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Static Pile Passive Aeration Composting
of
Poultry Manure Slurry

by

Weiguo Zhan

M.A.Sc. Thesis

submitted to the School of Graduate Studies and Research
under the supervision of
Dr. Leta Fernandes

in partial fulfilment of the requirements for the degree
of
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in
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Abstract

Static pile passive aeration composting (SPPAC) method is simple and economical. It can be applied to treat and stabilize animal wastes and reduce their adverse impact on the environment such as water, soil and air pollution. A study was carried out to investigate the effectiveness of SPPAC process for poultry manure slurry treatment under high initial MC conditions, using peat and straw as the bulking agents. Four treatments were examined, two of which were mixtures of poultry manure slurry and peat with initial MC of 73 and 80%. The other two treatments consisted of poultry manure slurry and chopped straw with initial MC of 72 and 76%, these two treatments had similar performances and results. Three replicate piles were monitored simultaneously for each treatment. The piles were trapezoidal and $3.35m^3$ in volume. Two open-ended perforated pipes were laid at the bottom of each pile to provide aeration. A total of 316 thermocouples were installed in the compost piles to monitor temperature over a period of four months.

Within 5 days thermophilic temperatures over 45°C were attained in the compost piles confirming that passive aeration was effective and exothermic composting reactions started rapidly. Temperature distribution results illustrated that air diffusion and convection were the predominant aeration mechanisms. Cluster analysis of the temperature results provided a depiction of passive aeration, *i.e.*, the ambient air was drawn into the compost through the lower parts of the piles to fill the void created by the up-moving heated air in the system. The temperature results also confirmed that the perforated pipes in the bottom of each pile increased aeration only in their vicinity.

The compost with high moisture was successfully handled using the SPPAC method, no symptoms of anaerobic conditions were recorded. Mass balance results showed that nitrogen loss was lower in the compost of higher MC and lower pH, maximum 37% and 50% from the peat compost and the straw compost, respectively. Based on the guidelines of the Ontario Ministry of Environment, the final compost contained high levels of essential plant nutrients, the percent of total of nitrogen, phosphorus and potassium was greater than 4%, and the heavy metal levels were low. The peat is a better bulking agent than the straw. The performance among the three replicate piles of each treatment was highly stable and reproducible. The composting process took 30 to 90 days for the process to finish depending on the amount of poultry manure slurry in the different treatments.

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GLOSSARY

C/N	carbon to nitrogen ratio
dm	dry matter
MC	moisture content, %
NH_3-gas	released ammonia gas, ppm
NH_3-N	ammonia nitrogen, %
NO_3-N	nitrate nitrogen, %
$\%P_{ini}$	initial phosphorus concentration, % dry matter
$\%P_{fnl}$	final phosphorus concentration, % dry matter
P_{total}	total phosphorus, kg
SPPAC	static pile passive aeration composting
V	compost pile volume, m^3
VS	volatile solids, % dry matter
WHC	water holding capacity, water (weight)/kg material
Wt_{ini}	initial total compost weight, kg
Wt_{fnl}	final total compost weight, kg
Wt_{loss}	compost weight loss, kg

Chapter 1

INTRODUCTION

Modern specialized intensive animal production generates large amount of manure in either solid or liquid form. Because of the high costs for transportation and treatment, the tendency is to dispose of the manure onto the adjacent agricultural lands close to animal production operations. Very often surface and ground water contamination, soil compaction, nutrient imbalance, and phytotoxicity are caused because the amount of manure applied to the lands is very high and cannot be absorbed by the soil recycling system (Barrington, 1991).

Studies by NRC (1983) have confirmed that nitrogen, phosphorous, bacteria, and organic matter are the main constituents in animal manure that cause contamination problems. Barnett (1991), Gonzalez *et al.*, (1989), and Robinson and Draper (1978) have recorded numerous environmental pollution cases related to animal waste disposal. These include (A) surface water pollution in the drainage basins of Chaudiere, Yamaska, and Achigan-Assomption rivers; (B) Brittany ground water pollution; (C) phosphorous pollution in the Great Lakes; (D) bacteria contamination of well water in Manitoba; (E) human deaths and poisoning by nitrate contaminated water; (F) 8% of the total fish kill in the US; (G) animal kill cases; (H) halting of plant growth and delayed crop ripening caused by nitrite phytotoxicity; and (I) cause of acid rain in some European countries as a result of ammonia gas released from the "manure mountains".

1.1 ANIMAL WASTE COMPOSTING

Awareness of the adverse environmental impacts resulting from animal waste mismanagement has inspired studies on the development of pollution attenuating technologies. Of these, composting has received growing attention. By nature composting is a biological process, during which aerobic microorganisms decompose organic matter to support life activities such as syntheses and metabolism. As a result, temperature in the system rises to a thermophilic level, over 45°C, and the waste materials are transformed chemically and physically. High temperature is also the driving force for inactivating pathogens, found in most animal wastes. Composting can be carried out in reactor, static pile, and windrow systems. End products from composting treatment of animal manure are biologically stable, rich in crop nutrients, easy and safe to handle, and thus can be applied as soil conditioner or fertilizer (Lau and Wu, 1987).

Manure slurries often contain over 90% moisture. Aerobic composting of such materials is impossible because of the difficulties in piling and aerating of these slurries. Bulking agents are used to adjust the initial moisture content as well as to create a material that possesses a porous structure, through which air can circulate easily. For composting the generally recommended moisture content is within the range of 50 to 60% (Poincelot, 1974). However, to reduce the moisture content in manure slurries from about 90% to the above referred level requires large amount of bulking agents, which results in high operating costs. On the other hand, less use of bulking agents will lead to higher moisture content in the initial compost. If not properly controlled, high moisture content tends to hinder aeration and thereafter induces undesirable anaerobic conditions during composting which can be identified with low temperatures, below 35°C, and occurrence of foul odours (Haug,1980).

The two most commonly used composting aeration methods are pile turning for windrow composting and forced aeration for static pile composting. Nevertheless, intensive labour and relatively high capital investment are the major disadvantages of these two methods. To minimize these drawbacks, Haug (1980) suggested the application of the static pile natural ventilation method. Ishii *et al.* (1991) reported that static pile composting using natural ventilation was successful with an initial moisture content of 50%. Higher moisture content may cause composting failure under natural ventilation conditions. Schuchardt (1987) found that anaerobic conditions developed in a study on composting piles with 75% moisture content.

In order to improve natural ventilation for the composting process, static pile passive aeration composting has been examined by some researchers. It is based on the theory that ambient air is drawn into static piles through the lower parts of the piles due to air pressure gradient induced by the up-moving warm air in the pile that is driven by buoyant forces. McGarry and Stainforth (1978) reported on a passive aeration method, in which air was drawn into the static piles through some artificial holes made with timber poles in the material. Although relatively successful, the operation was quite cumbersome. Mathur *et al.* (1990) laid perforated pipes at the bottom of composting piles for passive aeration purposes. It is a much simpler procedure, however, its performance has not been evaluated, and further studies are required. Yet there is no readily available information on SPPAC effectiveness, which could be obtained through detailed monitoring of the temperature distribution in the static piles.

1.2 STUDY OBJECTIVE

Application of SPPAC method for manure slurry using minimum amount of bulking agents, *i.e.*, composting with high initial moisture content conditions, is an attractive animal waste management alternative because of its operational simplicity, low cost and low labour input. This composting method is particularly useful for farms that are equipped with slurry manure handling systems. Besides, high moisture is also potentially beneficial for reducing nitrogen loss, which is almost inevitable during manure composting. Nevertheless, there is a lack of information on the effectiveness of SPPAC method under initial high moisture content conditions. Accordingly, a pilot scale study on poultry manure slurry composting using SPPAC method was initiated and carried out at the farm of the Centre for Food and Animal Research of Agriculture Canada in Ottawa.

The objectives of this study were: (A) to examine the effectiveness of the static pile passive aeration composting method for poultry manure slurry under high initial moisture conditions, 72 to 80%. (B) To evaluate the performance of peat and straw as the bulking agents for composting. (C) To observe the process reproducibility among the three replicate compost piles for each of the treatments.

Chapter 2

LITERATURE REVIEW

Composting, an old technology, has only been scientifically investigated since the 1950's. Studies on many respects of composting were conducted with the leading efforts on composting treatment of municipal wastes. During the 1960's, composting gave way to landfill technology because of the low landfill tipping fees and the limited market for compost. By the mid 1970's operating landfills were being filled up and new accessible locations became very limited. Since then composting has become one of the best alternatives for sludge disposal particularly in the US and west European countries, and many technologies have been developed in these countries. In this chapter the major accomplishment in composting work in the past years are reviewed. Special attention is given to animal manure composting studies because it is the topic of this thesis.

2.1 COMPOSTING SYSTEMS

In 1925 Sir Albert Howard worked out the first modern composting process in Bangalore, India (Gotaas, 1956), and it was named the Indore Process. This method included (A) ground trenches of 0.6 to 0.9 m deep, (B) alternate layers of municipal refuse, human and animal waste, earth, straw, and leaves in the trenches, and (C) manual over turning of the materials during a period of 120-180 days. From then on, pile and reactor composting systems have been developed to meet distinct situations and requirements.

There are two types of pile composting systems, namely windrow and static pile. Long rows, typically 2 to 4 m wide and 1 to 2 m high, of piled wastes for composting treatment are called windrows. It is also called turned windrows because over-turning is applied to windrows for aeration purposes. Fig.2.1 shows a turned windrow composting operation. Simple operation and relatively low costs are the advantages of this method. But large land area and significant labour are required, and odour, dust, and some pathogens are likely to be liberated into the air during the turning operation (Millner *et al.*, 1980). Pile turning, which practically depends on temperature, moisture content and foul odour, is most critical to this system. Lau and Wu (1987) successfully handled 56,775 m^3 (15 mega gallons) raw pig and poultry manure per day with

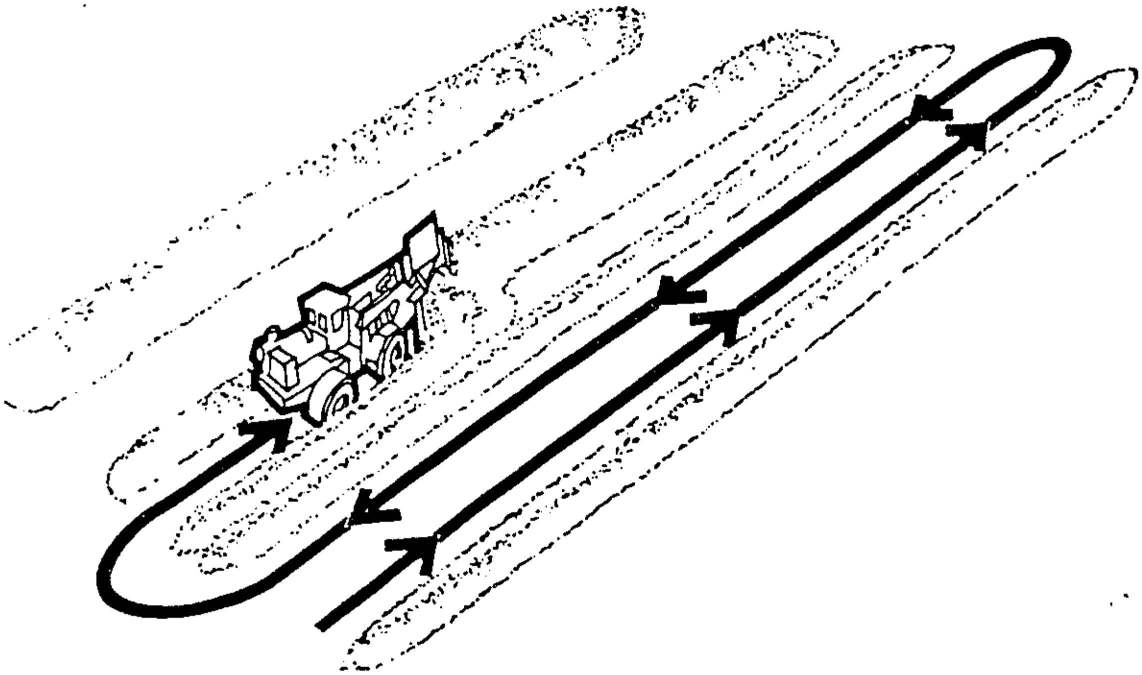

Fig.2.1 Typical turned windrow composting method, Golueke (1977)

turned windrow system. In the first five days the piles were turned once a day. From the 6th to 21st day turning was done once every four days. Gonzalez *et al.* (1989) used the turned windrow method in treating mixture of pig slurry, poultry and cattle manure, and clay soil. Turning was done once every seven days during a 70-day period. There is no commonly used pile turning schedule because the windrow composting operation has not been standardized.

About 20 years ago, static pile composting was initiated in the US. In this method, solid wastes are stacked up in piles of different shapes. Air is supplied to the material either mechanically or naturally. Fig.2.2 shows a static pile composting system with forced aeration. Static pile composting method involves lower labour requirement compared to turned windrow method. It is also more effective in destroying pathogens according to De Bertoldi *et al.* (1982) and Pereira-Neto *et al.* (1986). But the costs in energy consumption and aeration equipment are high. Regardless, it is the most widely used composting technology in the US presently for sewage sludge. .

Composters, reactor composting systems, also called in-vessel systems, are designed to obtain high level control and efficiency of the process. They do not require large land area, but costs in equipment, maintenance and energy consumption are high. Horizontal, vertical, inclined, and multilevel composters are the four basic categories. Composting materials are unloaded or conveyed

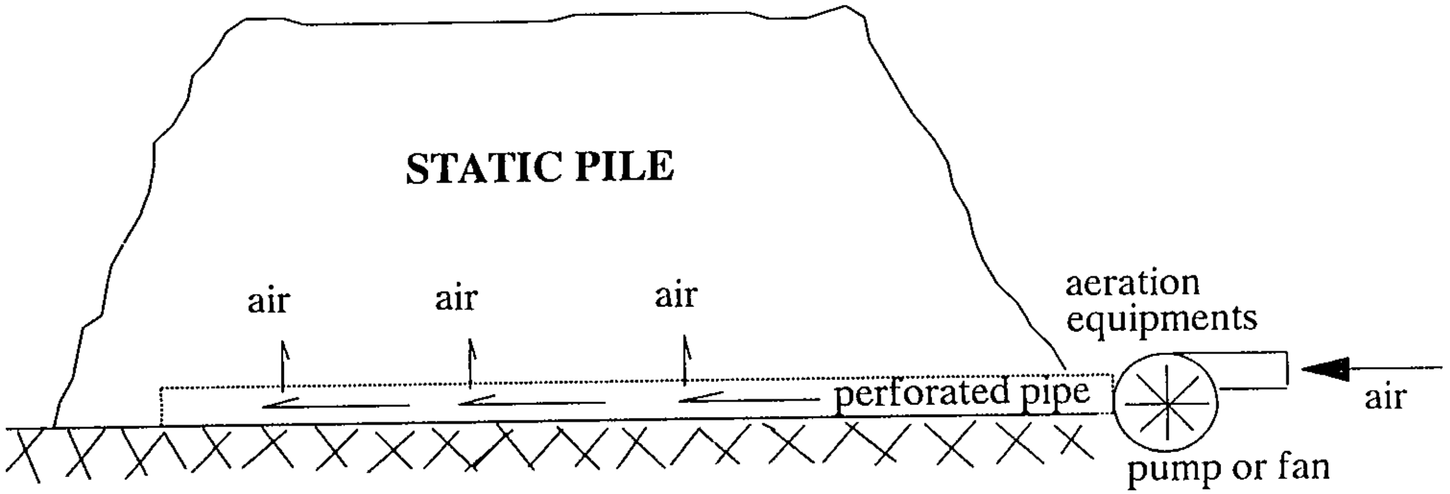

Fig.2.2 Typical static pile forced aeration composting system

into these reactors continuously. Air supply is controlled through mechanical stirring and/or forced aeration. Detailed descriptions of composting reactors were summarized by Anderson *et al.* (1984) and Sidwick (1987).

Although levels of complexity of different composting systems vary significantly, biological nature of composting processes is basically the same in each of them.

2.2 COMPOSTING PROCESS

Composting, being a biological process, involves substrate biodegradation due to the activity of microorganisms under aerobic conditions.

2.2.1 Microorganisms

One of the original composting microorganism isolation studies was done at Michigan State University (1955). A mixed population of indigenous bacteria, fungi and actinomycetes was found to be dominant during composting. Along with the rise of temperature, the governing microbial population changed from mesophyllic (25°C-45°C) bacteria and fungi to thermophilic (45°C-65°C) bacteria, fungi and actinomycetes. There was, however, no clear separation between the two temperature sensitive microorganism groups. Poincelot (1972) demonstrated that both mesophyllic and thermophilic microorganisms could be identified from samples throughout the composting process. In addition, algae, protozoa, and virus were also detected in compost samples, but in very small numbers (Haug, 1980).

In municipal refuse windrow composting experiments, Golueke and McGauhey (1953) found that mixed actinomycetes and fungi, which were blueish grey to light green and powdery with earthy odour, appeared near the end of the process in a 10 to 15 cm thick peripheral layer of the windrow piles. This was explained as being due to (A) complete aerobic condition probably succeeded only in the outer layers and (B) temperatures over 70°C at interior locations of the pile exceed the thermal death point of actinomycetes and fungi. Beaudet *et al.*(1990), Finstein and Morris (1975), Kane and Mullins (1973), and Gray (1970) reported that thermophilic bacteria and fungi found in compost could only grow at temperature below 65°C. Many observations suggest that a composting process can be retarded when the system temperature exceeds 70°C.

Functions of the different group of microorganisms are of primary interests in the composting studies from a microbiological point of view. Finstein and Morris (1975) found that organic matter was initially decomposed by bacteria, during which period the major part of heat was produced within the composting mass. Temperature of the mass was increased quickly thereafter. Waksman (1967) pointed out that actinomycetes contribute most significantly to decomposition of cellulosic and, to some extent, lignaceous components, which are part of the substrate that are less easily to consume. Apparently fungi have functions similar to that of actinomycetes. Because these microorganisms act together during composting, it is very difficult to separately define their functions (Golueke, 1977). Generally speaking, there is still much to be learned about the functions of the different microbial groups and their behaviours during composting.

It was thought that bioaugmentation seeding or inoculating the compost with microbial strains might help the process. Many studies since 1950's revealed that the effect of inoculation is not significant. Poincelot (1974) pictured it as "throwing a pebble over a cliff during a rock slide". Golueke (1977) stated that inoculation for composting is unnecessary and ineffective because (A) the types of microbes needed, which are absent from the treated material, are impossible to be estimated with the microbiological technology of the day, (B) it is impossible to know the types of microbes that are insufficient in numbers, and (C) strains that are claimed to be more effective than the indigenous microbial population are seriously doubted with respect to their adoptive and competitive ability to thrive in the environment.

2.2.2 Substrate

The energy and nutrients that are required for composting microbial growth activity, basically metabolism, come from substrate, which is mainly in organic form. Different substrates, including some hazardous industrial wastes and some pesticide residues, have been extensively subjected to composting treatment (Haug, 1980). Human and animal wastes, municipal refuse, sewage sludge, agricultural and food production leftover are all compostable organic substrate.

Particle size of the substrate is one of the key factors that affects the speed of a composting process. The smaller the particle size, the larger the surface area that is available for microbes to grow on. Tests by Batzer (1954) confirmed that finely ground substrate favoured and accelerated the composting process. Golueke (1977) suggested that the maximum particle size should be between 0.025 to 0.05 m for municipal refuse, 0.01 m or less for woody material such as straw, wood shavings, and greater than 0.025 to 0.05 m for paper and garbage. In general, particle size is not so critical for easily decomposable substrate.

