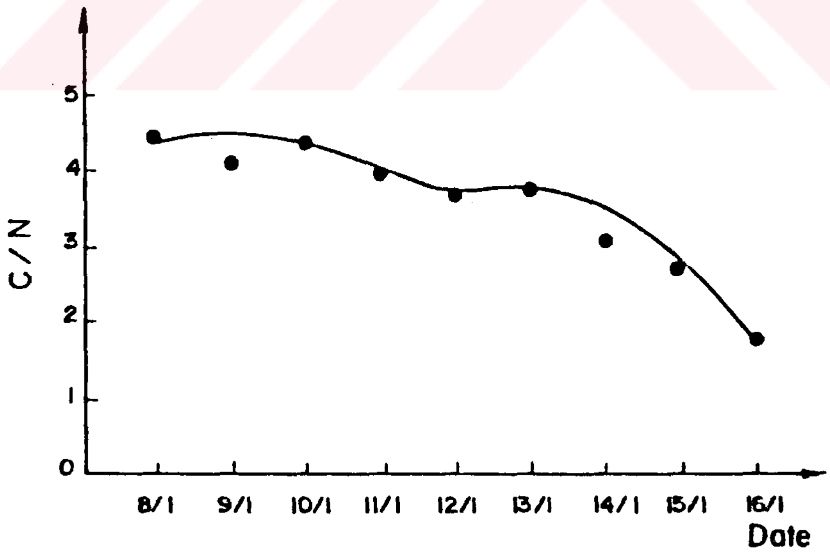

Figure.27. Change of (C /N) ratio with respect
to time. (December 1986)

which could not be accepted as a proper compost before an initial dehumidification and sterilization. The results of analysis; temperature, gas composition, TOC and (C/N) ratio observations with respect to time are given as Table 9, and Figures 28,29,30,31,32,33, 34,35. The operating conditions were as follows:

Mixing frequency : 1/day

The number of rotation in each mixing : 2

The flow rate of compressed air : 2 l/min

The temperature of compressed air : 16.5^{o}C

The temperature of ambient air in laboratory : 16.5^{o}C

Air humidification : Not applied.

4.2.7 February 1987

The ash and garbage were seperately collected in order to eliminate moisture problem which were encountered during the previous three runs. Further, sieving was applied in the following manner: Four different sizes of sieve as 120,80,60 and 30 mm. was manufactured and a part of the solid waste seperated for sorting and physical-chemical analysis were sieved to get an information about particle size characteristics of average Bursa solid waste. For this month, two types of sample of 35 kg. weight each have been obtained and loaded to the two seperate compartments of the reactor. First compartment received the sample from the portion of the waste that passed 60 mm. sieve while the second one received the sample from "OTHER UNCLASSIFIED REMAINING PORTION" of the average Bursa solid waste as it was done in earlier runs. The operating parameters were:

Table 9. Results of Analysis for January 1987 Run

DATE	HUMIDITY (%)		TEMPE-RATURE(^oC)		GASSES (%)				TOC (mg/gr) (C)		(N) (mg/gr) (N)		$PO_4^{\equiv}$ (mg/gr)(P)		C/N		C/P		TOTAL VOLATILE SOLIDS(%)	
					I		II													
	I*	II**	I	II	O_2	CO_2	O_2	CO_2	I	II	I	II	I	II	I	II	I	II	I	II
30.1.87	80	75	27	30	85	15	93	7	285	315	56.28	48.10	105	78	5.1	6.5	2.7	4.1	71	49
31.1.87	82	75	35	38	77	23	85	15	257	280	46.10	47.51	85	69	5.6	5.9	3.0	4.1	87	75
1.2.87	84	77	39	40	70	30	78	22	230	247	40.16	45.25	79	87	5.7	5.5	2.9	2.8	66	58
2.2.87	84	78	43	43	56	44	66	34	220	223	40.04	39.87	85	70	5.5	5.6	2.6	3.2	56	65
3.2.87	84	78	38	43	66	34	82	18	186	192	32.52	30.24	88	86	5.7	6.3	2.1	2.2	55	58
4.2.87	84	78	30	33	78	22	92	8	148	151	38.87	33.72	100	70	3.8	4.5	1.5	2.2	60	56
5.2.87	86	80	25	25	92	8	95	5	120	130	41.85	38.28	92	85	2.9	3.4	1.3	1.5	36	48
6.2.87	88	81	20	20	100	-	100	-	108	114	42.76	41.76	84	77	2.5	2.7	1.3	1.5	58	52

*I Indicates only fruit and vegetable residues

**II Indicates fruit and vegetable residues pluss excess paper

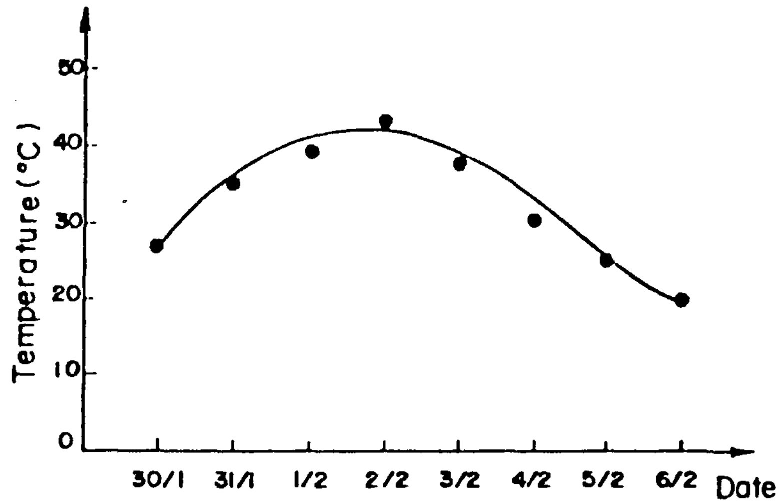

Figure.28 For 1st Compartment change of temperature with respect to time. (January 1987)