Information on compositions and degradability of composting substrate is important for process design. Heterogeneity is, nevertheless, a characteristic of most of the substrates, there is not a common formula. Each type of substrate needs to be examined individually, which not only causes time-consuming work for system design, but also imposes tremendous difficulty for a general mathematical description of the composting process.

2.2.3 Biodegradation

Composting starts when microbes begin to utilize substrate. Poincelot (1972) reported that 100% of sugars and starches were utilized during composting. Gossett and McCarty (1975) obtained 50% lipid and protein mass reduction and 0% change of lignin. The reported degradability of substrate varies. It is subject to the different microbial environments as well as the physical and chemical conditions. Beaudet *et al.* (1990) inoculated a thermophilic strain into swine waste to observe its function in composting reactions. The reaction rate was found to be higher at 45°C than that at 35°C, and 55°C was identified as the optimum temperature for the treatment. When temperature was over 60°C the reaction rate became lower. It was concluded that thermophilic microbes degraded the organic matter in the swine wastes faster than mesophyllic microbes. Bourque *et al.* (1987) showed that oxidative conditions encouraged growth of indigenous microorganisms, which degraded malodorous substance such as phenol, p-cresol, and volatile fatty acids.

Biodegradation rate during composting is commonly measured by O_2 uptake and CO_2 generation. Results in Fig.2.3 reported by Plat *et al.* (1984) shows two peaks of CO_2 generation rates during composting of a mixture of wool industry sludge and sawdust. The first peak indicates a biodegradation

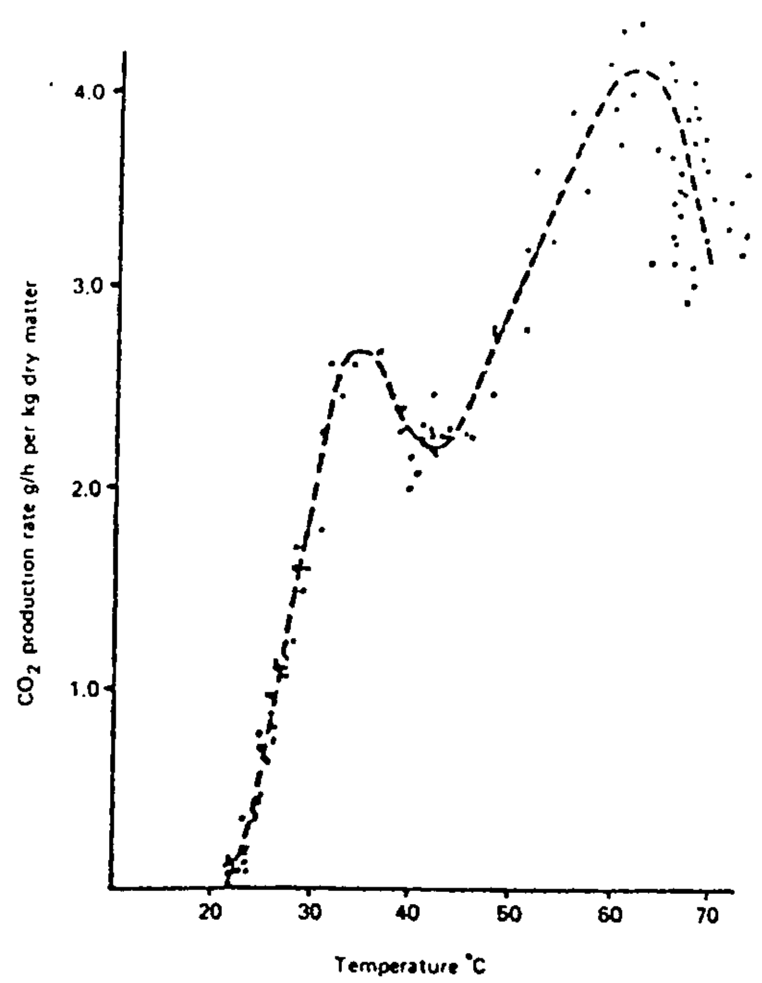

Fig.2.3 CO_2 generation during composting, Plat *et al.* (1984)

activity climax in the mesophyllic stage, 35°C, whereas the second higher peak is an indication of a biodegradation activity climax in the thermophilic stage, 60°C. It illustrates that higher composting reaction rates occur in the thermophilic stage. Theoretically, if composition and degradability of the composted material are known, the stoichiometric O_2 demand can be calculated based on the balanced oxidation reaction equations. However, this situation is hardly real for the heterogenous materials subjected to composting treatment. Therefore, although many O_2 uptake measurements have been recorded (Beaudet *et al.*, 1990, Lossin, 1971, Regan and Jeris, 1970, Schulze, 1964, and Snell, 1957), no conclusion can be drawn from them because of the different materials, conditions and equipment involved.

2.2.4 Temperature

Temperature rise in a composting system is caused by the heat generated during microbial reactions, which are exothermic in nature. A typical temperature profile during composting is shown in Fig.2.4. It can be seen that temperature rises from ambient to mesophyllic level, below 45°C, and to thermophilic level, over 45°C. It remains at the latter level for a period of time, and then descends to the ambient value. Considering the slope of the temperature profile as the indication of the speed of the process, Golueke (1977) depicted the commonly recorded temperature history during composting process. In the early stages when the process speed is highest due to decompo-

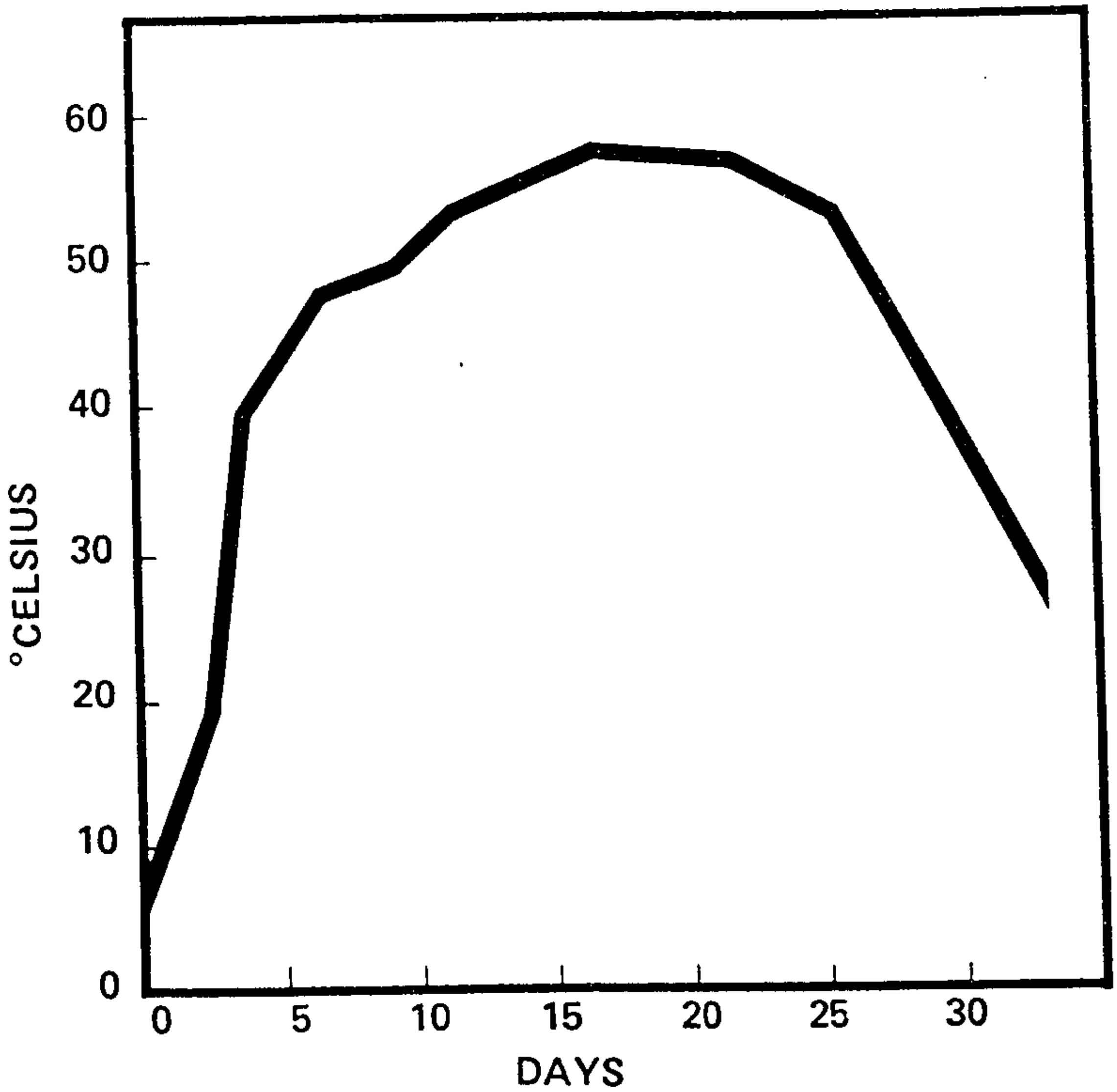

Fig.2.4 Typical composting temperature profile, Golueke (1977)

sition of the easily compostable substrate, there is a linear correlation between temperature rise and decomposition rate at temperatures lower than 30°C. Afterward with temperatures going up, the process slows down gradually until 70°C, above which the rate of composting reaction is negligible. Temperatures higher than 70°C are not desired because they reduce the composting reaction rates by hindering the microbial growth (Bonazzi *et al.*, 1990 and Hansen *et al.*, 1989). Haug (1980) stated "different investigators have found optimum values (temperature) ranging from as low as 45 to above 70°C". *i.e.*, within this temperature range the composting microbial activities may be in the optimum state.

Within a composting pile temperature can vary significantly from one location to another. The typical temperature distribution results shown in Fig.2.5 were reported by Stentiford *et al.* (1985). When the suction aeration method was used, the highest temperatures, over 65°C, occurred in the core of the pile and near the aeration pipes. When using the blowing aeration method the highest temperatures were observed in the top parts of the piles. It was possibly due to the dryness of the material nearest to the blowing pipes that caused the inhibition of microbial activity resulting in the lowest temperature. Provias (1984) presented temperature distribution results from turned windrow compost piles. The highest temperatures, over 65°C, were in the pile core parts, which was mainly due to the effect of insulation.

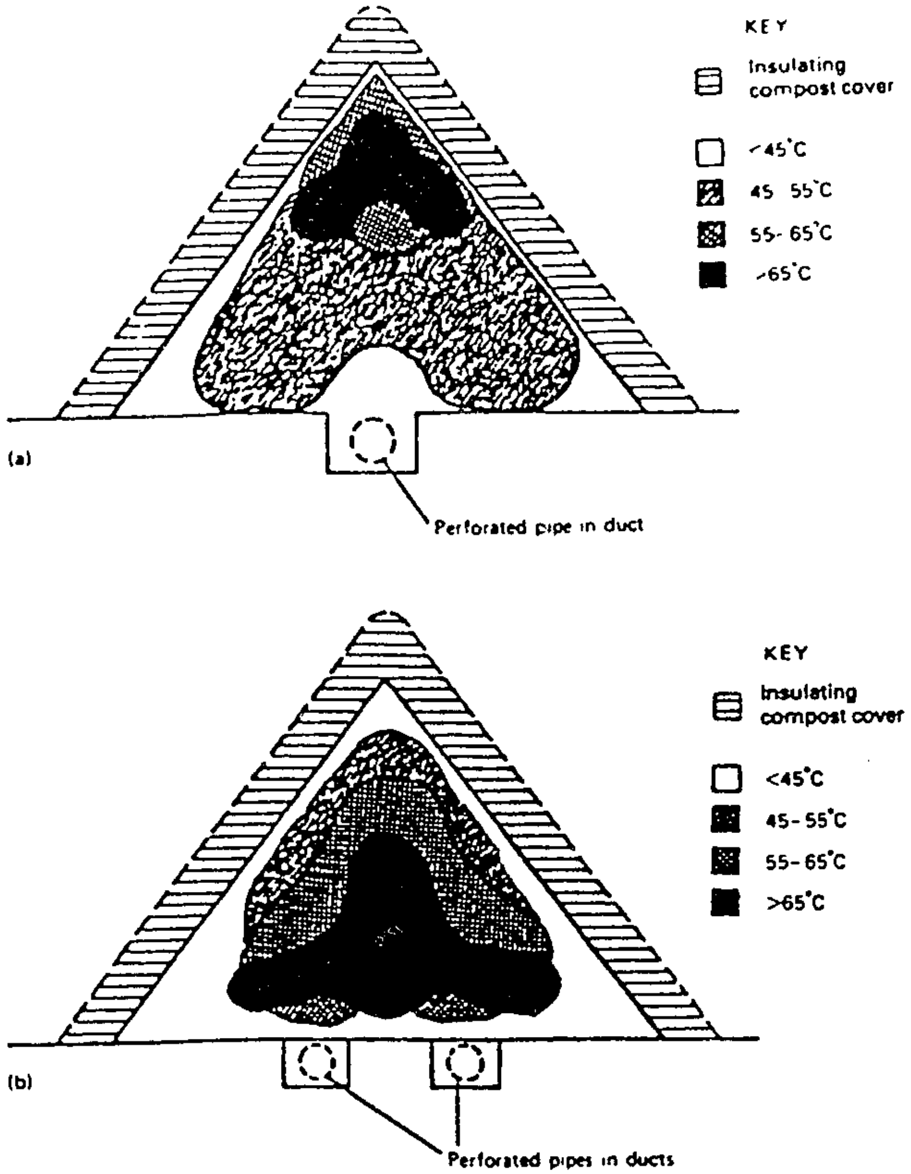

Fig.2.5 Typical cross-sectional temperature distribution in a compost pile using (a) blow and (b) suction aeration, Stentiford *et al.* (1985)

The turned windrow composting method provides good temperature control. Although temperature drops sharply at the time of turning, it recovers within 5 to 7 hours (Bonazzi *et al.*, 1990). Temperature in static pile composting systems is controlled through aeration. Low composting temperatures may be caused by: (A) insufficient air supply, this may be detected by foul odour and seepage due to high moisture content and (B) moisture content is too low to support normal microbial function.

2.3 FACTORS AFFECTING COMPOSTING PROCESS

A composting system is extremely complicated. It involves physical, chemical and biological reactions in a system where the substances are in gas, liquid and solid phases, and it is influenced by many factors. Presented in the following section are studies on the composting factors including aeration moisture content, temperature, carbon and nitrogen as well as carbon to nitrogen ratio and pH. These are the most important factors controlling the microbial functions during composting.

2.3.1 Aeration

There are primarily three reasons for composting under aerobic conditions. (A) Malodours are mainly associated with anaerobic conditions; (B) elimination of pathogens, parasites and weed seeds from the treated materials are more effective under aerobic conditions due to the related thermophilic temperatures, over 45°C; and (C) high biochemical reaction rates and release of energy in the form of heat are the results of aerobic conditions. The temperature changes and compost aeration are closely associated to each other during composting processes. Willson *et al.* (1980) reported that the lower aeration rates delayed the temperature rise to 60°C by about 10 days. On the other hand, higher aeration rates caused faster temperature drops due to the heat removing effect of aeration. In practice, aerobic conditions are maintained by aeration of the composting systems. In addition to providing oxygen, aeration also enables to remove excess moisture, surplus heat and exhaust gas from bacterial respiration (Haug, 1980).

In windrow systems, aeration is applied through pile turning. Air is trapped in the voids of the material during the turning operation, and some air may come in through natural ventilation. Forced aeration with pump, fan, and perforated pipes supplies air to static pile composting systems by either blowing or sucking mode. Willson *et al.*, (1980) found that under sucking aeration condition for the Beltsville's process the temperature became so high that the microbial activities were most likely inhibited. Higgins (1982) pointed out three other disadvantages of the sucking aeration method: (A) non-uniform airflow distribution, (B) clogging of aeration ducts with condensate water, and (C) a scrubber pile is needed for odour removal. These problems were solved by applying the Rutger's process (Finstein *et al.*, 1983), in which blowing aeration method was used.

Besides turning and forced aeration, non-forced (natural) aeration, as it is named, refers to natural air movement around and within composting systems. Non-forced aeration method has not been used widely due to the low level air supply control. Nevertheless, it is simple and economical. It also has the potential to reduce nitrogen losses in comparison to forced aeration. Haug (1980) developed a theoretical model featuring the correlation between natural ventilation rate and the porosity and particle size of composting materials, Fig.2.6 depicts the natural ventilation concept. He suggested that natural ventilation could be the most significant mechanism in supplying air into the conventional windrow composting systems. Based on the model, for a 1 to 3 m high static pile, the estimated O_2 requirement is 1 to 3 times more than that required stoichiometrically, and an about 100 time increase in air flow rate may be obtained in the pile when the material particle size is enlarged by a factor of 10. Normally with the decrease in moisture as composting proceeds, the porosity increases, and so do natural ventilation rates.

Mathur *et al.* (1990) reported on a passive aeration static pile composting method. By laying perforated pipes at the bottom of static piles, this method may create a natural aeration mode in composting material. As the hot air in the material moves upward and releases from the piles, leaving a natural

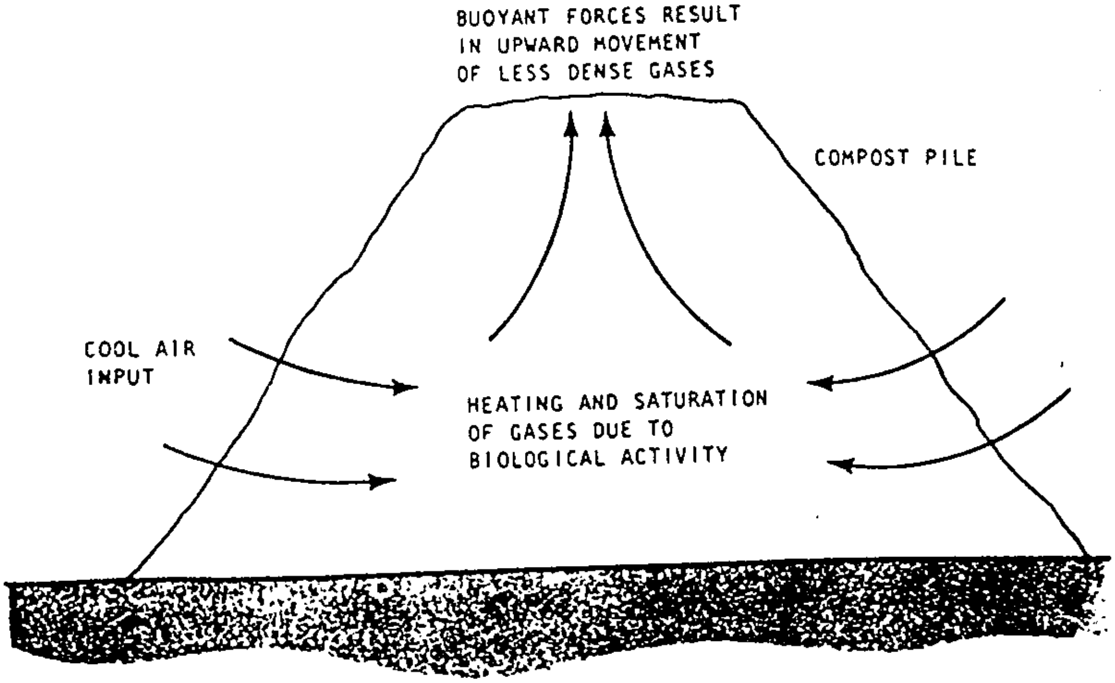

Fig.2.6 Schematic illustration of natural ventilation mechanism of static compost pile, Haug (1980)

pressure drop behind, the ambient air is drawn in the pile through the perforated pipes to balance the pressure drop. In this way a so-called "passive aeration" mechanism is created. This is a promising method because of its simplicity and low cost, however, there is a need for more detailed study in order to evaluate its performance and the effectiveness.

Aeration control is essential for composting. Haug (1986) described five aeration controlling methods: (A) manual methods such as use of throttling valves, (B) on-off blower sequencing by timer, (C) O_2 and CO_2 content feedback control, (D) temperature feedback control, and (E) air flow rate control. In practice, foul odour is an indication of insufficient air supply. Golueke (1977) stated that for municipal refuse a putrefactive odours developed under anaerobic conditions, the intensity of the odour is proportional to the extent of anaerobiosis, and it disappears following increased air flow or compost turning. There is a fundamental difficulty for standardizing aeration design because of the diversity of materials which require different amount of air during composting.

2.3.2 Moisture Content (MC)

A proper MC during composting process is essential for microbial metabolism. Theoretically free water, *i.e.*, 100% moisture, is required for metabolism because it actually occurs in the water phase. However, for composting operations a MC lower than 100% is needed in order to pile up the materials and allow temperatures to rise to the thermophilic level, 45 to 65°C. MC between 50 and 60% is generally considered being appropriate in composting practice (Poincelot, 1974). Composting studies at the Michigan State University (1955) were carried out to test garbage containing MC ranging from 25% to 68% with 0.454 kg laboratory composters for a 140-hour period. It was found that the optimum MC, which corresponded to the highest O_2 uptake rate, was from 52 to 58% at temperature of 40°C. This temperature is relatively low compared to the commonly reported composting temperatures, which are around 60°C. Schuchardt (1987) composted pig manure slurry mixed with straw using turned windrow method and found that 67% MC caused a water shortage resulting in diminished microbial activity, and another trial showed that a MC of 75% was too high and anaerobic conditions were observed in the bottom parts of the windrows.

Golueke (1977) suggested that the maximum allowable MC should be chosen for composting operations to ensure that microbial metabolism be best supported, and MC lower than 45% is not recommended. The maximum MC relies on the compost physical properties such as particle size and shape, water holding capacity and shrinkage. For a compost material that shrinks significantly, the maximum MC should be lower. Seepage from composting piles indicates that the water proportion is too high, while dusty conditions imply that the material is too dry.

In general animal manure slurries contain about 90% moisture in general (Meek *et al.*, 1975). To commence a composting process, this high MC needs to be reduced in order to pile up the material. Bulking agents such as peat, straw, wood chips, *etc.*, are commonly used for this purpose. Animal manure slurry composting under high MC conditions will potentially reduce the costs on consumption of large amount of bulking agents and decrease nitrogen losses through ammonia hydrolysis. These advantages, however, have not yet been fully studied.

2.3.3 Carbon and Nitrogen

During composting microorganisms utilize nitrogen and carbon for protein synthesis and energy for growth and maintenance. As a result, some carbon in organic substances is transformed into CO_2 and released from the system, meanwhile nitrogen and a fraction of carbon are stored in bodies of living organisms. Based on this, the ratio of carbon to nitrogen, denoted as C/N, is commonly used to estimate the efficiency of composting process. In general, C/N ratio higher than 50 delays the start of composting process due to insufficient nitrogen, while C/N ratio lower than 15 does not delay the process but causes significant nitrogen losses. Commonly recommended C/N ratio for composting ranges between 20 and 35 (Golueke, 1977). C/N ratio can be adjusted to a certain level with materials that are rich in either nitrogen or carbon. However, carbon in materials such as wood chips and sawdust, which are common bulking agents or organic amendments, is not readily available for microbial degradation because it is in lignaceous form that is hard to break down (Golueke and Diaz, 1987). Godden and Penninckx (1986) demonstrated that only 15% of the lignin was degraded in a cattle manure composting experiment.

Nitrogen losses during composting cause objectionable odour and economic devaluation of the compost. Animal manure generally yields low C/N ratios, which tend to lead to nitrogen losses during composting. Kirchmann (1985) concluded that nitrogen losses were mainly in the form of ammonia gas during composting process. The lower the C/N ratio, the higher the nitrogen loss. If C/N was above 50, there would be no nitrogen losses. In windrow composting, nitrogen losses occur primarily at the time when the piles are turned. Hence, less nitrogen losses may be expected from static pile composting system. Under high MC conditions, due to hydrolysis more ammonia will be dissolved in the water phase, and lower nitrogen losses can be expected. Optimizing system conditions for nitrification can also reduce nitrogen losses (Snell, 1957).

Fig.2.7 shows the evolution of different forms of nitrogen in a composting

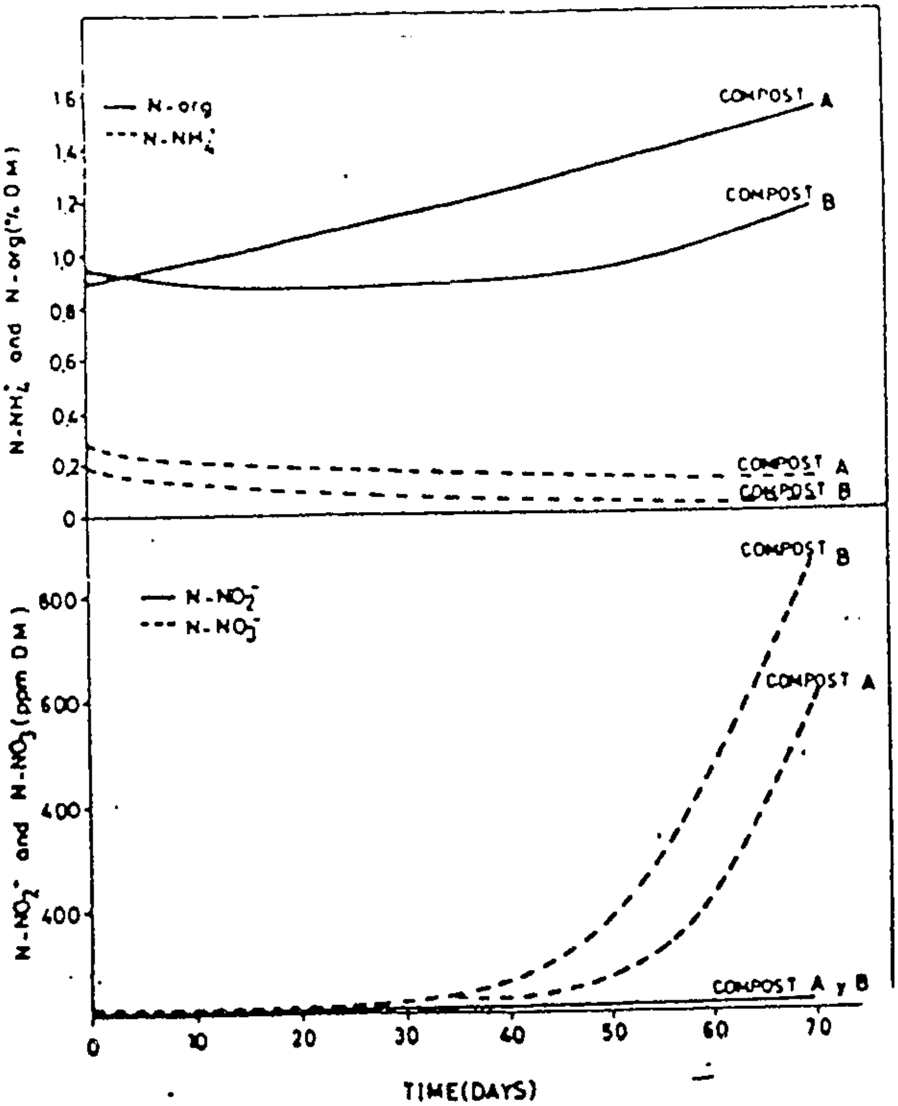

Fig.2.7 Variation of nitrogen of different forms during composting, Gonzalez *et al.* (1989)

experiment by Gonzalez *et al* (1989). It can be seen that throughout the process organic nitrogen (N-org) increased, ammonia nitrogen (N-NH_4^+) diminished, and nitrite nitrogen (N-NO_2^-) remained at a very low level. Nitrate nitrogen (N-NO_3^-) increased significantly, but only after 40 days, when the system temperature dropped below 35°C. This is because the nitrification bacteria are most active under mesophyllic aerobic conditions (Finstein *et al.*, 1980).

2.3.4 pH

In general, fungi survive in a wide pH range, 5.5 to 8.0, while bacteria grow best at pH of 6.0 to 7.5. However, the upper pH limit for fungi was found to be a function of nutrients. Golueke and McGauhey (1953) studied municipal waste composting and reported that the pH dropped to about 4.5 to 5.0 in the beginning stage of the process followed by a rise to about 8.0 to 9.0 in several days and, afterwards, a gradual plunge to and stabilization near the neutral state. The early stage pH drop was related to production and dissolution of CO_2 and organic acids. Further decomposition of these organic acids, production of NH_4^+ and release of CO_2 resulted in pH increase.

Considering that the initial pH drop might suppress microbial growth, Shell and Boyd (1969) and Golueke and McGauhey (1953) used ferric chloride and lime as a buffer agent for composting of municipal refuse and dewatered sewage sludge. Unexpectedly, reduced microbial growth and greater nitrogen loss were the net results of these efforts. Composting studies at Michigan State University (1955) showed that (A) pH slightly higher than 5.0 to 6.0 speeded up the garbage composting process, (B) pH increased gradually to the range of 8 to 9 as the garbage was digested, and (C) high pH and high nitrogen content resulted in a substantial nitrogen losses.

High pH is believed to be one of the major factors for nitrogen losses during composting, since it favours volatilization of ammonia. Garbage composting studies by Snell (1957) suggested that high initial total nitrogen was maintained when pH was held below or at about 5.0. Jakobsen (1987) tested the possibility of reducing ammonia losses by adding calcium chloride to compost piles. While pH level was kept low, the following reactions transformed ammonia to ammonium chloride and precipitate calcium carbonate so that ammonia volatilization was reduced,

$$NH_3 + CO_2 + H_2O \rightarrow NH_4HCO_3$$

$$2NH_4HCO_3 + CaCl_2 \rightarrow 2NH_4Cl + CaCO_3\downarrow + H_2CO_3$$

2.4 COMPOST MATURITY AND APPLICATION

Knowledge of compost maturity status is essential for determining the process completion time. Application of compost product depends on its physical and chemical properties.

2.4.1 Compost Maturity

Substrate stabilization is the most important feature of composting practice. However, complete stabilization of organic matter, *i.e.*, conversion of all the organic matter into H_2O, CO_2 and inorganic minerals, is neither practical nor suitable for composting purposes. As a matter of fact, high quality compost is rich in humus and organic matter. Therefore, the term "maturity" is more correct than "stabilization" for describing the biological status. In practice the compost maturity is neither a well defined condition, nor a status that can be easily determined. Quantitative compost maturity standards are still to be established. Generally, matured compost should not cause any nuisance during storage and damage to plants if applied to soil.

Morel *et al.* (1984) reported a series tests on maturity of municipal refuse compost. The methods were categorized into three groups. In the first group are those indicators that measure microbial activity. Respiration is measured by oxygen uptake and carbon dioxide production. Biochemical parameters such as Adenosine Tri-Phosphate and enzyme activity are tested at both acceleration and maturity stages during composting. Based on observation of grass growth in a mixture of soil with compost, a multiple regression equation is formulated to correlate total organic carbon and concentration of water soluble sugars with degradability of compost in soil in order to determine its maturity state. The second group involves the evaluation of several chemical parameters of compost such as C/N and concentration of sugar components. The third group is based on crop growth tests, *e.g.*, phytotoxicity test. Some of the maturity parameters reported for these measurements are listed in Table 2.1. However, these values from this particular study cannot be generalized to other tests under different conditions.

If composting process is operated properly, *i.e.*, aeration, MC, C/N ratio and pH are well controlled, the temperature descent to the ambient level is an indication that the compost is matured. Hirai *et al.* (1983) suggested that organic-carbon to organic-nitrogen ratio in water extracts of compost samples is a better compost maturity criterion than the conventional C/N ratio, *i.e.*, the total carbon to total nitrogen ratio, because microbial metabolism occurs only in the water phase. It was found that conventional C/N ratio of well matured compost ranged from 5 to 20 depending on the type of raw materials, while the organic-carbon/organic-nitrogen ratio falls between 5 to 6 regardless of the type of material. Zucconi *et al.* (1981) pointed out that if phytotoxicity exists, compost is far from being matured, and suggested that the latent toxicity should be analyzed to evaluate compost maturity. Finstein *et al.* (1980) recommended that the outset of nitrification is an indication of a nearly matured compost. Nevertheless, there has not been a standardized parameter or a group of parameters for compost maturity evaluation. There is very little information regarding measurements of animal waste compost maturity.

Table 2.1 Maturity tests for municipal refuse compost, Morel *et al.* (1984)

Method	Measurement	Maturity Value
Respirometric	oxygen consumption	< 40 mg/kg DM* /hr
Degradability	multiple regression analysis, CM**	< 2.4
Chemical	organic matter and nitrogen	< 50
	C/N ratio	10-18 in 240 days
	water soluble sugars	25-45 mg glucide/g DM

* dry matter

** $CM=3.166-0.011A=0.059C+0.082P$

A: days of maturation
C: total organic carbon
P: hot water extractable sugars

Another important aspect of the compost maturity is related to pathogen destruction during composting, which is expected to be fulfilled by thermophilic temperatures. In general, most pathogens, parasites and weed seeds are deactivated within one hour at temperature between 45 to 60°C (Golueke and Gotaas, 1952). Finstein *et al.* (1978), Wiley and Westerberg (1969) and Golueke and Gotaas (1952) noted that pathogens were totally eliminated when thermophilic temperatures were kept for several days. USEPA (1981) standardized pathogen abolishment operations for the static pile composting method by maintaining temperature at or above 55°C over a three-day period. Russ and Yanko (1981) reported that repopulation of pathogens occurred in composting piles while temperature was dropping. This might have been due to a uncompleted pathogen removal in some parts of the piles.

2.4.2 Compost Application

Generally accepted values of good compost are C/N ratio of 10 to 20; pH of 7 to 8; rich in humus, dark brownish colour; earthy smell; low levels of toxic components and non-biodegradable material; and elimination of human and plant pathogens. Nitrogen, phosphorous and potassium concentration of matured compost is a measure for its value as soil conditioner and/or fertilizer. Common applications of compost are found in horticulture, gardening, greenhouse, mushroom production, and land scape.

Vogtmann *et al.* (1978) reported that nutrients in compost were more readily available to plants than those in fresh manure. Besides, part of nitrogen and phosphorous in compost are in the organic form and can be used as long-term plant nutrients as they are released gradually into the soil under the function of humus (Poincelot, 1974). It is particularly good for crops with the long growing seasons. Lau and Wu (1987) analyzed compost product from poultry manure, and the results are included in Table 2.2. It contains fairly high level of nitrogen, potassium and phosphorous and low but detectable metal concentrations in comparison to the recommended metal content level in matured compost in Austria. It is also potentially a good soil conditioner or fertilizer, which was verified by field crop growing tests that showed not only a significant improvement in both quality and quantity of crop production, and no pests or diseases were reported, but also reduced soil acidity, increased humus, total nitrogen and exchangeable potassium, which are beneficial changes for the soil. Godden *et al.* (1986) showed that after the application of manure compost to a loamy acidic soil the pH and the cationic exchange capacity increased immediately, while the microbial and enzyme activities increased several weeks after application.

2.5 SUMMARY

Many composting methods, such as windrow, static pile and in-vessel, have been used in treating materials from most of the waste streams. Composting

Table 2.2 Observed and recommended properties for manure compost, Lau and Wu (1987)

Parameters	Manure Compost[a]	Recommended[b] Values
Moisture (%)	53 ± 13	25 - 53[c]
pH	8.0 ± 0.4	7.0 - 8.5
Total nitrogen (%)	2.5 ± 0.3	0.5 - 1.5[d]
Total K_2O (%)	1.7 ± 0.3	0.3 - 1.0[d]
Total P_2O_5 (%)	3.4 ± 0.4	0.4 - 0.8[d]
C/N ratio	12.9 ± 1.2	
	concentration[e] (ppm)	
Pb	23.7 ± 12.2	200[f]
Cd	0.12 ± 0.08	1[f]
Cu	40.8 ± 6.5	100[f]
Zn	206 ± 16	300[f]
Ni	2.0 ± 0.6	30[f]
Cr	2.3 ± 0.9	50[f]
Hg	0.02 ± 0.01	1[f]

[a] Each value is a mean ± standard deviation, based on 6 measurements.

[b] Requirements for solid waste compost in Austria.

[c] Higher moisture content can be tolerated in loose compost.

[d] The value of these nutrient elements are the minimum figures.

[e] The value is expressed in ppm on a dry weight basis, based on 9 measurements. Each value is mean ± standard deviation.

[f] The values are recommended not to be exceeded in solid waste compost in Austria.

is a very complicated process. Many factors influence its performance. Aeration, moisture, carbon, nitrogen content and pH are most critical ones. There are still many aspects in composting process that are not clearly known, for instance, the effectiveness of passive aeration under high moisture content conditions. Therefore, more studies are needed. Since compost temperatures are closely related to aeration conditions, it is most likely that detailed information on temperature distribution in a composting pile can be used to determine the aeration conditions, especially for the passive aeration conditions, under which the air flow rate is difficult to measure.

Chapter 3

MATERIALS AND METHODS

3.1 MATERIALS

In this study the material for composting treatment was poultry manure slurry from the Greenbelt Farm, Agriculture Canada, Ottawa. Sphagnum peat moss and chopped barley/oat straw, 2.5 cm long, were the selected bulking agents. Physical and chemical properties of the poultry manure slurry and the bulking agents, including MC, volatile solids, ash, pH, carbon, nitrogen, phosphorus, and potassium are listed in Table 3.1.

3.1.1 Water Holding Capacity of Bulking Agents

Since high moisture composting was one of the objectives of this work, an estimation of water holding capacity (WHC) of the bulking agents, peat and

Table 3.1 Characteristics of the raw materials

PROPERTY	POULTRY MANURE SLURRY	BULKING AGENTS PEAT	 STRAW
Moisture Content, %	90	52	14
Volatile Solids, % dry matter	67	97	91
Ash, % dry matter	32	3	8
pH, water extract	7.1	3.8	8.2
Carbon, % dry matter	41	48	45
Nitrogen, % dry matter	4.6	1.9	0.8
Phosphorus, % dry matter	4.1	0.01	0.14
Potassium, % dry matter	2.2	0.04	1.5

straw, was necessary to ensure that MC of the initial compost was below the saturation level. WHC is defined as:

$$WHC = \frac{water\ absorbed\ at\ saturation(kg)}{raw\ material\ used(kg)} \qquad (3.1)$$

In a laboratory test under 1 atmosphere and 20°C conditions, it was found that WHC is 5.7 and 4.3 for the peat and the chopped straw, respectively. *i.e.*, 1 kg raw peat can absorb 5.7 kg water, whereas 1 kg straw can absorb 4.3 kg water.