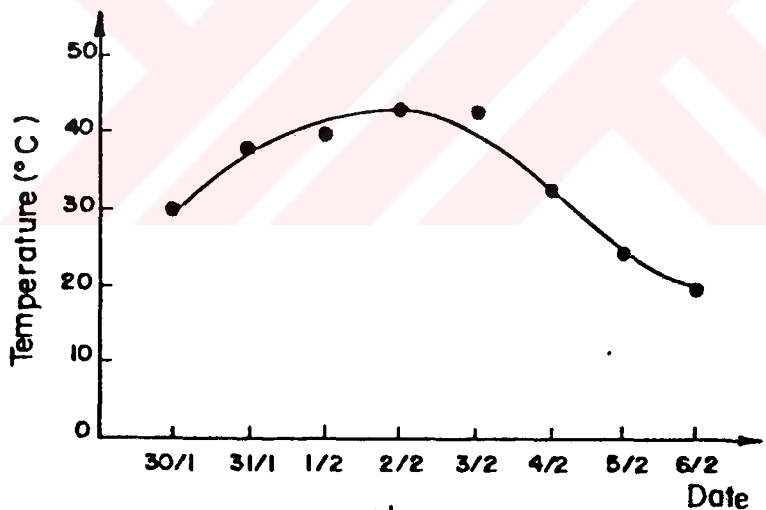

Figure.29 For 2nd Compartment, change of temperature with respect to time. (January 1987)

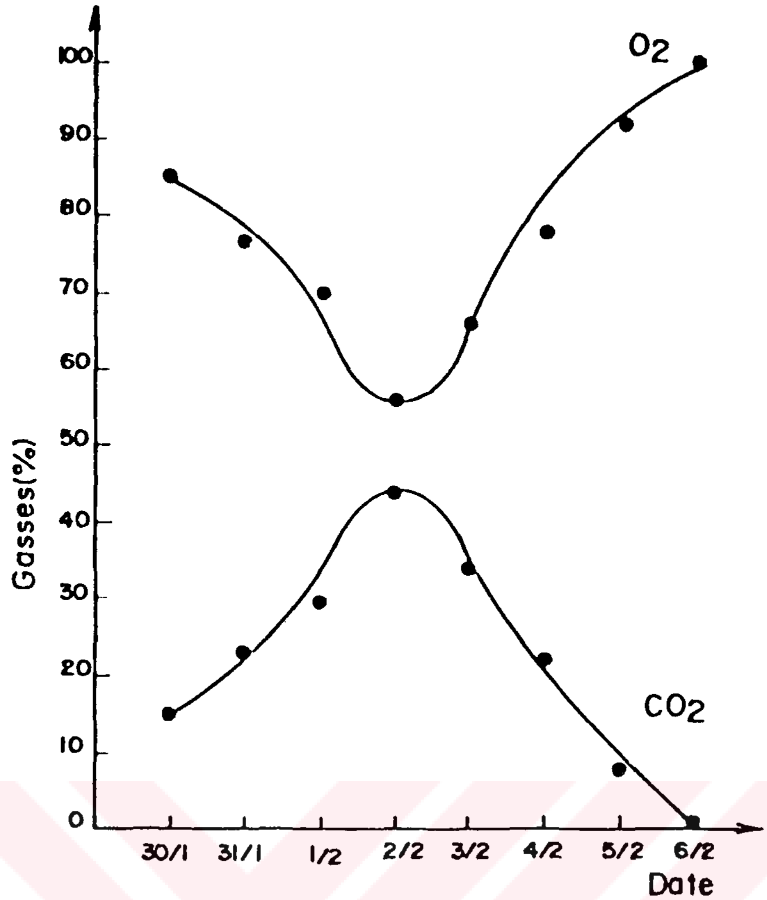

Figure.30.For.1st Compartment, change of gas composition with respect to time. (January 1987)

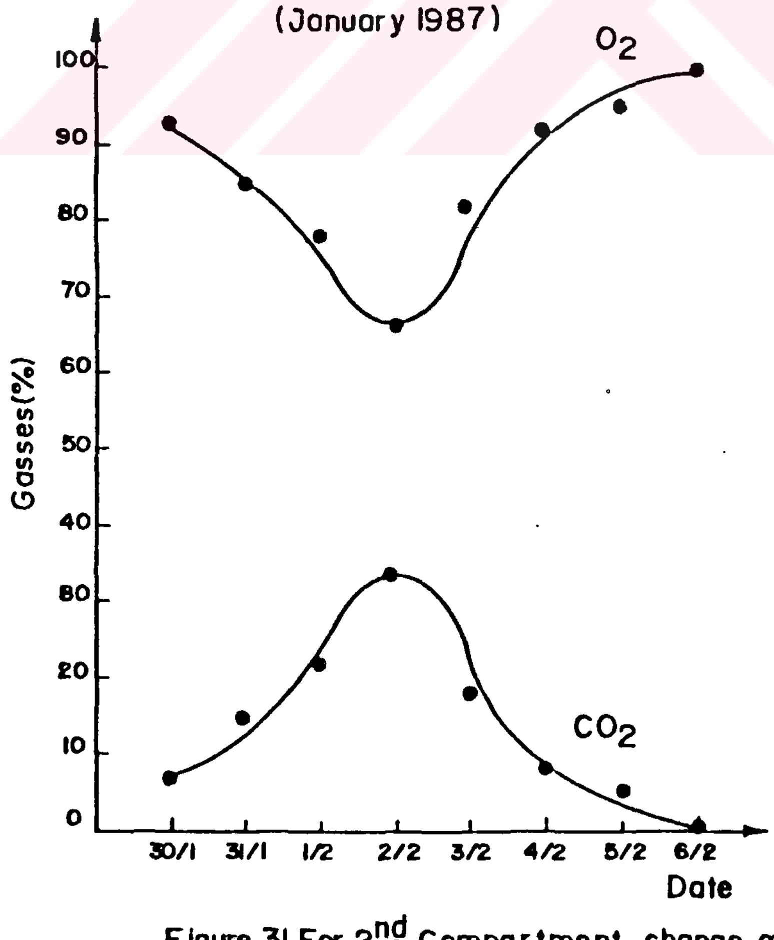

Figure.31.For 2nd Compartment change of gas composition with respect to time. (January 1987)

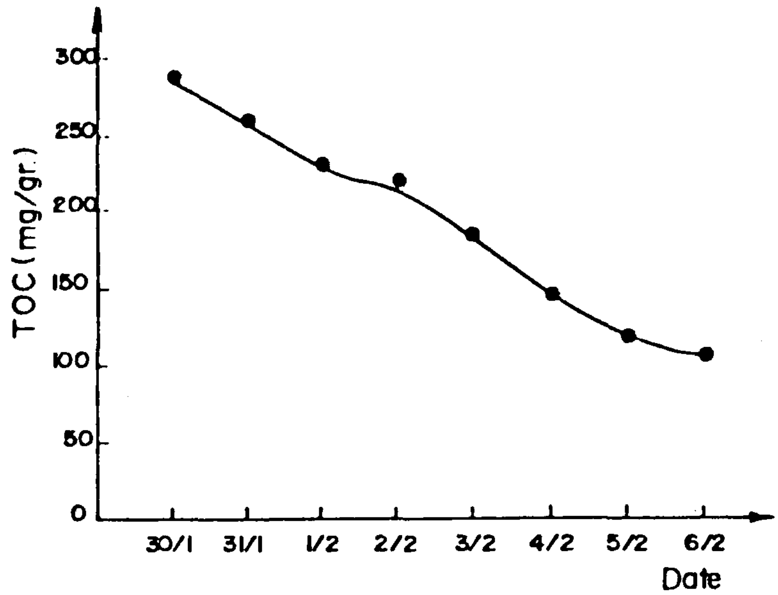

Figure.32. For 1st Compartment, change of TOC with respect to time. (January 1987)

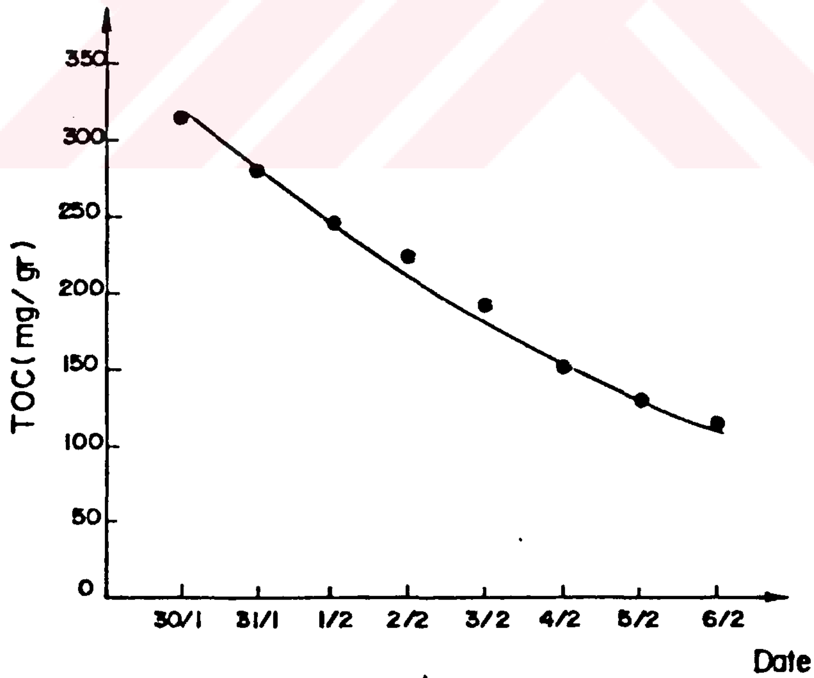

Figure.33. For 2nd Compartment, change of TOC with respect to time. (January 1987)

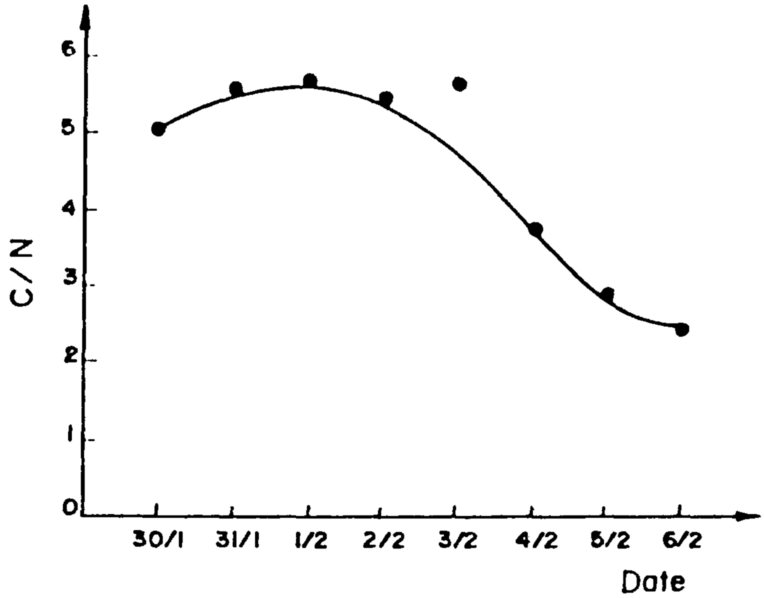

Figure.34. For 1st Compartment, change of (C/N) ratio with respect to time. (January 1987)

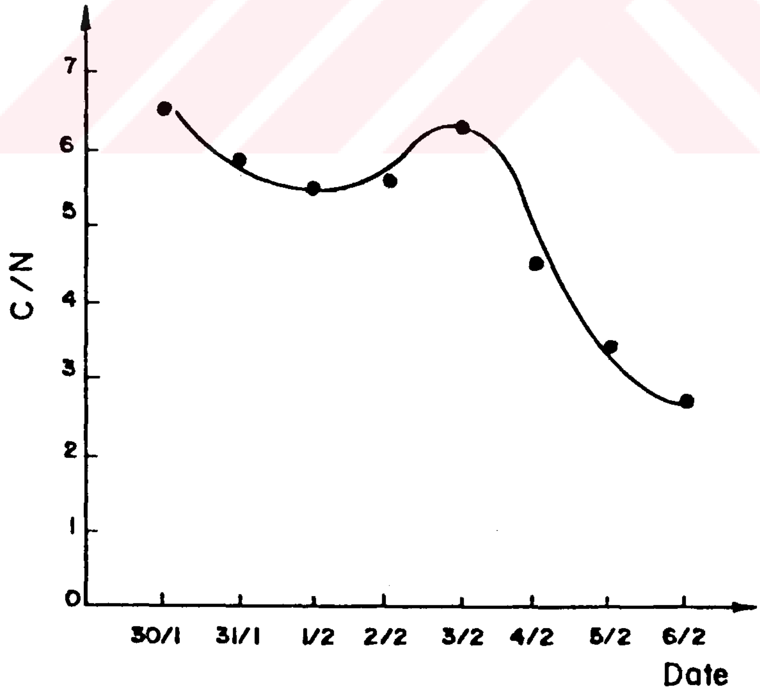

Figure.35. For 2nd Compartment, change of (C/N) ratio with respect to time. (January 1987)

Mixing frequency : 1/day

The number of rotation in each mixing : 2

The flow rate of compressed air : 2 l/min

The temperature of compressed air : 26^{o}C

The temperature of ambient air in laboratory : 13.6^{o}C

Air humidification : Not applied

As it can be seen from operating conditions, the pilot plant was modified and air was compressed to the reactor after being heated to the laboratory temperature prevailed during summer months.