Since MC of the poultry manure slurry was 90%, the saturation ratio of poultry manure slurry to peat in the compost mixture would be:

$$(0.9x)/(1-x) = 5.7$$

where x is the proportion of poultry manure slurry in the mixture, and 1-x is the proportion of peat. Solving for x:

$$x = 0.86$$

and

$$1-x = 0.14$$

Therefore, the saturation ratio of poultry manure slurry to peat is:

$$0.86 / 0.14 = 6$$

Thus, 1 part raw peat can be mixed with 6 parts of poultry manure slurry before the mixture is saturated. Since MC of the peat is 52%, the saturation MC of the mixture is:

$$MC = (0.86 \times 0.9 + 0.14 \times 0.52)100 = 84.7\%$$

Based on this result, 80% MC was chosen as the upper level for the initial compost prepared from poultry manure slurry and peat. Similarly, the saturation ratio of poultry manure slurry to straw as well as the saturation MC of this mixture can be determined as that for peat, and the value are 4.9 and 77%, respectively. Eventually, 76% MC was set as the upper limit for the initial compost from poultry manure slurry and chopped straw.

3.1.2 Compost Treatments

Four compost treatments were investigated in this study. Treatments I and II composed of poultry manure slurry and peat with initial MC of 73 and 80%, respectively. While Treatments III and IV composed of poultry manure slurry plus chopped straw with the initial MC of 76 and 72%, respectively. The amount of poultry manure slurry and the bulking agents used in one pile of each treatment are listed in Table 3.2. Also ratios of poultry manure slurry to the bulking agents, based on both raw and dry matter, are calculated and listed in the same table. For example, in each of the Treatment I piles 714 kg poultry manure slurry and 489 kg peat were used, therefore, the raw material ratio is 1.5, and from the MC data in Table 3.1 the dry matter ratio of poultry manure slurry to peat for Treatment I is 3.04. The initial conditions of the four treatments, including MC, volatile solids, ash, pH, carbon, nitrogen, phosphorus, potassium, ammonia nitrogen, nitrate nitrogen, and pile bulk density, are listed in Table 3.3.

Table 3.2 The raw materials used in each compost treatment

TREATMENT	POULTRY MANURE SLURRY (PMS), kg	BULKING AGENTS (BA)		PMS to BA RATIO (raw)	PMS/BA RATIO (dry matter)
		PEAT, kg	STRAW, kg		
I	714	489	-	1.5	3.04
II	1403	311	-	4.5	9.40
III	1092	-	275	4.0	4.62
IV	994	-	269	3.7	4.30

Table 3.3 Initial conditions of each compost treatment

PROPERTY	TREATMENT I	TREATMENT II	TREATMENT III	TREATMENT IV
Moisture Content %	73	80	76	72
Volatile Solids % dry matter	87	81	82	84
Ash % dry matter	12	18	17	16
pH water extract	6.3	7.2	7.9	7.9
Carbon % dry matter	46	42	41	45
Nitrogen % dry matter	2.9	3.3	2.3	2.3
Phosphorus % dry matter	0.9	1.6	1.2	0.9
Potassium % dry matter	0.6	1.1	2.7	2.2
ammonia nitrogen % dry matter	0.14	0.52	0.06	-
nitrate nitrogen % dry matter	0.001	0.001	0.001	-
Bulk Density kg/cubic meter	359	513	408	377

3.2 METHODS

Each of the four compost treatments was replicated three times resulting in a total of 12 composting piles of the same size. Fig.3.1 shows the dimensions and the trapezoidal configuration of composting piles. The pile volume (V) is calculated with following equation:

$$V=\frac{1}{3}h\,[A_1+A_2+(A_1A_2)^{\frac{1}{2}}] \tag{3.2}$$

where h is the pile height and A_1 and A_2 are bottom and top areas of the piles. Hence, the composting pile volume is:

$$V = (1/3) \times 1.0 \times \{7.8^2 + 0.4^2 + (7.8^2 \times 0.4^2)^{1/2}\}$$

$$= 3.35 \text{ m}^3$$

The bulk density for each treatment is calculated by dividing the total weight of the material in each pile with the pile volume, and the results as given in Table 3.3 are 359, 513, 408 and 377 kg/m³ for Treatments I, II, III and IV, respectively.

The compost mixture for each treatment was prepared in a farm-scale auger mixing truck. The amount of raw materials used were recorded by a weighing scale mounted on the truck. Thorough mixing of the materials was conducted for about 30 minutes. After mixing the material was discharged from the side chute of the truck into a front-end loader that was used to transport and stack up the material. Before the material was piled up, a basal layer,

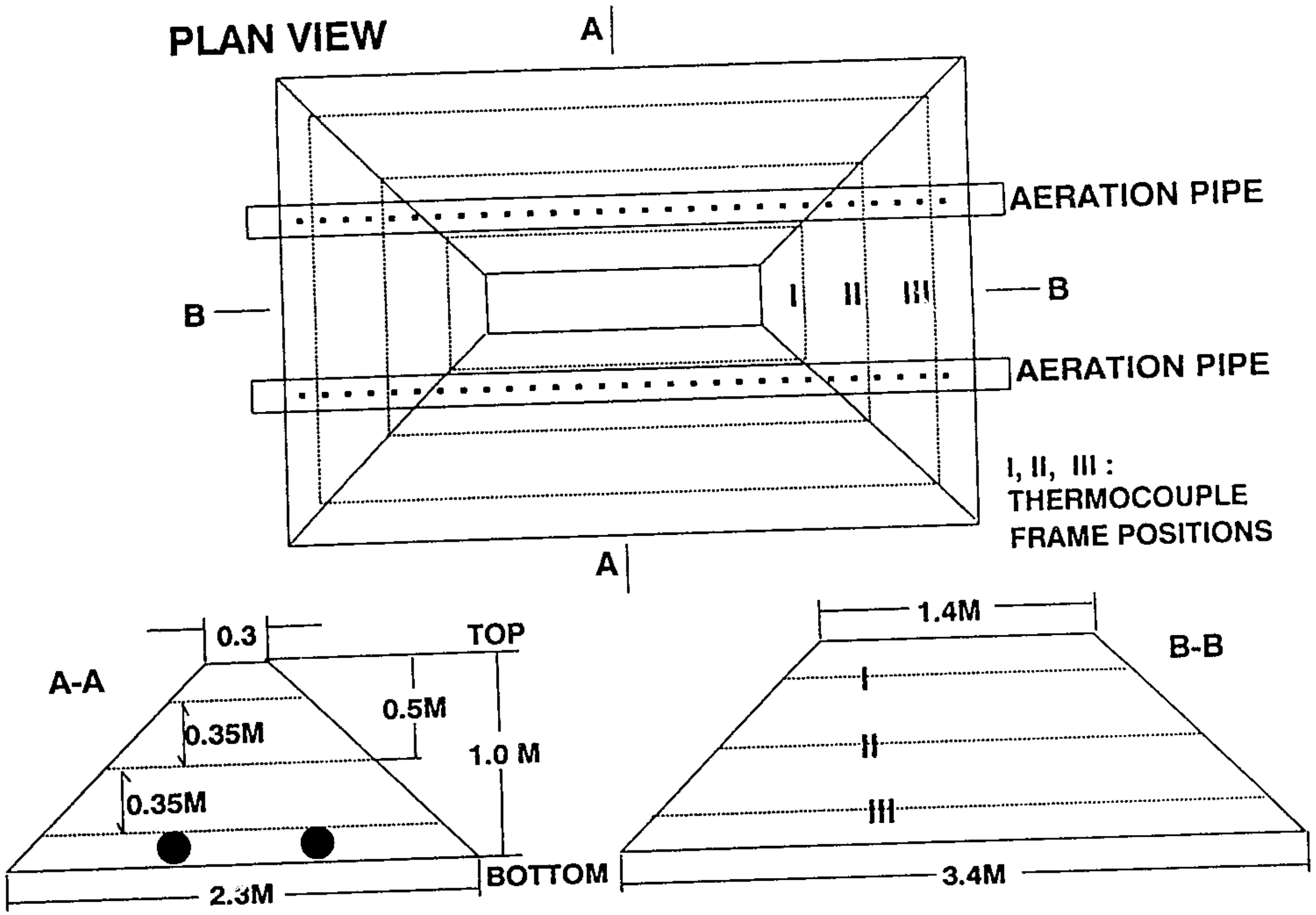

Fig. 3.1 Compost pile configuration

about 0.1 m thick, was prepared at the ground level using peat for Treatments I and II and non-chopped straw for Treatments III and IV. Two ABS perforated pipes 3.6 m long and 0.1 m in diameter were laid on the basal layer in such style that the perforations faced upward for passive aeration purpose. The compost piles were located in a open-front roofed barn. A trapezoidal wooden frame was used to shape and size the compost piles so that every pile would have the same shape and volume, 3.35 m^3. Finally, a cover layer of about 5 cm thick was applied to each of the piles, peat was used for Treatments I and II and non-chopped straw for Treatments III and IV.

3.2.1 Temperature Monitoring

As sketched in Fig.3.1, three grids of thermocouple mounted on plastic frames made of ducting pipes were installed in the bottom, middle and top part of each pile. Two types, A and B, of thermocouple layout were used. As shown in Figs.3.2 to 3.4 Type A layout consists of 33 thermocouples. It was used in four compost piles, one from each of the four treatments, and the 132 (33 x 4) thermocouples were connected to the Multi-Channel Automatic Data Logging Systems. Included in Appendix A as Figs 1, 2 and 3, type B layout consists of 23 thermocouples and was used in the other 8 remaining piles. Because of the limited number of data logger channels, out of the 184 thermocouples (8 x 23 = 184), 77 were connected to the data logging system, and the remaining 107 were monitored with a hand meter. In addition, five thermocouples were used

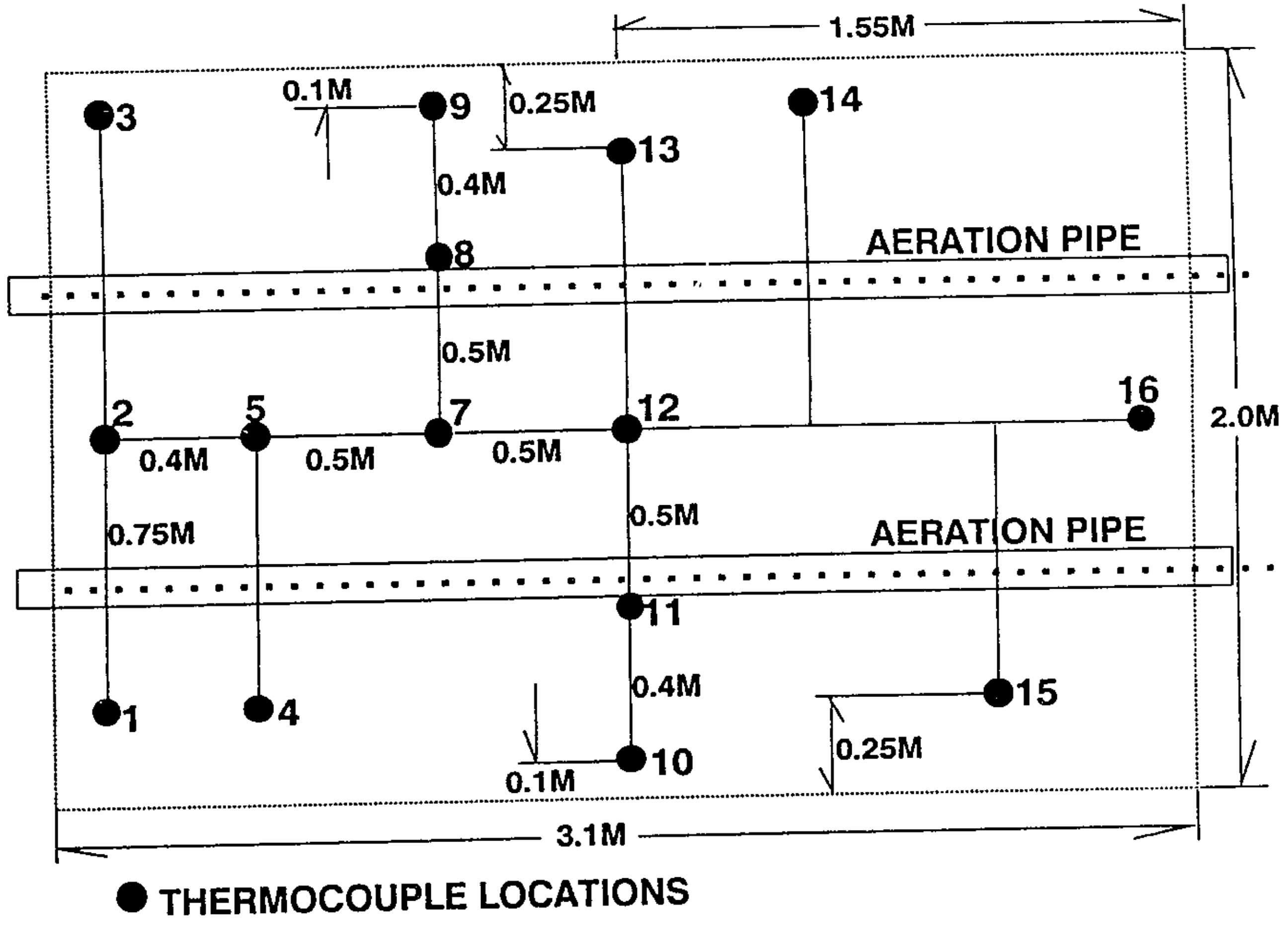

Fig.3.2 Thermocouple layout, Type A, bottom frame

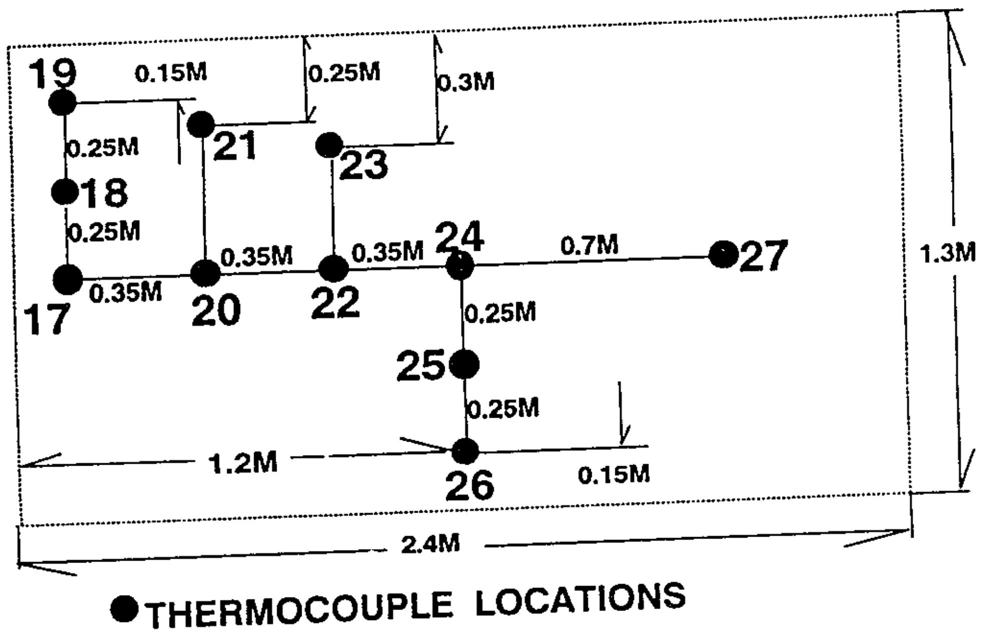

Fig.3.3 Thermocouple layout, Type A, middle frame

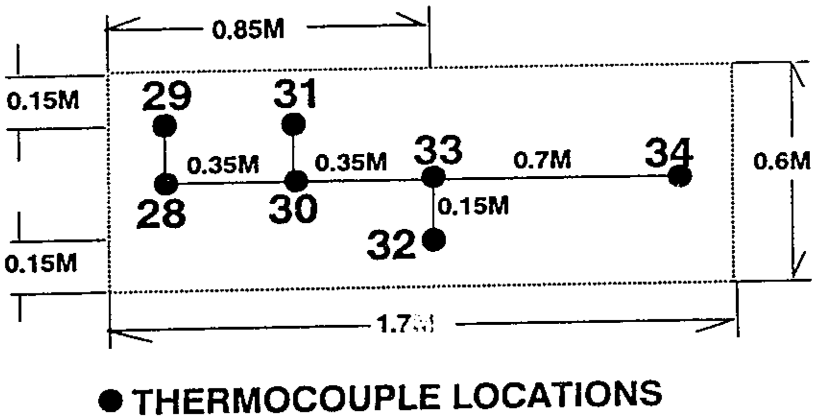

Fig.3.4 Thermocouple layout, Type A, top frame

for monitoring the ambient temperature in the barn, and they were connected to the data loggers. Fig.3.5 was sketched to show the overall compost pile layout and temperature monitoring set up.

Temperature monitoring in this study was carried out over a period of 113 days. Temperature readings were registered by the data loggers once every hour for the first 24 days, and once every 4 hours through the remaining process period. Temperature readings recorded by the data loggers were automatically sent to a Compaq Portable-XT computer, and were compiled as spreadsheet files. Hand meter readings were taken 25 times during the same period.

3.2.2 Test of Compost Properties

Grab compost samples from the piles were taken twice every week for the first three weeks, and once every week afterwards. In all 356 compost samples were taken from the 12 piles. Sample size was approximately 0.2 kg. Whole pile composite samples were taken in the first three sampling. From the fourth time on three separate composite samples from bottom, middle, and top parts of the pile, were taken. All samples were weighed, freeze-dried, grounded to 40 mesh, and analyzed for the following parameters: MC, volatile solids (VS), ash, pH of water extract, total carbon (C), total nitrogen (N), total phosphorus (P), total potassium (K), metals including Cd, Cr, Cu, Mo, Ni, Pb, and Zn, 2 normal

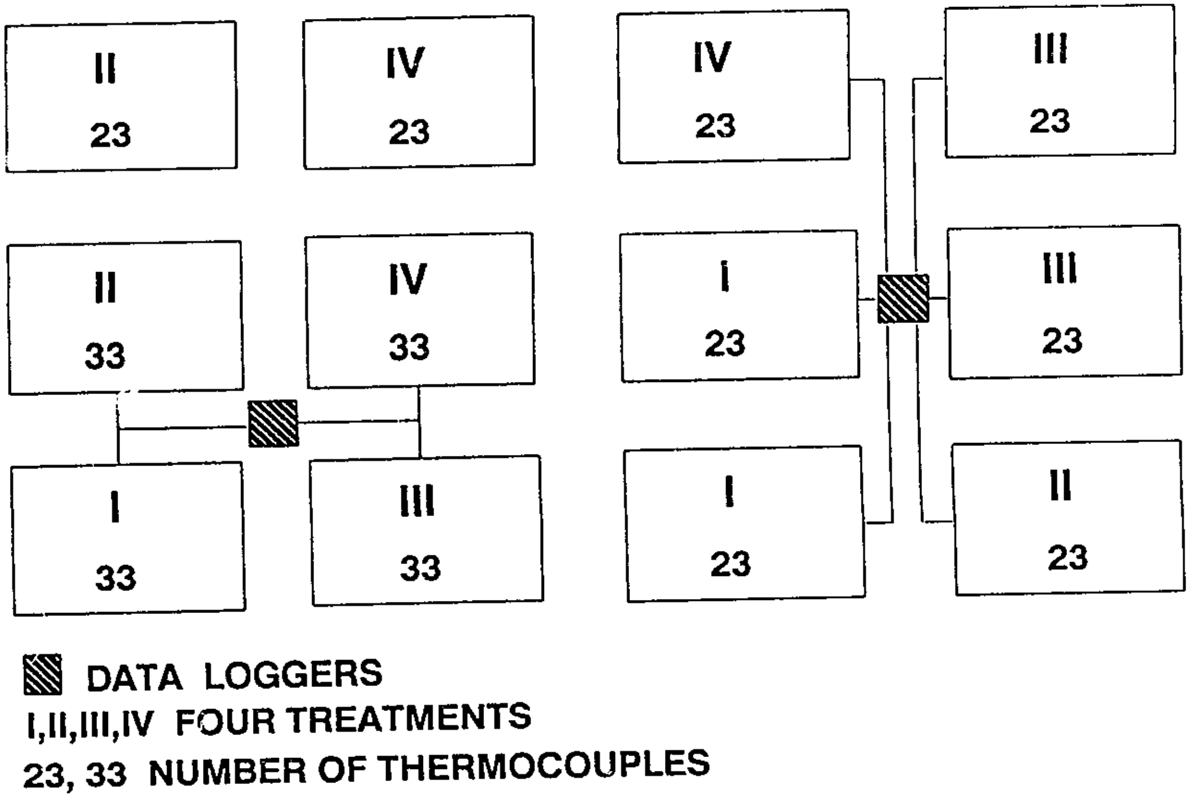

Fig.3.5 Overall view of compost pile set-up

KCl extractable ammonia nitrogen (NH_3-N), 2 normal KCl extractable nitrate nitrogen (NO_3-N), and ammonia gas (NH_3-gas) released from the compost piles.