Under these conditions, thermophilic phase was reached within 5 days for the first compartment (Figure 36) and within 4 days for the second compartment (Figure 37). That phase has terminated after 8 days for the first and also the second compartment. Stabilization was complete after 11 days for both compartments (Figure 38,39,40,41,42,43). The results of analysis are also presented in Table 10.

4.2.8 March 1987

For this month, a 70 kg. weight sample which was passed through 60 mm. sieve, has been loaded to two compartments of the reactor. The operating conditions were as follows:

Mixing frequency : 1/day

The number of rotation in each mixing : 2

The flow rate of compressed air : 2 l/min

The temperature of compressed air : 26^{o}C

The temperature of ambient air in laboratory : 14.7^{o}C

Air humidification : Not applied.

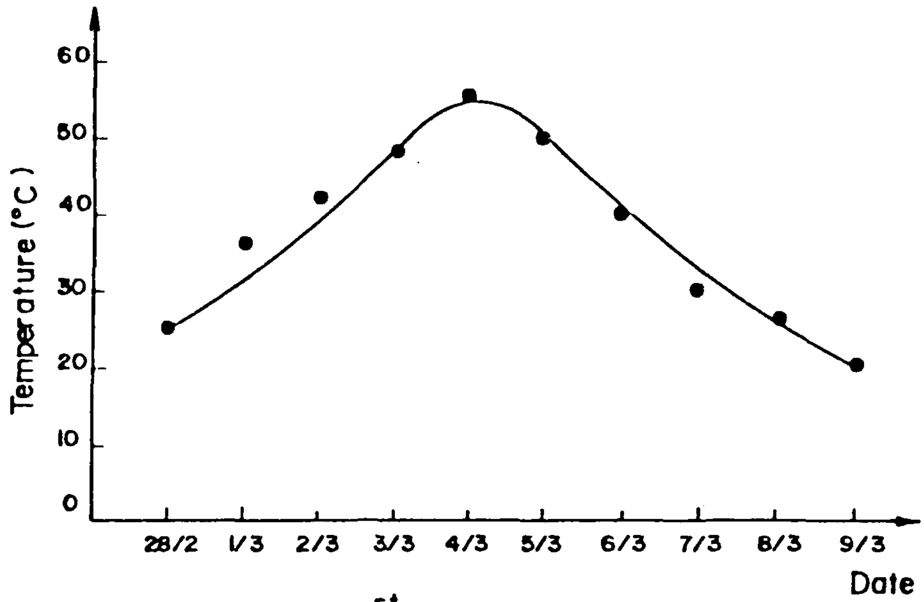

Figure.36.For 1st Compartment change of temperature with respect to time.(February1987)

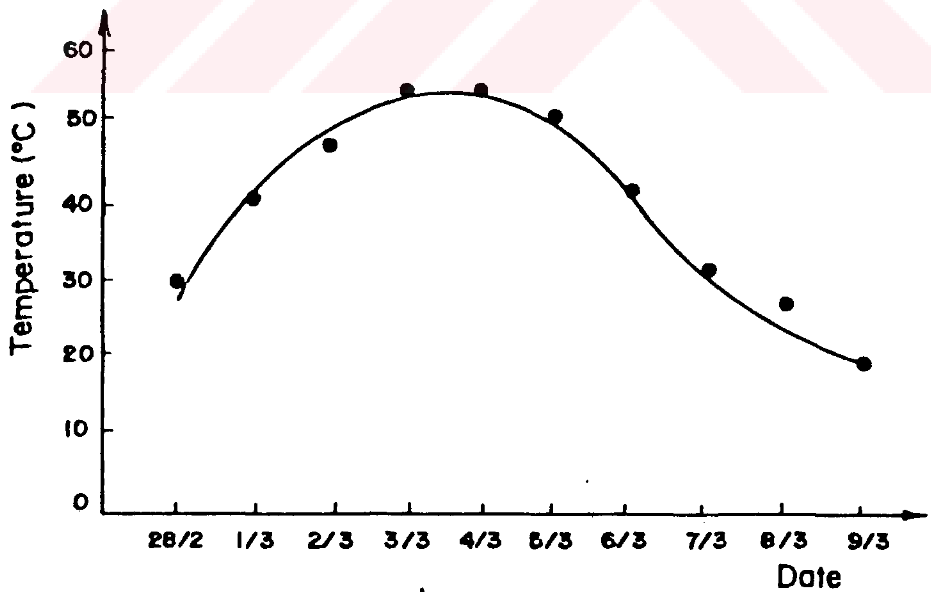

Figure.37. For. 2nd Compartment, change of temperature with respect to time. (February 1987)