MC of the samples was determined in two steps: (A) samples were weighed before and after freeze drying to determine the proportion of freeze dry moisture, and (B) the moisture left in freeze dried samples was determined by oven drying at 105°C (APHA *et al.*, 1985). The addition of these two parts of moisture was reported as the final result for MC. VS, ash, P, and pH were analyzed according to McKeague (1978). C and N were determined with LECO Analyzer. According to Sheldrick (1984), NH_3-N was analyzed with an ORION ammonia electrode, and NO_3-N with titration method. NH_3-gas was monitored with Drager hand pumps from day 9 through day 43. K was determined by FAAS (flame atomic absorption spectrometry) and Cd, Cr, Cu, Mo, Ni, Pb, and Zn by ICPMS (inductively coupled plasma mass spectrometry). During the composting process on-site observations of the visible changes of the compost material and related occurrences were carried out along with monitoring and sampling. Equipment used in this research is listed in Table 3.4.

Table 3.4 Equipment used for this study

PURPOSE	EQUIPMENT
Temperature Recording	Multi-Channel Automatic Data logging Systems: DIGI II, DIGI III, DIGI IV and FLUKE 2240C, Compaq Portable-XT Computer
Raw Compost Mixing	Oswalt Feed Mixer
Piling	New Holland Skid-Steer Front-End Loader
Compost Sample Processing	Freezer, Freeze Dryer, Grounder
Moisture Content Analysis	Oven
Volatile Solids and Ash Analysis	Muffle Furnace
pH Analysis	Fisher Accumet 210 pH Meter
Carbon and Nitrogen Analysis	LECO CHN-600
Ammonia Nitrogen Analysis	ORION Ammonia Electrode
Nitrate Nitrogen Analysis	Technicon Auto-Analyzer
Ammonia Gas Measurement	Dragger Hand Pump
Phosphorus Analysis	Klett Spectrophotometer
Metal Analysis	Flame Atomic Absorption Spectrometry and Inductively Coupled Plasma Mass Spectrometry

Chapter 4

RESULTS AND DISCUSSIONS

In this chapter, results from each compost treatment are reported and discussed. Similar compositions of the composts of Treatments III and IV have resulted in comparable outcome, which was confirmed by ANOVA statistical test. To avoid unnecessary repetition, mainly the results from Treatment III are included in the following discussions.

4.1 MECHANISM AND EFFECTIVENESS OF PASSIVE AERATION

In this section the information on passive aeration effectiveness is derived from the temperature monitoring results. The temperature data are reported in Appendix B. The temperature variations with time during composting process is designated as temperature profile. In general, the temperature profiles recorded from different locations in each pile are different from each other. In Table 4.1 it can be seen that the variations, between the minimum and maximum values, are significant in every treatment. For example, in Treatment II temperature rose at a rate of 1.9 to 44.4°C/day, peak values in the range of 43 to 68°C were reached from day 2 through 13, the peak duration was 0.1 to 63 days. The temperatures eventually dropped to the ambient level in 10 to 113 days at the rates of 0.3 to 4.6°C/day.

Composting microbial activities such as respiration, metabolism, and synthesis rely mainly on exothermic biochemical reactions, which are the fundamental reasons for temperature rise during the process. Essentially, temperature development can be related to two factors in composting systems: compost composition (availability of compostable organic matter and water) and aeration. In order to express temperature as a function of aeration, it is preferred that the compost composition be set as a constant or as uniform as possible throughout the system. For this reason, a thorough mixing of the poultry manure slurry and the bulking agents, peat or straw, was carried out. In addition, some symmetrical locations within the compost piles were monitored for temperature to check the material uniformity. If the temperature profiles at the symmetrical locations were similar, it was an indication of the compost uniformity. In fact, similar temperature profiles were recorded at the symmetrical monitoring locations and typical results are displayed in Fig.4.1,

Table 4.1 Temperature ressutls from compost Treatments I, II and III

Temperature Profile Characteristics*	Treatment I		Treatment II		Treatment III	
	minimum	maximum	minimum	maximum	minimum	maximum
temperature rise rate, C/day	3.9	31.5	1.9	44.4	19.2	41.6
peak temperature time, day	1	3	2	13	1	3
peak temperature, Celsius	32	71	43	68	67	75
peak duration, day	0.2	3.8	0.1	62.5	0.2	1.3
back to ambient time, day	6	40	10	113	48	71
temperature drop rate, C/day	1.0	6.5	0.3	4.6	0.7	1.0

* 33 temperature profiles from each treatment

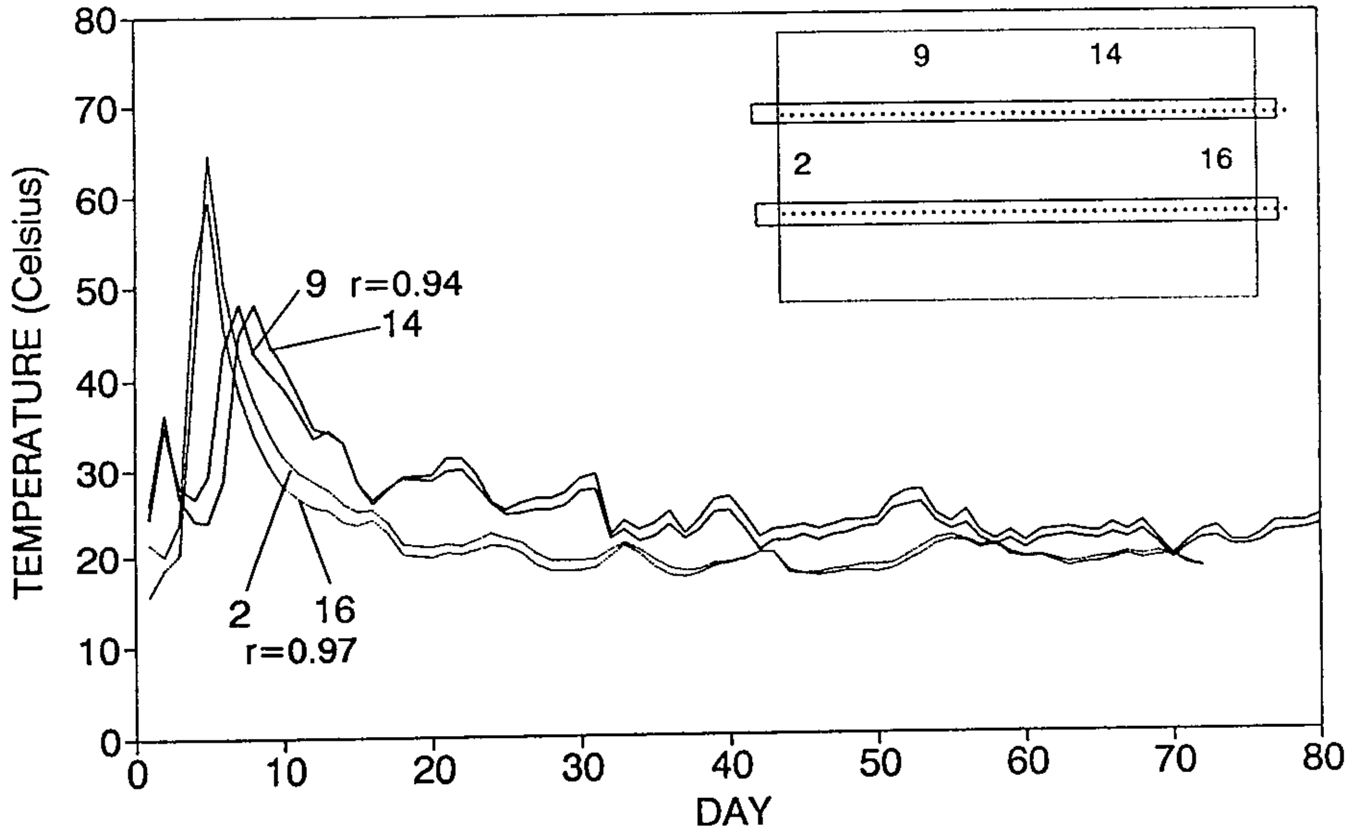

Fig.4.1 Temperature profiles from symmetrical locations, 2&16 (Treatment I) and 9&14 (Treatment III)

the correlation coefficient (r) is 0.97 for profiles 2 and 16 and 0.94 for 9 and 14, both are significant with 99% confidence. In general, temperature profiles at the symmetrical monitoring locations in each treatment superimposed each other throughout the entire period of the composting process. This result suggested that the raw material was thoroughly mixed, hence, the compost in each treatment could be considered uniform.

Therefore, the most probable factor causing the variations among the temperature profiles was the variable aeration conditions at different locations in each pile. Accordingly, the passive aeration conditions in each treatment can be examined using the recorded temperature information.

4.1.1 Temperature Profiles and Passive Aeration

4.1.1.1 Treatment I

The temperature distribution results for Treatment I are shown in Fig.4.2, the numbers attached to the curves indicate the corresponding temperature, and the two black circles at the bottom of each figure depict the two perforated pipes. On day 5, higher temperatures up to 65°C occurred at the exterior parts, while temperatures were lower in the interior parts. By day 10, higher temperatures around 60°C were recorded in the core region of the compost pile. The pile started cooling down from the peripheral zone, by day 30, the highest temperature was about 35°C in the core, however, the exterior parts had

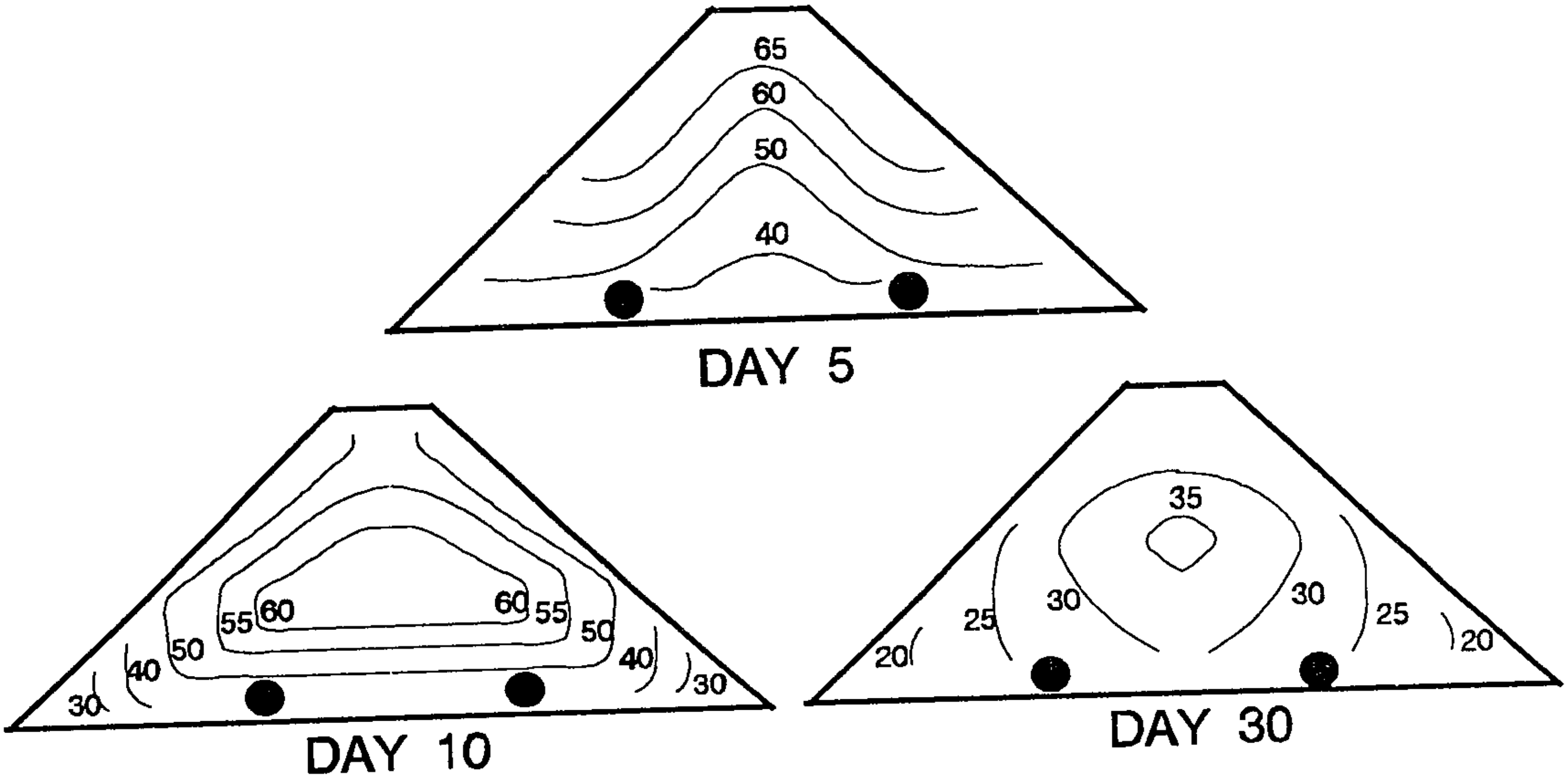

Fig. 2 Temperature distribution for Treatment I

already dropped to the ambient temperature, around 20°C. These results indicated that the amount of air, which was required for effective aerobic exothermic composting reactions to occur and thus to raise temperature to the thermophilic level, was first available to the materials close to the pile surfaces, and then to those in the pile interior parts. Natural air diffusion through the pile surfaces would be the most probable reason for this type of air availability.

The distance from the monitoring locations to the pile surfaces affected the amount of available air at these locations. At any given time, the greater the distance, the smaller the amount of available air. In addition, the temperature distribution results also indicated that the amount of air originally entrapped in the compost when setting up the piles was insufficient for microorganisms to act similarly throughout the entire pile. Otherwise, thermophilic temperatures would have occurred at about the same time throughout the whole pile or earlier in the pile central parts rather than in the peripheral parts because of less heat exchange with the ambient air.

Typical temperature profiles for Treatment I are shown in Figs.4.3 and 4.4. The temperature profiles have a common crest type configuration: sharp rise, short peak duration with the peak values around 60 to 65°C, and followed by dropping to the ambient temperature. These results indicate that passive

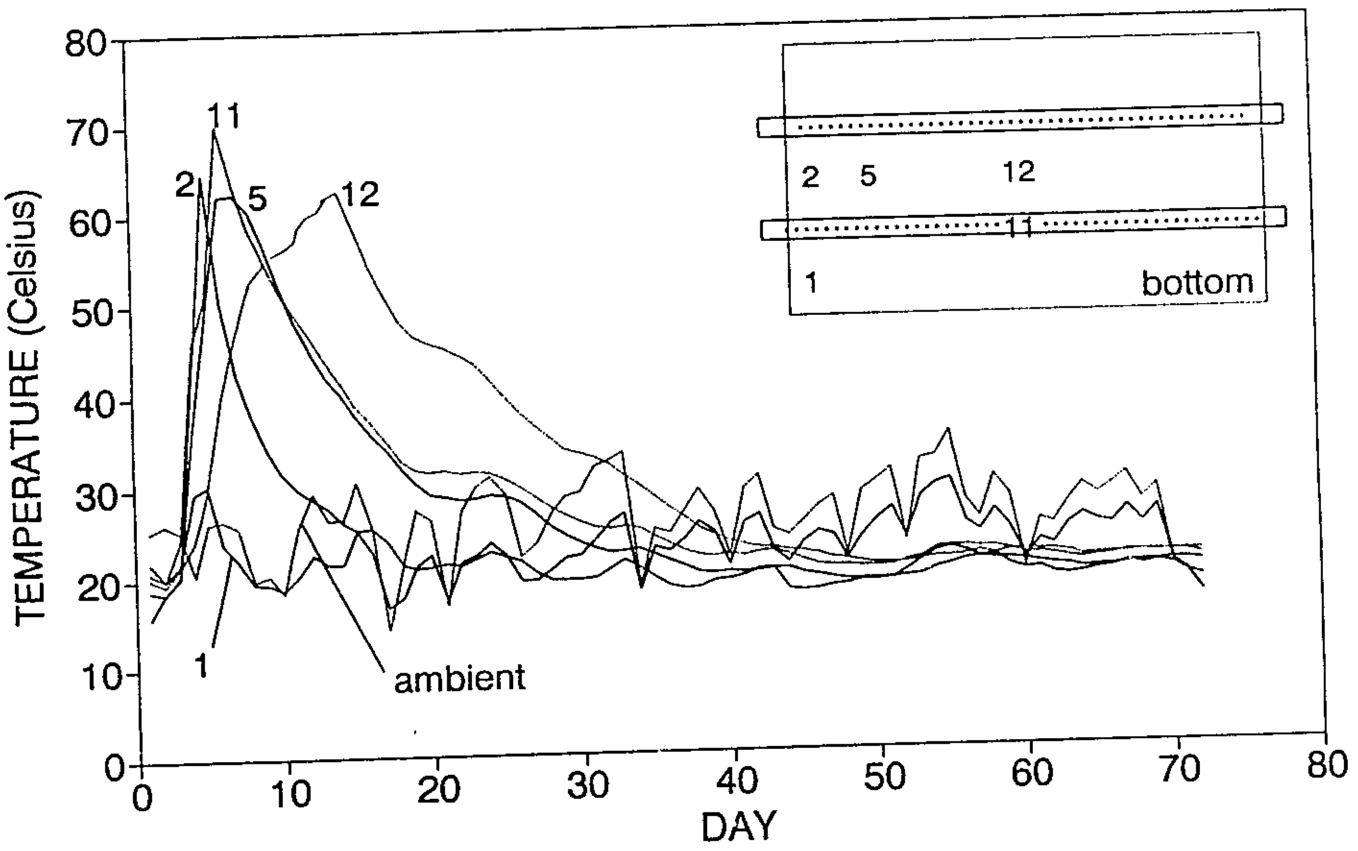

Fig.4.3 Temperature profiles from locations 1, 2, 5, 11, 12 and ambient of Treatment I