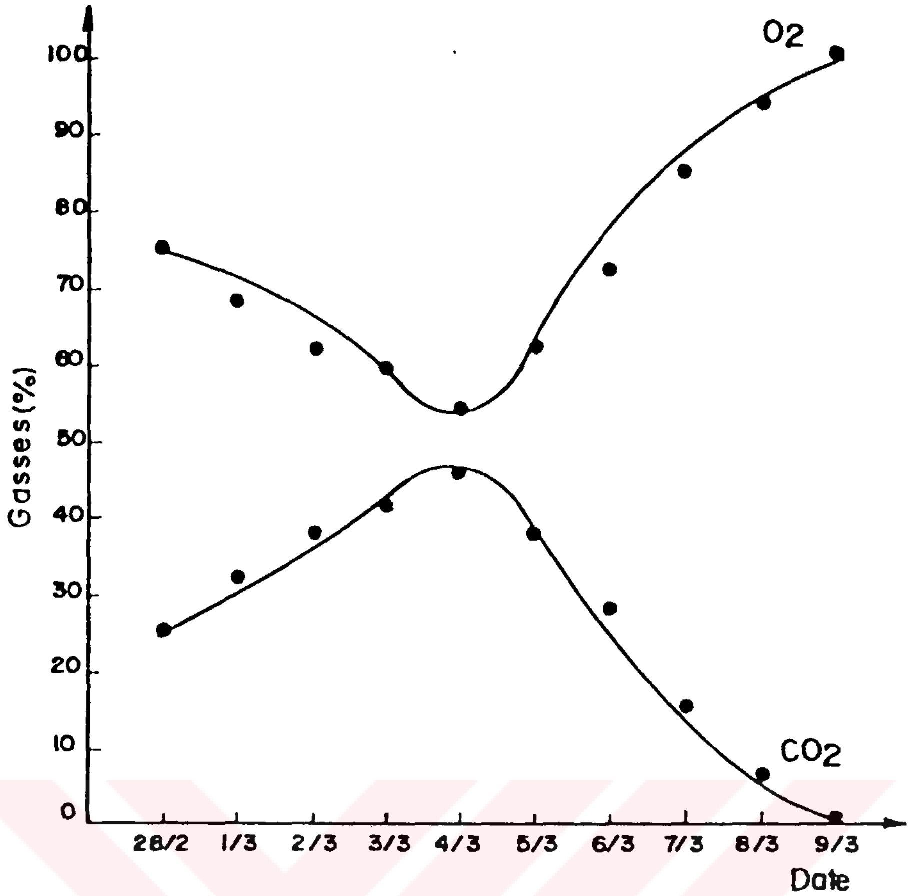

Figure.38. For 1st Compartment, change of gas composition with respect to time. (February 1987)

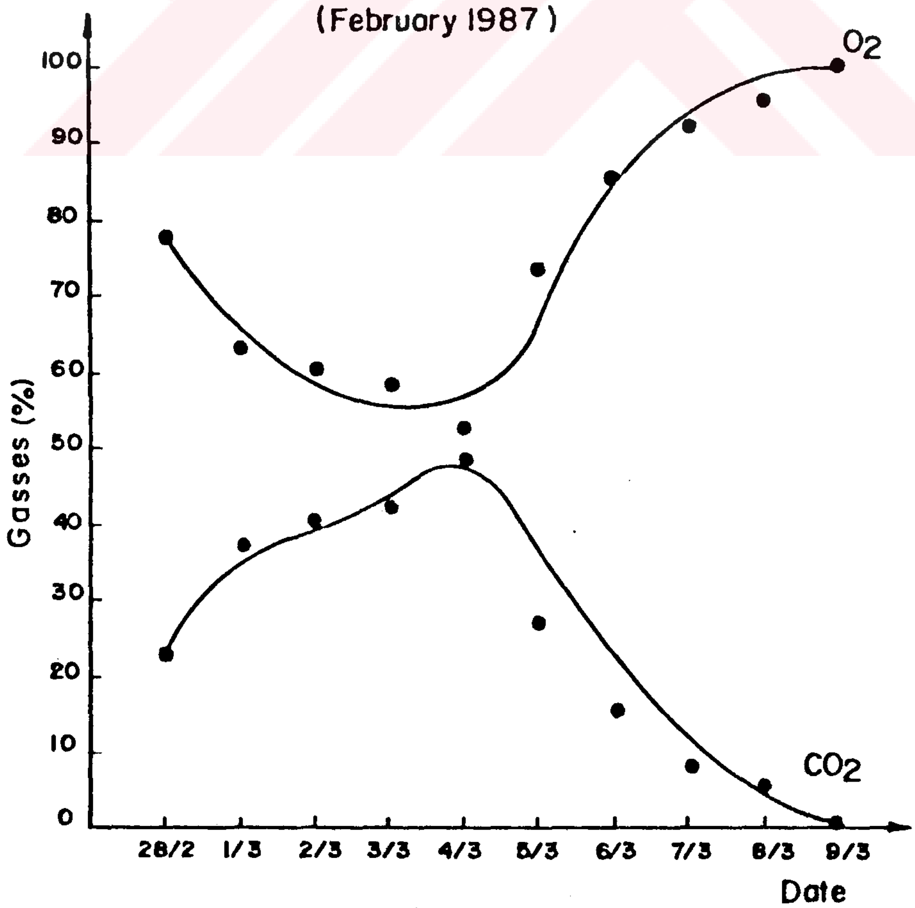

Figure.39. For 2nd Compartment, change of gas composition with respect to time. (February 1987)

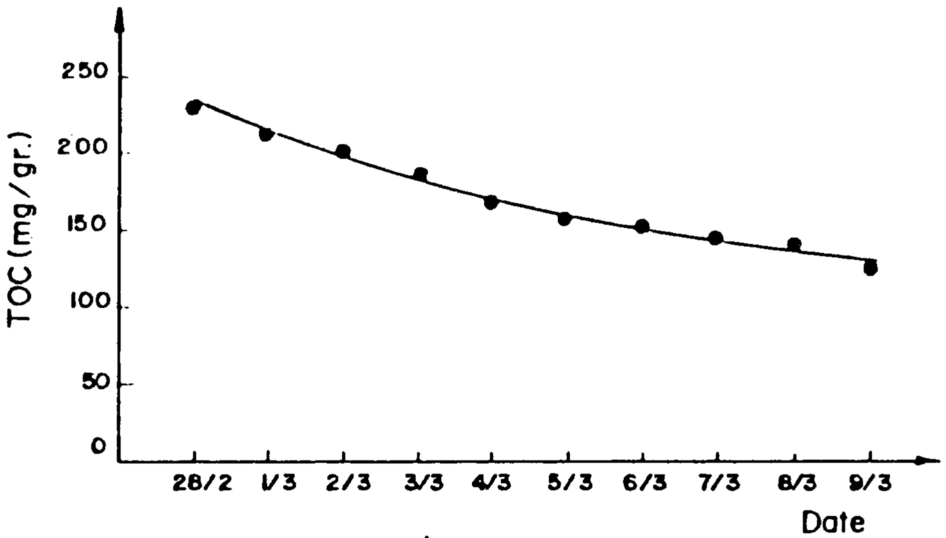

Figure.40.For 1st Compartment, change of TOC with respect to time. (February 1987)

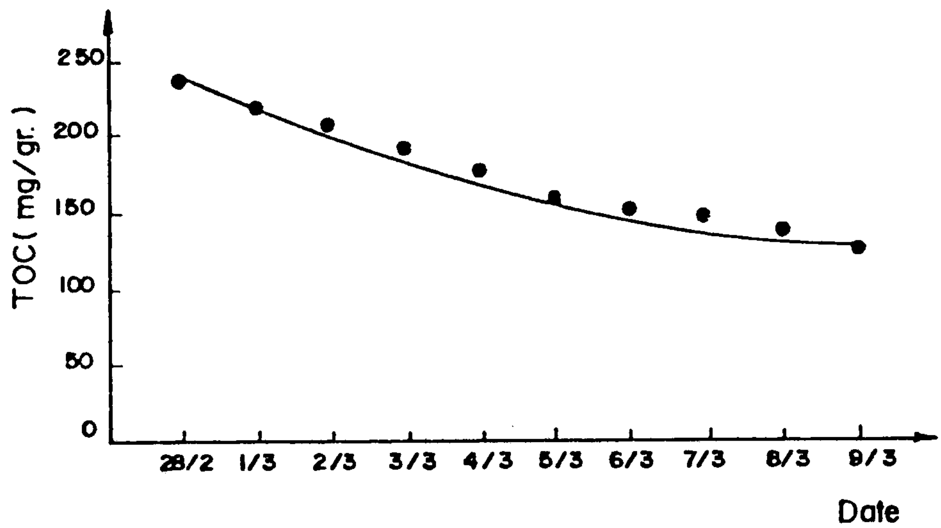

Figure.41. For. 2nd Compartment, change of TOC with respect to time. (February 1987)

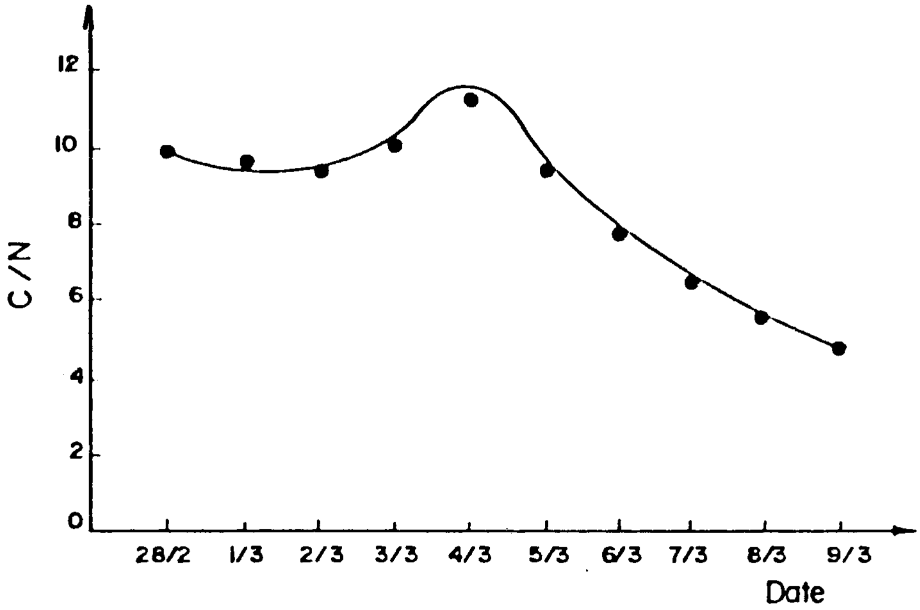

Figure.42.For 1st Compartment, change of (C/N) ratio with respect to time. (February 1987)

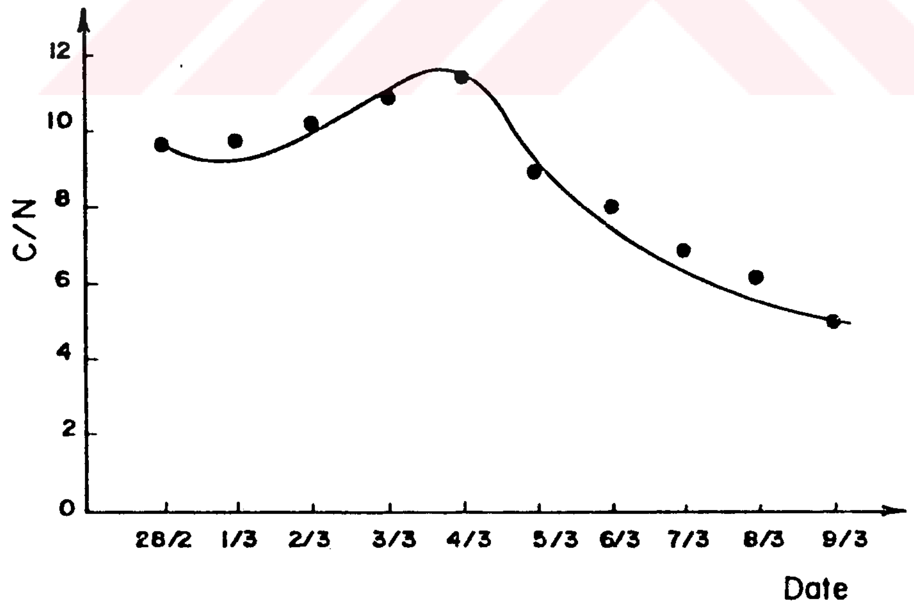

Figure.43.For 2nd Compartment, change of (C/N) ratio with respect to time. (February 1987)