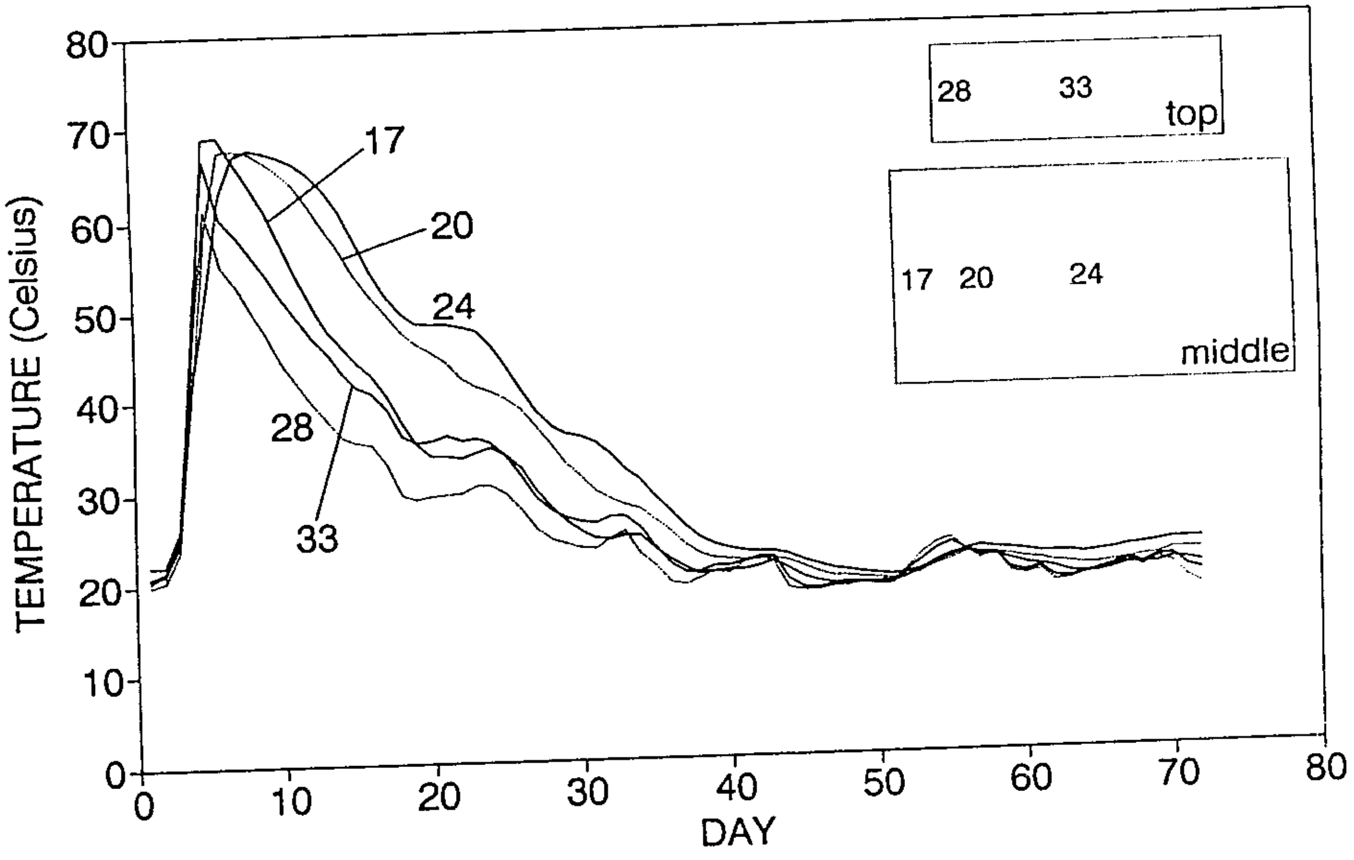

Fig.4.4 Temperature profiles from locations 17, 20, 24, 28 and 33 of Treatment I

aeration was effective for Treatment I. Most likely, the material structure of this treatment was porous, and air was effectively available to the compost even in the potentially most compacted area, the bottom centre, represented by location 12. Air diffusion effect was exhibited by the delayed temperature peaks for the relatively inner locations. For instance, the peak temperature of 63°C at location 12 was reached within 15 days at a rate of 4°C/day, while at location 2 it took only 5 days to reach the peak of 62°C at a much faster rate of 22°C/day.

The air diffusion stand can be further supported by the ambient influence on the temperature results. The temperature profiles of the corner location 1 and the ambient display a significant correlation, r=0.75 (based on 72 readings). It should be noticed that the peak temperature at location 1 was low, 33°C, which indicates that the heat loss to the ambient from the compost in the pile corners was so strong that temperature could not reach to the thermophilic level. On the other hand, temperature at the side location 2 attained a peak of 65°C, even though it was comparable to location 1 in terms of the distance to the pile surface. It must be the corner effect, *i.e.*, 270-degree exposure to the ambient air, which caused the low temperature at location 1. It would be necessary to increase the thickness of the insulation layer for Treatment I piles in order to raise temperature at the corner locations to the thermophilic level. In the middle and top part of the pile from peripheral locations 17 and 28 to central locations 24 and 33 (Fig.4.4), the temperature profile variation is smaller than that from 2 to 12 in the bottom (Fig.4.3). This could be attributed to less compaction, rising heat from bottom part, and short distance to the pile surfaces.

In addition to diffusion, air was also introduced into the compost piles by the perforated pipes. This information can be examined by comparing the temperature profile of location 5 with that of location 11. These two locations were both in the pile bottom part and about 0.5m from the pile surfaces, which made them comparable in terms of air diffusion effect. However, there was a significant difference between these two locations concerning their aeration conditions, *i.e.*, location 11 was immediately above one of the two perforated pipes, whereas location 5 was 0.4 m away from both of the pipes. The higher peak temperature at location 11, 71°C, compared to the 62°C peak at location 5 was an indication that some extra air was available to location 11 through the perforated pipe beside air diffusion through pile surfaces. Although temperature over 70°C is not unusual in composting practice, it is generally considered as being high for compost microorganisms to survive. Therefore, the locations around the perforated pipes may be over aerated. On the other hand, the peak temperature of 63°C for location 12, the most compacted location in the pile, is within the optimum range, which reflects a suitable aeration condition. It seems that the necessity of the perforated pipes for Treatment I should be reconsidered, and it is possible that similar results for Treatment I could be achieved without the addition of the perforated pipes.

4.1.1.2 Treatment II

Temperature distribution results for Treatment II are shown in Fig.4.5. The general trend was similar to that of Treatment I (Fig.4.2), from day 5 through day 10 higher temperatures occurred earlier at the peripheral parts and later in the interior parts, which reflected that air diffusion was the driving mechanism of aeration. Also, thermophilic temperatures had prevailed throughout the piles in the first 10 days, hence, passive aeration was effective for Treatment II. By day 70 the peripheral zone were cooled down to the ambient level, while the interior region was still around 40°C. This is a much longer period than that for Treatment I. It should be noted that the latter contained less amount of poultry manure slurry (Table 3.2).

Typical temperature profiles for Treatment II are shown in Figs.4.6 and 4.7. Unlike Treatment I, significant differences exist among these temperature profiles, especially those from the pile bottom and middle parts. It can be seen that there was a distinct temperature profile configuration transition from the peripheral to central locations. The inner the location, from 2 or 17 to 12 or 24, the slower the temperature rise, the later and the lower the peak, and the longer the peak duration. For example, at the peripheral location 2 tempera-

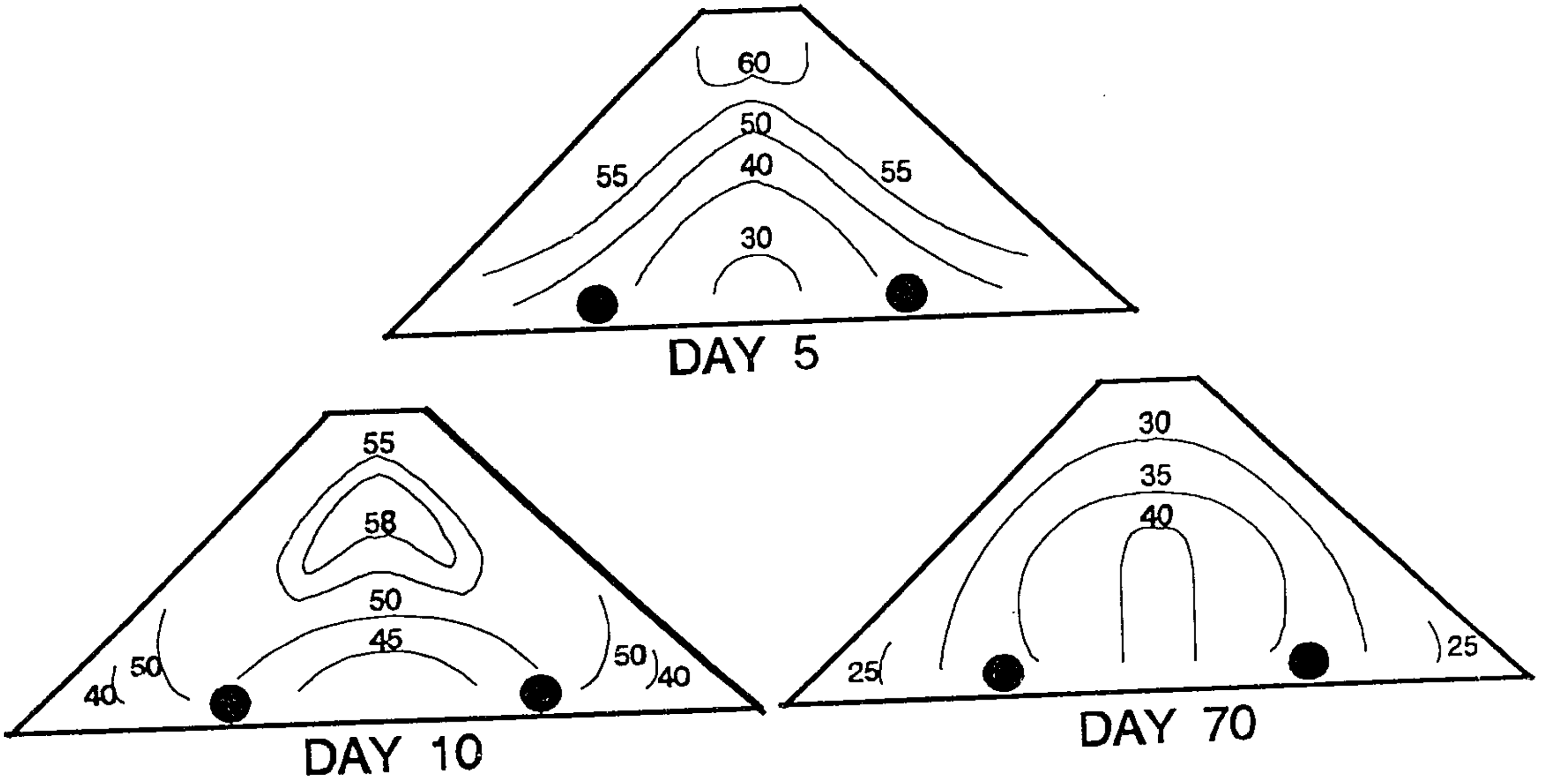

Fig. 5 Temperature distribution for Treatment II

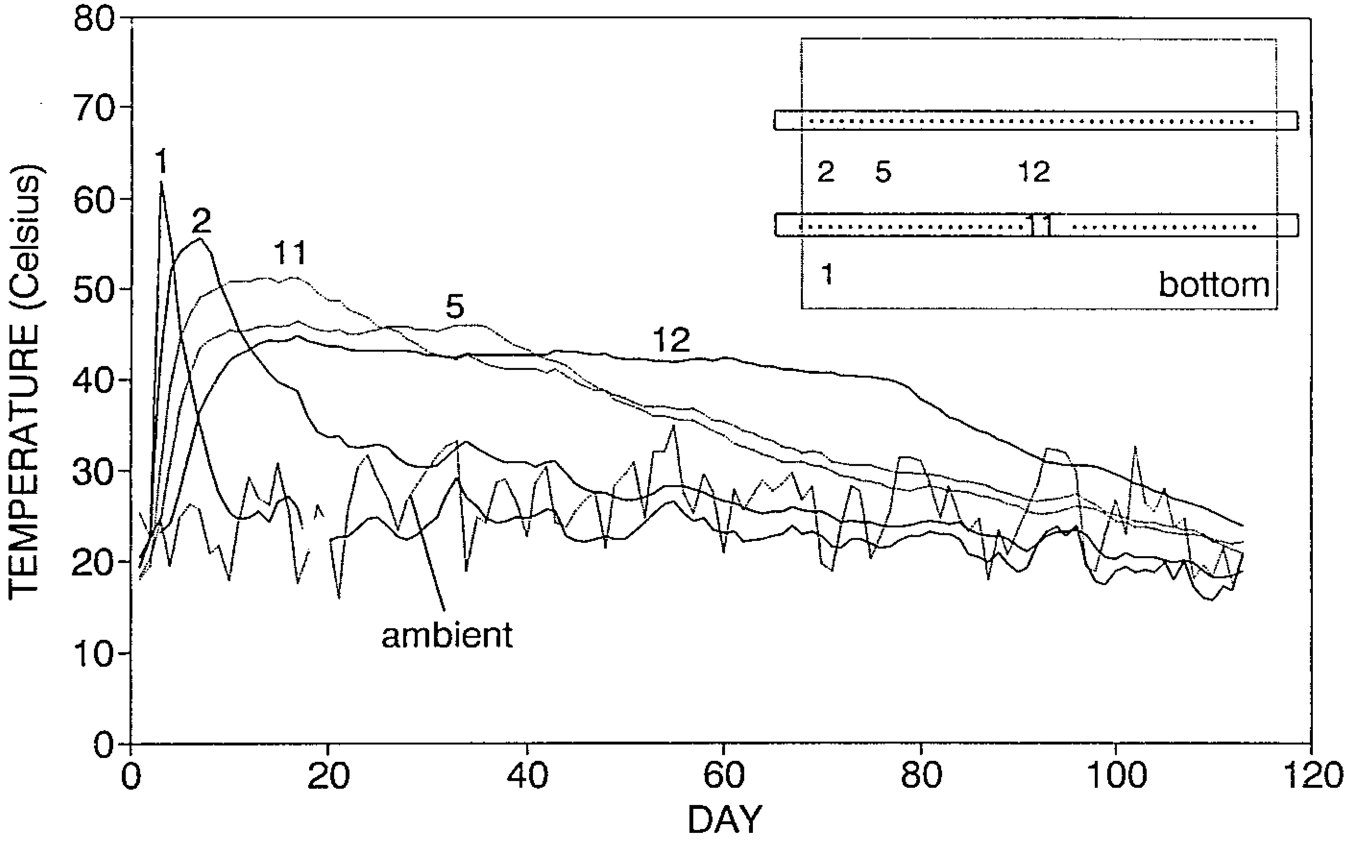

Fig.4.6 Temperature profiles from locations 1, 2, 5, 11, 12 and ambient of Treatment II

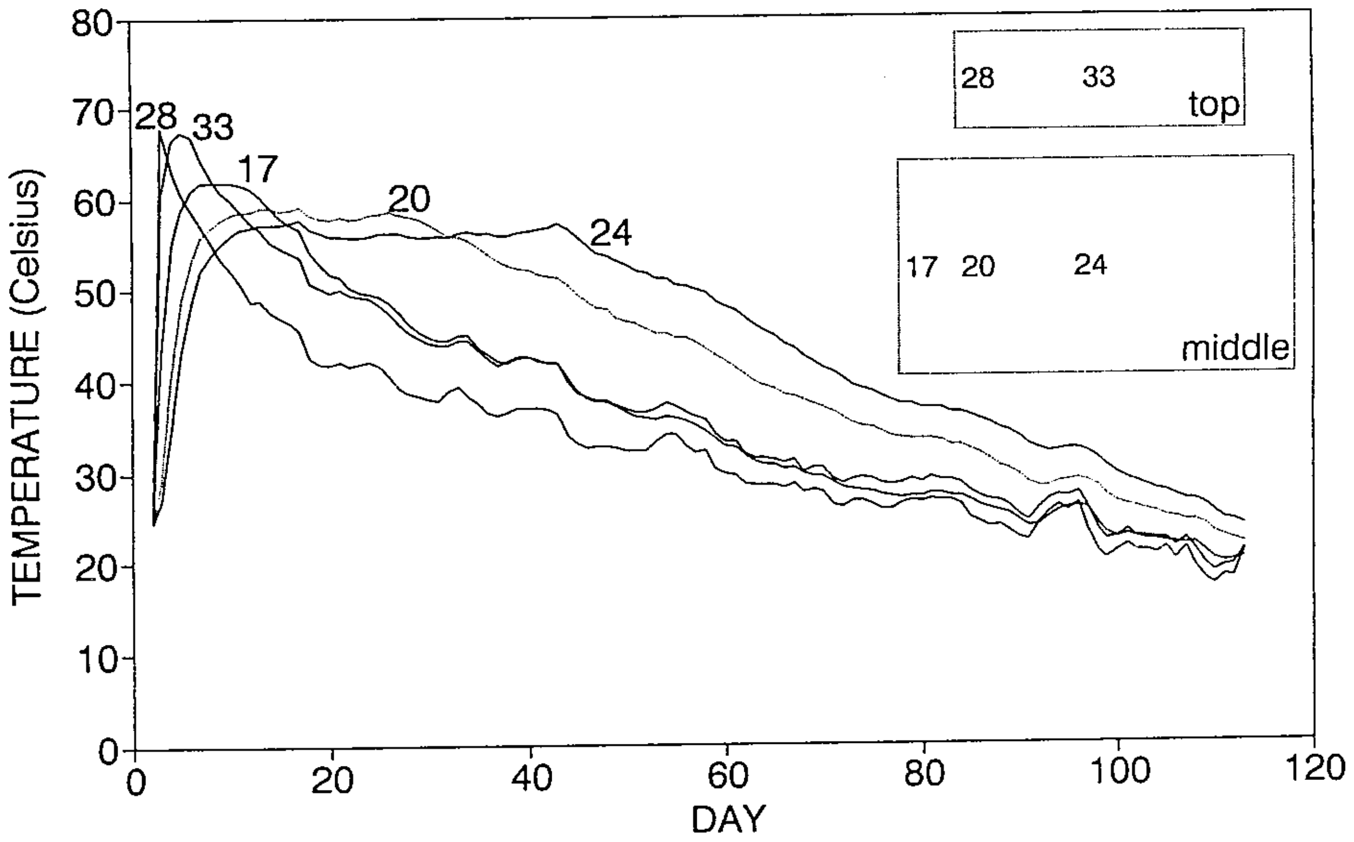

Fig.4.7 Temperature profiles from locations 17, 20, 24, 28 and 33 of Treatment II

ture rose to a peak value of 56°C in about 6 days at a rate of 6°C/day, and was maintained for 3 days. In comparison, temperature at central location 12 rose to a lower peak of 44°C in about 15 days at a rate of 1.6°C/day. It maintained around the peak level for more than 60 days.

This greater variation in temperature development for Treatment II than in Treatment I suggest that air circulation had encountered greater resistance in Treatment II. This was most likely the result of the lower material porosity, which was the aftermath of higher initial bulk density of Treatment II, 513 kg/m^3, compared to 359 kg/m^3 for Treatment I. Longer processing period should be expected for those relatively interior locations where lower air supply rates must have occurred. Comparing with the corresponding location in Treatment I (Fig.4.3), it is apparent that microorganisms in the bottom central parts of the Treatment II pile, location 12, could not generate sufficient heat to raise the local temperature over 45°C, which was an indication of a condition of limited air supply. This lower temperature was compensated by a long processing time, over 100 days.

However, this situation could have been improved with additional use of perforated pipes. At location 11, which was immediately above one of the pipes, had a higher peak temperature of 52°C with a shorter peak duration of about 10 days compared to the 47°C peak and 30-day peak duration for location 5.

Thus, the perforated pipes were necessary for improving the local aeration under Treatment II condition. The faster rise of temperature at location 11 must be due to more intense microbial activity that was the result of greater amount of available air. Aeration conditions similar to that at location 11 should be expected for location 5 if it had the similar accessability to a pipe. Therefore, there is a possibility of tapering off the aeration variations in Treatment II by increasing the number of the perforated pipes, consequently, the processing time could be shortened.

The aeration difference between Treatments I and II due to the compost's properties are also shown by the temperature results from location 1 for both treatments. Recall that temperature at location 1 in Treatment I could not even reach 35°C (Fig.4.3) due the loose material which induced significant heat loss. While in Treatment II, temperature at the same location had a peak of 61°C. This result suggests that less heat loss occurred from Treatment II compost. From another point of view, the peat insulation layer of Treatment II, about 0.05 m thick, was sufficient.

4.1.1.3 Treatment III

The temperature distribution results for Treatment III in Fig.4.8 show that while air diffusion was an important factor, the perforated pipes seemed to have greater effect on aeration in the early stage of the process. It can be seen

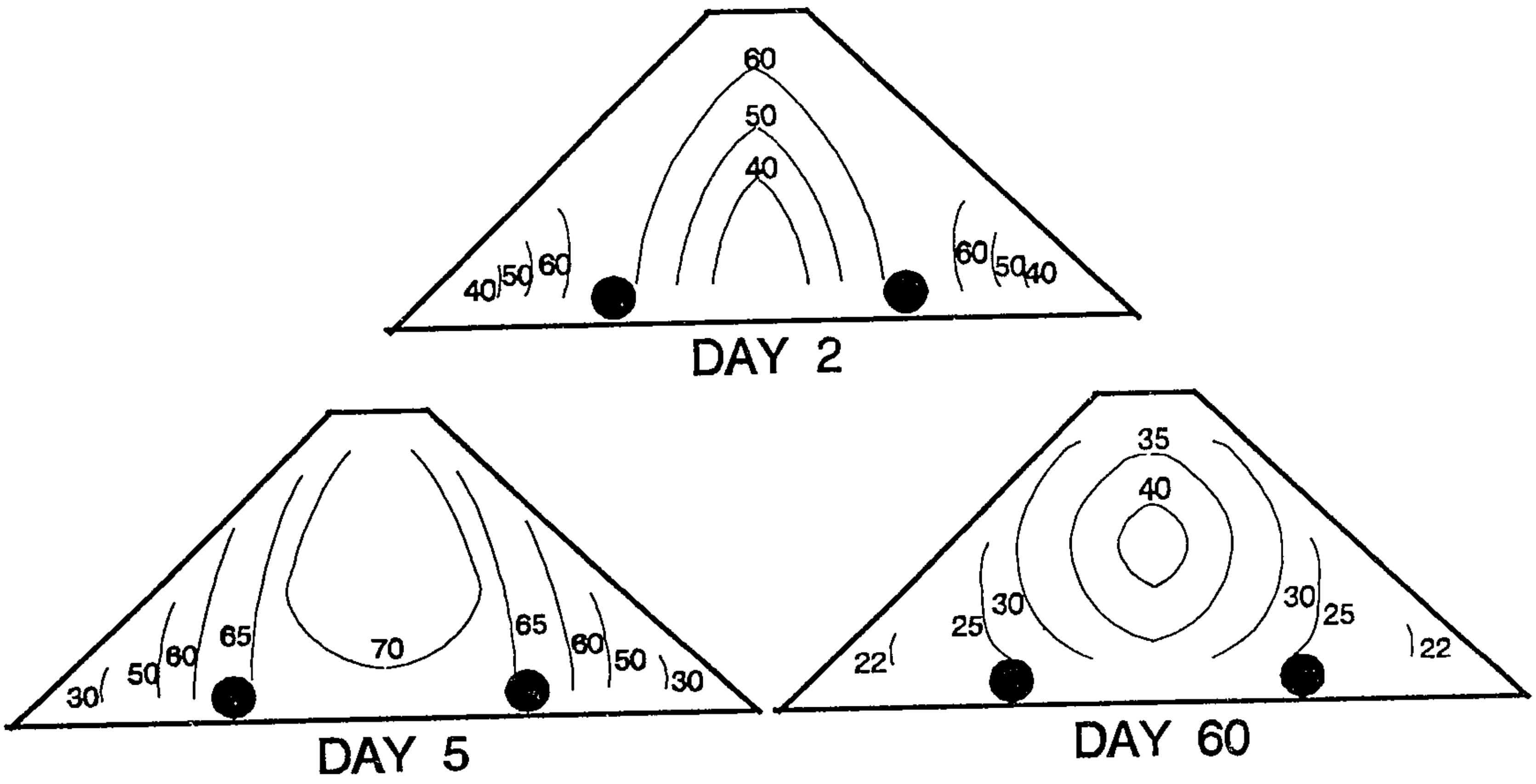

Fig. 8 Temperature distribution for Treatment III

that on day 2 the higher temperatures, around 60°C, were situated right above the two pipes as well as the upper peripheral parts, while the lower temperatures were recorded from the central lower parts and the bottom corners. Only after 5 days, were the thermophilic temperatures achieved throughout the whole pile. This confirmed effectiveness of passive aeration for Treatment III. Temperatures over 40°C lasted more than 60 days in the pile core zone.

A distinctive occurrence in Treatment III was that two-peak temperature profiles were registered at some locations. As shown in Figs.4.9 and 4.10 the two-peak temperature profiles were recorded explicitly at the peripheral locations in bottom and middle parts of the pile such as 2, 5, 11, 19 and 23. The two-peak configuration diminished progressively towards the inner locations. For example, two-peak profile for location 2 was very obvious, however, for location 5, 0.5m inward from the pile surface, the two-peak pattern was almost insignificant, while at location 7 the profile had only one peak. Similar situation also occurred in the middle part of the pile. In the top part, however, the temperature profiles did not display the two-peak configuration. In the literature, there is no report of this type of temperature behaviour. The two-peak temperature results are quantitatively summarized in Table 4.2. The first temperature peak of 37 to 74°C occurred within 3 days, while the second one, 43 to 73°C, in 4 to 9 days, maximum about 9 days between the two peaks.

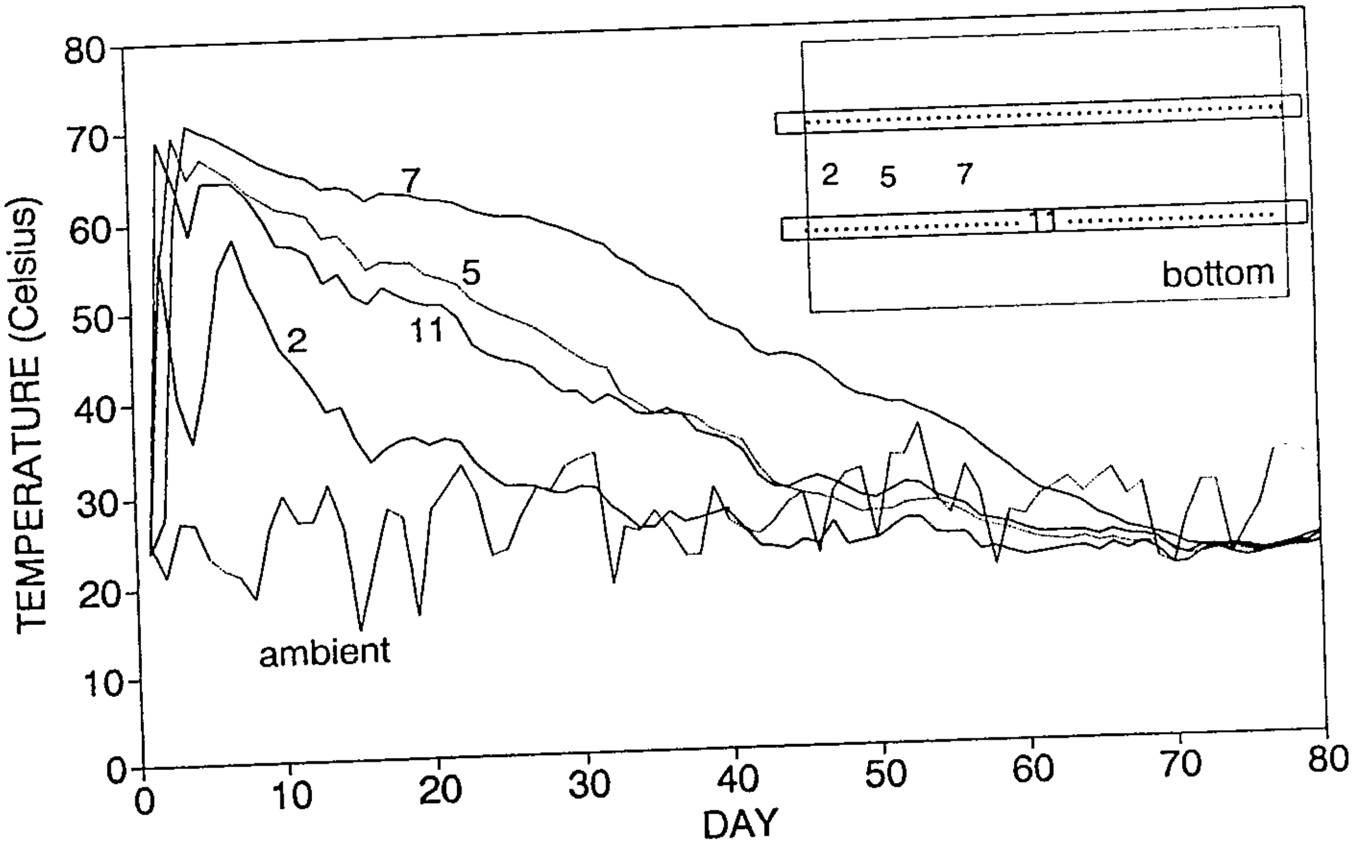

Fig.4.9 Temperature profiles from locations 2, 5, 7, 11 and ambient of Treatment III

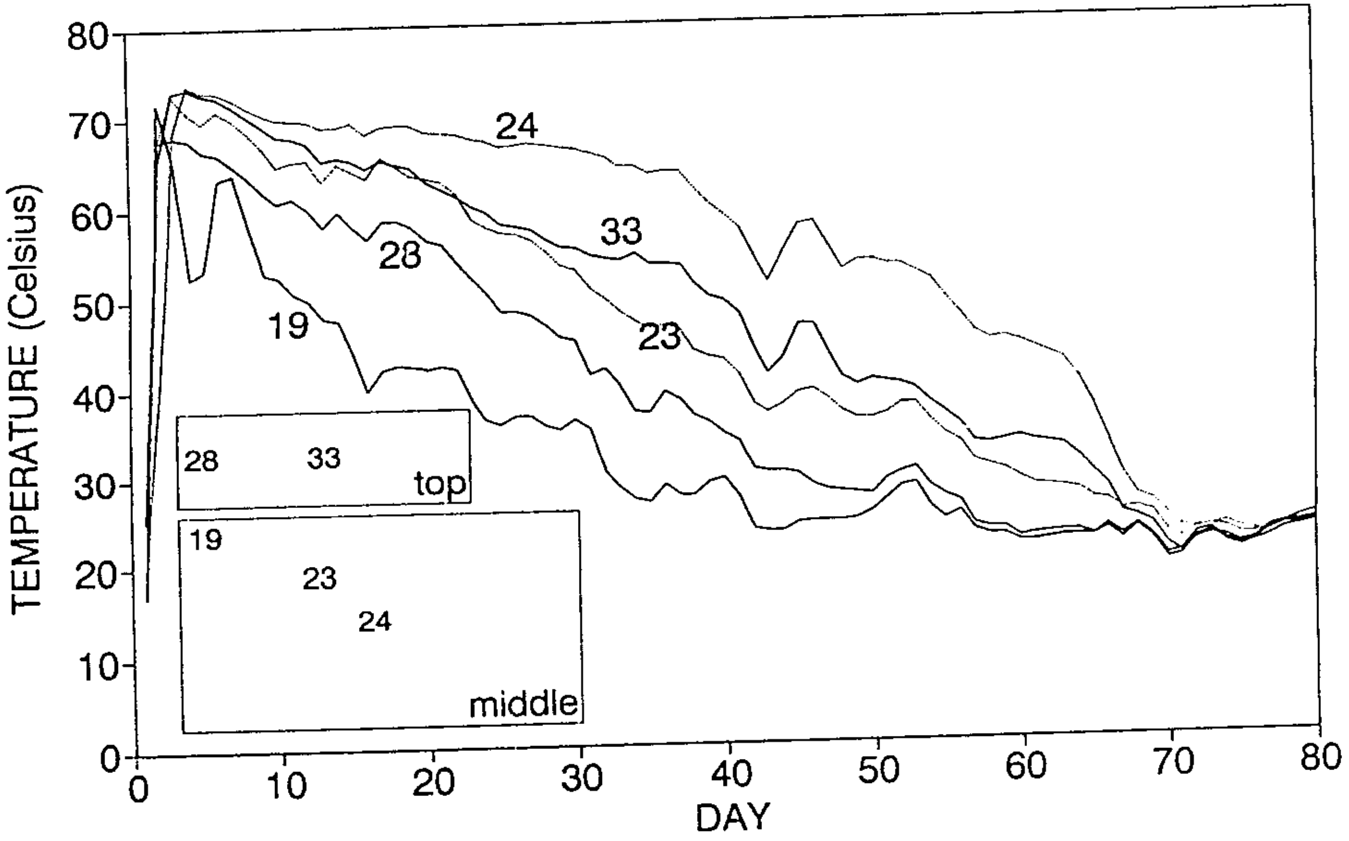

Fig.4.10 Temperature profiles from locations 19, 23, 24, 28 and 33 of Treatment III

Table 4.2 Two-peak temperature results from Treatment III

Temperature Profile Characteristics*	FIRST PEAK		Temperature Profile Characteristics*	SECOND PEAK	
	minimum	maximum		minimum	maximum
temperature rise rate, C/day	19.2	64.8			
peak temperature time, day	0.3	1.5	peak temperature time, day	4	9
peak temperature, Celsius(C)	37	74	peak temperature, Celsius(C)	43	73
peak duration, day	0.04	0.42	peak duration, day	0.08	1.25
temperature drop rate, C/day	2.4	16.4	back to ambient temp. time, day	13	79
valley** temperature time, day	3	4	temperature rise rate, C/day	2.9	16.2
valley temperature, C	20	69	temperature drop rate, C/day	0.6	4.2

* 18 temperature profiles in total

** valley: the lowest point between the first and the second temperature peak

It shows in Fig.4.9 that there was no drastic decrease in the ambient temperature, that could be considered as a reason for the temperature drop from the first peak. The ambient temperature was between 20 and 27°C during the two peak period. In addition, the ambient factors including temperature, humidity and pressure should have similar effect to Treatment I, II and III since they started at about the same time. Therefore, the occurrence of the two-peak temperature development in Treatment III was not likely due to the ambient factors. The relatively high temperatures in the early stage of the process might have inhibited microorganism activity, thus inducing the two-peak temperature occurrence. However, high temperature occurred in the periphery of all the compost piles in the three treatments such as location 2 (Figs.4.3, 4.6 and 4.9). But, only in Treatment III piles did the two-peak temperature profile appear. Therefore, inhibition of microbial activity due to high temperature was unlikely an important factor contributing for the two-peak temperature development.

Heat loss might be one of the reasons for the temperature drop from the first peak. Comparing the temperature profiles of locations 5 with that of location 11 (Fig.4.9), the temperature drop was faster at the latter location, from 70 to 58°C in 2 days, while it was from 70 to 64°C in 3 days for the former location. This result suggests that more heat might have been removed from location 11 by the extra air from the perforated pipe.

However, heat loss cannot be the only reason for the temperature drop from the first peak, otherwise, the appearance of a second temperature peak would not have occurred. There must be other factors other than heat loss that were responsible for the two-peak temperature development. One possible reason was that in the compost of poultry manure slurry plus chopped straw there were two fractions of compostable organic matter: easy to degrade and hard to degrade. In the early stage of the process, the easy to degrade organic matter was readily utilized by microorganisms, hence temperature started rising and reached the first peak quickly. After this portion of organic matter was utilized, a period of time was needed for the bacteria to readjust and utilize the hard to degrade organic matter, presumably by inducing enzymes that would be able to decompose this type of substrate. During this readjustment period, biodegradation activity might have dropped to a low rate, and so did the resulting heat generation. Therefore, the compost material close to the pile surfaces could lose heat, and temperature dropped.

Since the initial material was uniform, the two-peak temperature profiles should have occurred throughout the whole pile. However, the two-peak figure diminished towards the centre of the piles. Two possible factors would contribute to this. First, the reduced heat loss at the inner locations, because of greater distance from centre to surfaces, might have diminished the significance of two-peak profile configuration. Secondly, the delay in starting the composting process and temperature rise at the interior locations and the time for temperature to drop from the first peak at the interior locations could have coincided with the time for temperature to rise to the second peak at the peripheral locations. In such condition, there would not be sufficient time for the materials at the interior locations to cool down, therefore, only one peak was recorded. The rationale for the one-peak temperature profiles observed for all the monitored locations in the pile top part would be that temperature drop in those location was curtailed by the upward moving heat.

4.1.2 Statistical Analysis

4.1.2.1 Average Temperature

Average peak temperatures for the bottom, middle and top parts of each treatment are calculated and given in Table 4.3. Higher peak temperatures occurred in either the top or the middle part, whereas lower peak temperatures were in the bottom part exclusively. For example, in Treatment I the highest average peak temperature, 66°C, occurred in the middle, while at the bottom, 49°C, was the lowest. Because of the lower degree of compost compaction in the top and middle passive aeration would have been more effective than in the more compacted bottom. Thus, composting reactions would be more intense resulting in higher rates of heat generation as well as higher temperature. In addition, naturally rising warm air from lower parts of the piles should also be a contributing factor to the higher temperatures in the pile upper parts.

Table 4.3 Average temperature for Treatment I, II and III

Treatment I	average peak temperature (celsius)	thermophilic temperature duration (day)
Top part	59	7
Middle part	66	12
Bottom part	49	2

Treatment II	average peak temperature (celsius)	thermophilic temperature duration (day)
Top part	64	22
Middle part	58	41
Bottom part	46	3

Treatment III	average peak temperature (celsius)	thermophilic temperature duration (day)
Top part	71	31
Middle part	70	38
Bottom part	54	6

Also shown in the table is that thermophilic temperatures, above 45°C, lasted longest in the middle part, maximum 41 day for Treatment II, this was possibly because of lower level of heat exchange between the compost and the ambient air.

4.1.2.2 Cluster Analysis

Cluster analysis is a method for classification of studied subjects based on their statistical similarities. These similarities include not only those between each single subject, but also those between a single and a group of subjects as well as those between groups. Classified groups of subjects are called clusters. For example, temperature profiles recorded for each treatment in this composting study can be examined as the subjects. Yet, each of these temperature profiles corresponds to a recording location. The purpose of doing cluster analysis is to differentiate the locations into groups, and associate each one of the groups with a distinctive aeration regime in each treatment. Temperature profiles from 33 recording locations, one of which is ambient location, are used for the analysis for each treatment. The computer software for cluster analysis is developed by Lin and Butler (1990).