Table 10. Results of Analysis for February 1987 Run

DATE	HUMIDITY (%)		TEMPERATURE (^oC)		GASSES (%)				TOC (mg/gr) (C)		(N) (mg/gr)		$PO_4^{\equiv}$ (mg/gr) (P)		C/N		C/P		TOTAL VOLATILE SOLIDS (%)	
					I		II													
	I*	II**	I	II	O_2	CO_2	O_2	CO_2	I	II	I	II	I	II	I	II	I	II	I	II
28.2.87	41	43	25	30	75	25	77	23	232	238	23.5	24.9	85	76	9.9	9.6	2.7	3.1	28	24
1.3.87	42	44	36	41	68	32	63	37	217	221	21.4	22.7	75	67	9.7	9.7	2.9	3.3	26	32
2.3.87	44	46	42	48	62	38	60	40	202	209	21.3	20.5	69	62	9.5	10.2	2.9	3.4	32	29
3.3.87	45	48	48	55	59	41	58	42	187	195	18.5	17.9	78	74	10.1	10.9	2.4	2.6	28	26
4.3.87	46	50	55	55	54	46	52	48	171	179	15.1	15.7	83	77	11.3	11.4	2.1	2.3	21	28
5.3.87	50	51	50	52	62	38	73	27	159	161	16.8	17.9	92	82	9.5	9.0	1.7	1.9	25	26
6.3.87	52	55	40	42	72	28	85	15	152	155	19.6	19.3	98	87	7.8	8.0	1.6	1.8	26	22
7.3.87	53	56	30	32	85	15	92	8	146	149	22.2	21.6	102	91	6.6	6.9	1.4	1.6	25	25
8.3.87	53	56	26	28	94	6	95	5	143	141	24.9	23.2	105	96	5.7	6.1	1.4	1.5	27	29
9.3.87	55	58	20	20	100	-	100	-	127	129	26.1	25.8	110	100	4.9	5.0	1.2	1.3	31	32

*Solid waste passed through 60 mm. sieve excluding ash

**Average Bursa solid waste excluding ash

The temperature has reached to 60^{o}C (Figures 44) which indicated the thermophilic phase, at the end of the 6th day and complete stabilization has been achieved within 11 days. Humidity content of raw waste was 42 % which was within the favorable range. This run whose results of analysis and observation of gas compositions with respect to time are given in Table 11 and Figure 45, was considered as a successful run for compost production and final product had quality that can be assumed as a good compost as explained in the next section.

4.3 QUALITY OF PRODUCT

The quality of composts produced in August 1986, October 1986, February 1987, and March 1987 was determined after 1-2 months maturation period using the analysis methods proposed by WHO (11) and the measured values of certain parameters remained within the ranges acceptable for a good compost defined by WHO. The expected ranges for certain parameters were already given earlier as Table 1 and 2. Results of all quality analysis are presented in Table 12 and compared with the acceptable ranges for a good compost.

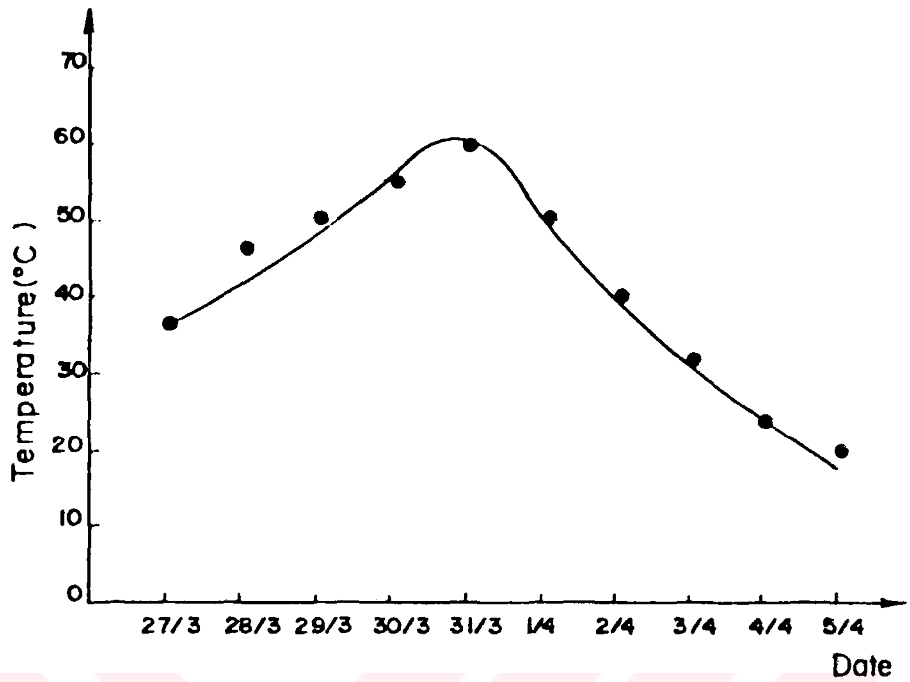

Figure.44. Change of temperature with respect to time. (March 1987)

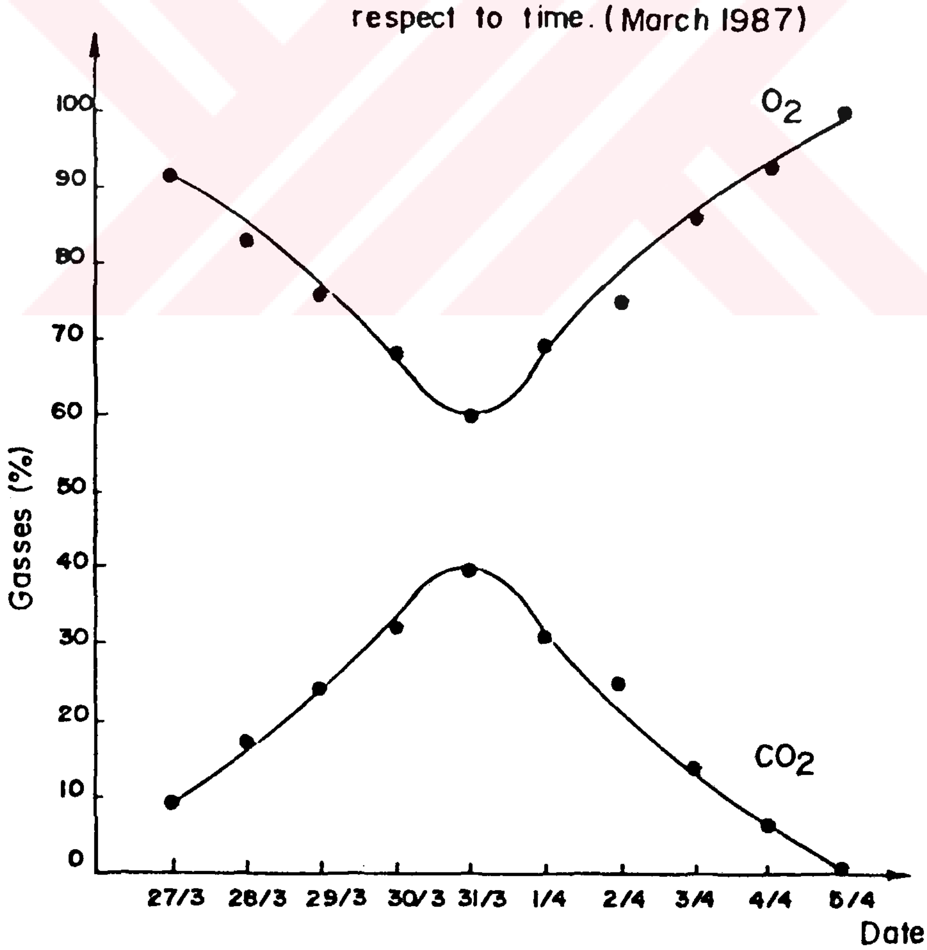

Figure.45.Change of gas composition with respect to time. (March 1987)

Table 11. Results of Analysis for March 1987

DATE	HUMIDITY (%)	TEMPERATURE (^oC)	GASSES (%)		TOTAL VOLATILE SOLIDS (%)
			O_2	CO_2	
27.3.87	42	36	91	9	15
28.3.87	43	46	83	17	14
29.3.87	43	50	76	24	11
30.3.87	43	55	68	32	14
31.3.87	44	60	60	40	11
1.4.87	44	50	69	31	13
2.4.87	45	40	75	25	11
3.4.87	46	32	86	14	10
4.4.87	47	24	93	7	12
5.4.87	48	20	100	-	11

Table 12. Results of Quality Analysis

Element	Proposed value (4)	August 1986	October 1986	February 1987		March 1987
				Sieved waste	Unsieved waste	
Moisture (g/100g)	30-50	45	43	47	45	41
pH(of a 1/10 slurry)	6-9	6.8	7.3	7.1	7.2	7.0
N(in g/100g)	0.1-1.8	3.36	1.73	1.85	1.82	1.78
P(P_2O_5) (g/100g)	0.1-1.7 (0.2-3.8)	4.5	3.2	2.7	2.9	3.4
K(K_2O) (g/100g)	0.1-2.3 (0.1-2.8)	3.5	0.73	2.2	1.9	3.1
S(g/100g)	0.5-3.0	1.73	2.54	1.97	2.32	1.65
Alkalinity (as CaO)	1-20	1	4.2	2.2	1.8	3.7
Total Salts (as KCl)	0.5-2.0	0.7	0.5	0.8	0.5	0.6

5. DISCUSSION AND CONCLUSION

This study was a part of an applied project named as "Solid waste problem of Bursa municipality" with a project code number of 86-03-02-03-01. Within the scope of this thesis, compost production possibilities from the solid waste of the city of Bursa were studied. To achieve this goal, it was carried out in three consecutive stages namely as characterization of Bursa solid waste, pilot compostability studies and finally quality analysis of compost obtained with respect to marketability.

The first part of the study was covered the chemical characterization of the Bursa solid waste for average and also different socio-economic group's wastes. It was realized for one year with monthly periods. Through this characterization, data about the chemical characteristics of Bursa solid waste was produced and this gave an idea about the seasonal and monthly variation of Bursa solid waste by considering chemical parameters of pH, TOC, nitrogen, phosphate, moisture content and volatile solids.

In the second part, studies on pilot composting plant were realized for eight months with monthly runs in order to monitor the process control variables and especially to determine the time required for obtaining a compost ready for maturation.

Finally, a quality of compost produced was determined with respect to marketability and compared with the WHO standards.

At the end, it has been shown that a compost that experienced the thermophilic phase and ready for maturation can be obtained from solid waste of the city of Bursa within 5-7 days using closed-controlled aerobic system. The waste that should enter the plant can either be the "OTHER UNCLASSIFIED REMAINING PORTION" of sorted and reduced size (2.5-5.0 cm.) waste or that portion of waste that passed 60 mm. sieve. Sorting means separation of paper, cardboard, plastics, nylon, tires, wood, bread, textile, bones, glass, iron, tin-cans, aluminium and copper.

Although compostability studies covered the eight months of a year, it was seen from the results of chemical analysis, for the months in which compostability studies were not practiced, that a proper compost ready for maturation can be produced for a whole year.

As it was explained before, for some winter months the thermophilic phase was not reached due to high humidity content. The collection practice was the main reason for this results in which ash and garbage were collected together. But, at the end of the project separate collection of ash and garbage during winter months was proposed. So, it can be said that composting of the part of city of Bursa solid waste can be achieved with no problem with the humidity level.

Quality analysis on the final products showed that it can be accepted as a good compost depending upon WHO standards. Since Bursa is in the middle of a fertile plain, compost produced may find a market due to its proper quality as a soil conditioner.

Further, time required for the production of compost ready for maturation can be reduced to 1-3 days using continously rotating systems with higher stabilization rates. And quality of produced compost can be enriched with the addition of certain nutrients according to the necessities of soil and also to the type of plants for which compost will be used.

In a further study, a high capacity system can be manufactured and may be studied continously instead of batch system which can be realized for only in-situ study. For this type of study; in addition to the temperature and gas compositions, pH which is an another important process control variable, can also be measured and detected in order to see the different phases of decomposition.

For in-situ and also laboratory batch studies effectiveness of different oxygen supply rates and different frequency of mixing on compost production may be taken into consideration and be optimized for certain region's solid wastes.

In laboratory and batch studies, number of system may be doubled to give a chance to study on large quantities. During manufacturing of pilot plant, care must be given to openings to supply easy filling and emptying of reactants. Size reduction may also be realized mechanically instead of manually to be able to get homogenity.

Anaerobic study with biogas collection facility might also be realized to check the possibility of biogas production and its composition, i.e. quality.

Finally, it can be concluded that this type of studies must be followed by an application of the compost produced to certain plants in order to get an idea about its effectiveness on plant growth. In addition to this, market surveying may also be accomplished.

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