The results, called dendrogram, from the cluster analysis are shown in Figs. 4.11, 4.12 and 4.13. In the figures the numbers on the left side refer to the temperature recording locations, among which AB stands for the ambient

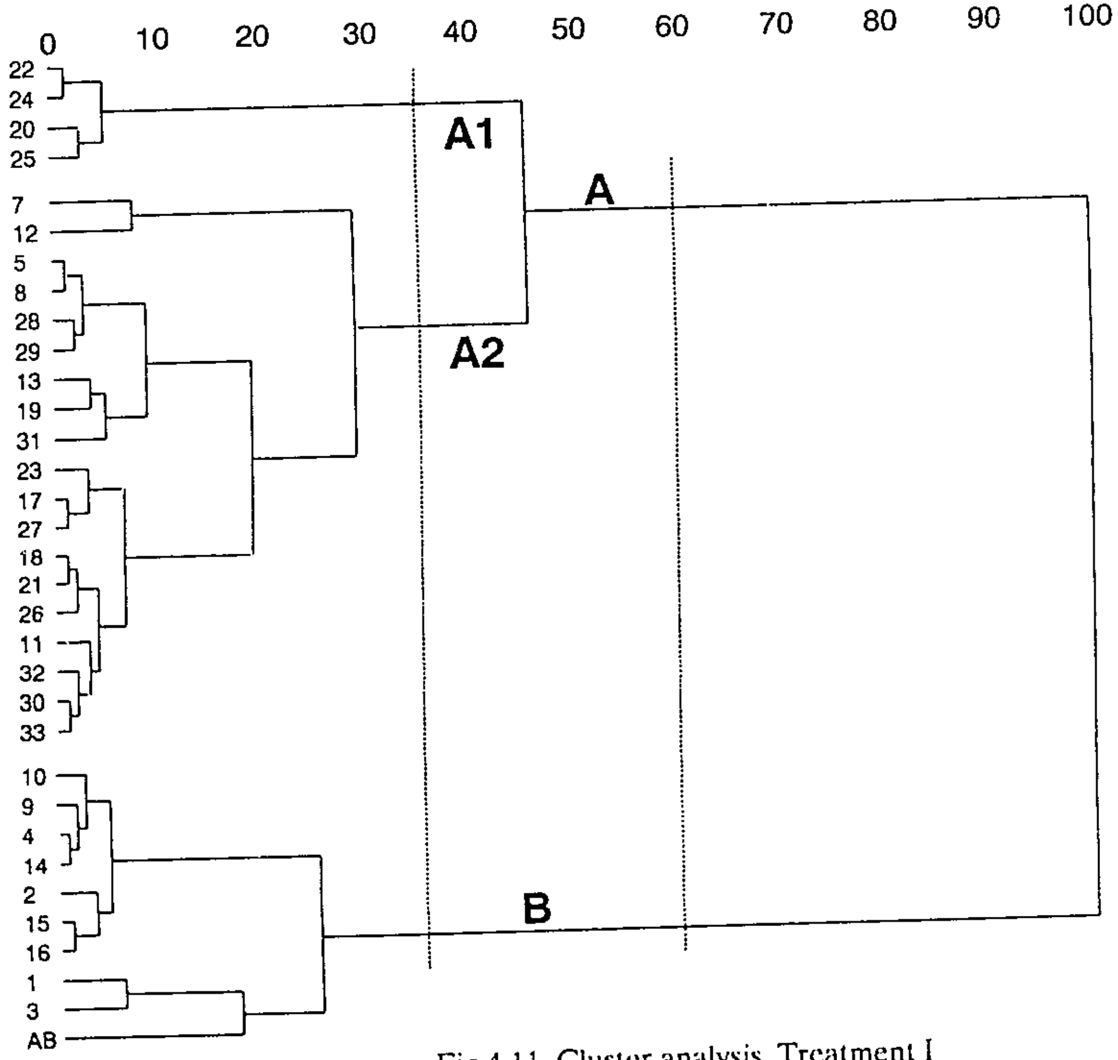

Fig.4.11 Cluster analysis, Treatment I

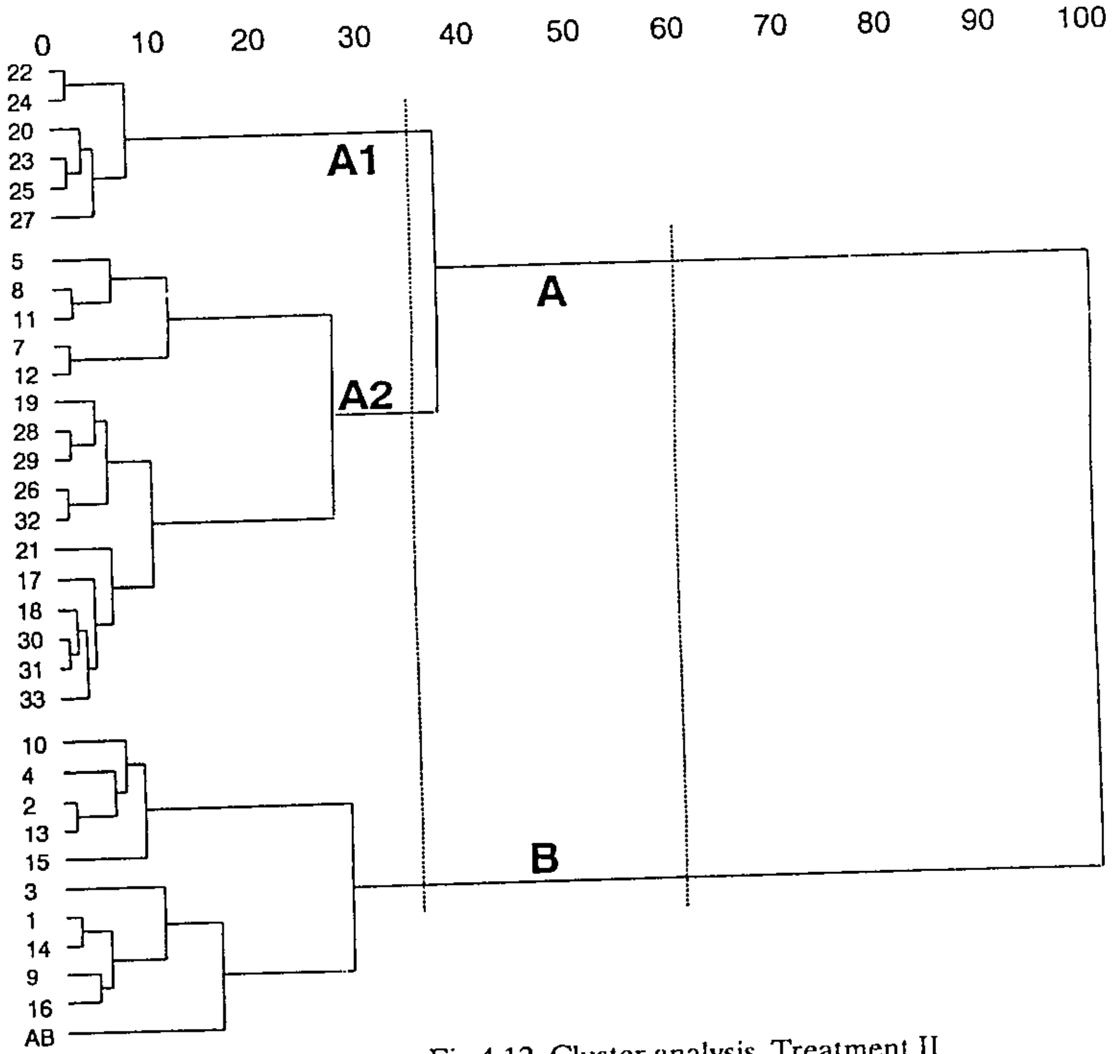

Fig.4.12 Cluster analysis, Treatment II

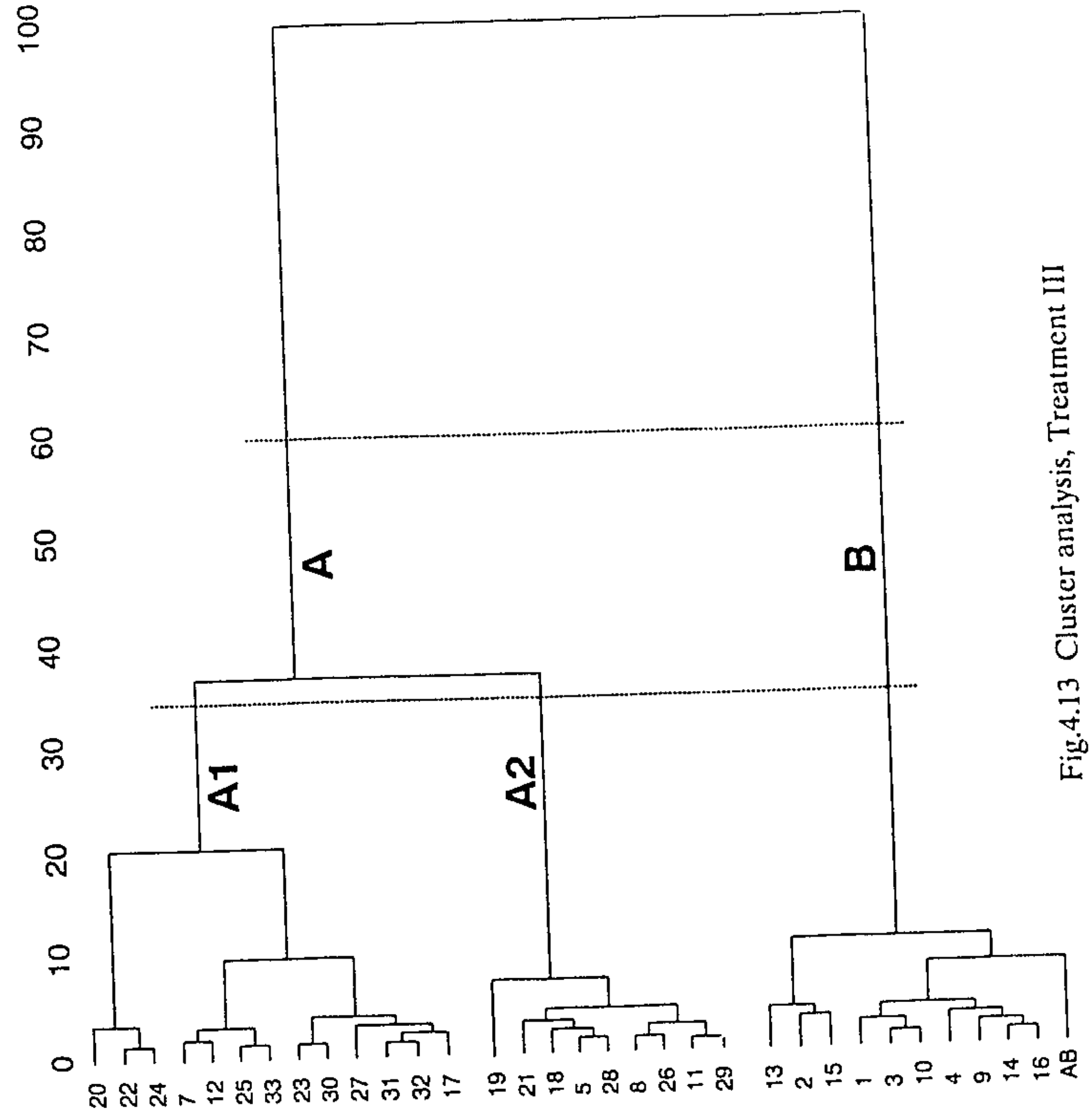

Fig.4.13 Cluster analysis, Treatment III

recording location. The numbers on the top from 0 to 100 are the calculated grouping reference, which is technically termed as "distance" and defined as a statistical measurement to evaluate the similarities between the studied subjects. Grouping of these locations can be done by drawing vertical lines at arbitrarily chosen distance levels such as the two vertical dash lines shown in the figures. More groups can be obtained by drawing grouping lines at smaller distance levels to the left. On the other hand, more information is required to interpret the physical meanings of the groups being generated. The following discussion will be concentrated on aeration information that is provided by the clustered groups of the 33 temperature monitoring locations in each compost pile.

The 33 locations are divided into two groups, A and B, by the first dash line on the right side (Figs.4.11, 4.12 and 4.13). Group A includes the locations in the pile middle and top parts as well as the interior locations in the bottom part. Group B contains the bottom peripheral and the ambient locations. Location 12 and 16 are typical examples of these two groups. This grouping result suggests that in each treatment there are two different temperature development regions, namely A the interior and upper parts and B the bottom peripheral region. The inclusion of the ambient location (AB) in group B specifically relates the ambient influence to the pile bottom peripheral region.

The second dash line from the right divides group A into two subgroups, A1 and A2. Subgroup A1 consists of the temperature profiles from the middle central region, while subgroup A2 includes those locations surrounding A1 region, locations 24 and 28 are typical examples of these two subgroups. The physical meanings of these two subgroups is that ambient air could diffuse into the A1 locations less easily than to A2 locations, which are closer to the pile surfaces. Fig.4.13 shows that the A1 region is much broader in Treatment III than that in Treatments I and II (Figs.4.11 and 4.12). It could be related to the size of the chopped straw particle being much greater than that of the peat, hence air diffusion would be easier in the straw piles. Further examination of the locations in the two subgroups of Treatment III reveals that subgroup A1 includes typically one-peak profiles locations, whereas those in subgroup A2 are two-peak profiles locations.

Based on the above grouping results the composting piles can be divided into three temperature regions, namely the middle centre (A1), the bottom periphery (B), and the transition region (A2) that is between A1 and B. These three regions, as sketched in Fig.4.14, are the result of the varied aeration conditions under the effect of air diffusion. This may be associated with the physical principle of passive aeration in static composting piles, *i.e.*, ambient air is drawn into the system mostly through the lower parts to fill out the voids that are left behind by the up-moving heated air in the system. The

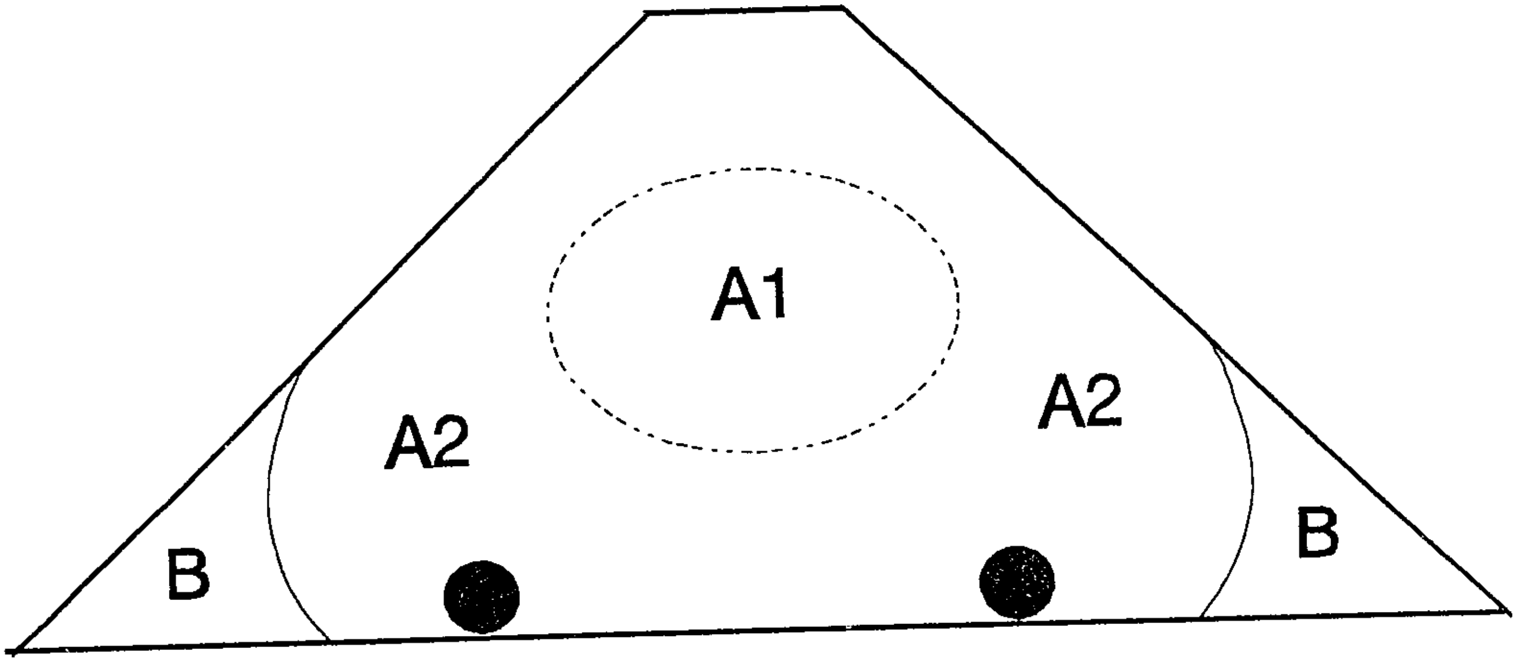

Fig. 14 Aeration zones in the compost piles of each treatment

upward movement of air is caused by the convection current induced by the heat generated in the system during the composting process. Recall the temperature distribution results for each treatment, it can be seen that the bottom peripheral region (B) is the low temperature region, the middle central region (A1) is the high temperature region, and the transition region (A2) is between A1 and B. Therefore, the cluster analysis results statistically support the viewpoint derived from temperature distribution results, *i.e.*, air diffusion and convection were affecting aeration significantly during the composting process.

4.2 COMPOSTING PROCESS AND COMPOST PRODUCT

A successful composting process and good quality final compost depend on effective microbial activity supported by air, water (MC), nutrients such as nitrogen and phosphorus, micro-nutrients as well as a favourable pH level.

4.2.1 Moisture Content

The reason for choosing high initial MC conditions for this study is linked to the objective of reducing the bulking agent consumption. However, anaerobic conditions can be easily induced because of the difficulty in air circulation caused by high water proportion in the material matrix, especially in the pile bottom section where the compost is most compacted. Anaerobic symptoms include low temperature, below 35°C, generation of offensive odours, and low biodegradation rates (Haug, 1980). The temperature results from Treatments I, II and III have shown no evidence of anaerobic conditions in the piles. Thermophilic temperatures prevailed quickly in the compost piles, and, from on-site observations, there was no record of offensive odours. Thus, passive aeration was not obstructed by the high initial moisture content, which was 73, 80 and 76% for Treatments I, II and III, respectively.

Fig.4.15 shows that in Treatments I and II piles MC decreased most notably in the first 10 days the total reduction was 9 and 8%, respectively. For Treatment III a decline of about 37% in MC was recorded in the first 45 days, afterwards, MC remained at a relatively constant level of about 48%. On site, rising steam from each compost pile was observed. The decrease of MC from the compost could be attributed to water evaporation under high temperature. The lower MC decrease in Treatments I and II than in III was mostly related to the higher water holding capacity of the peat. Aeration is also considered as a factor in removing moisture during composting (Haug, 1980). As dry ambient air passes through the wet compost, it tends to absorb certain amount of moisture before leaving the system, the more the air passed, the higher the moisture removed. From this point of view, the straw treatments would have greater tendency to lose more water in this manner because of the larger particle size and, thus, larger pores than in the peat treatments. Nevertheless, this moisture reducing mechanism have only minor effect if air flow is small.

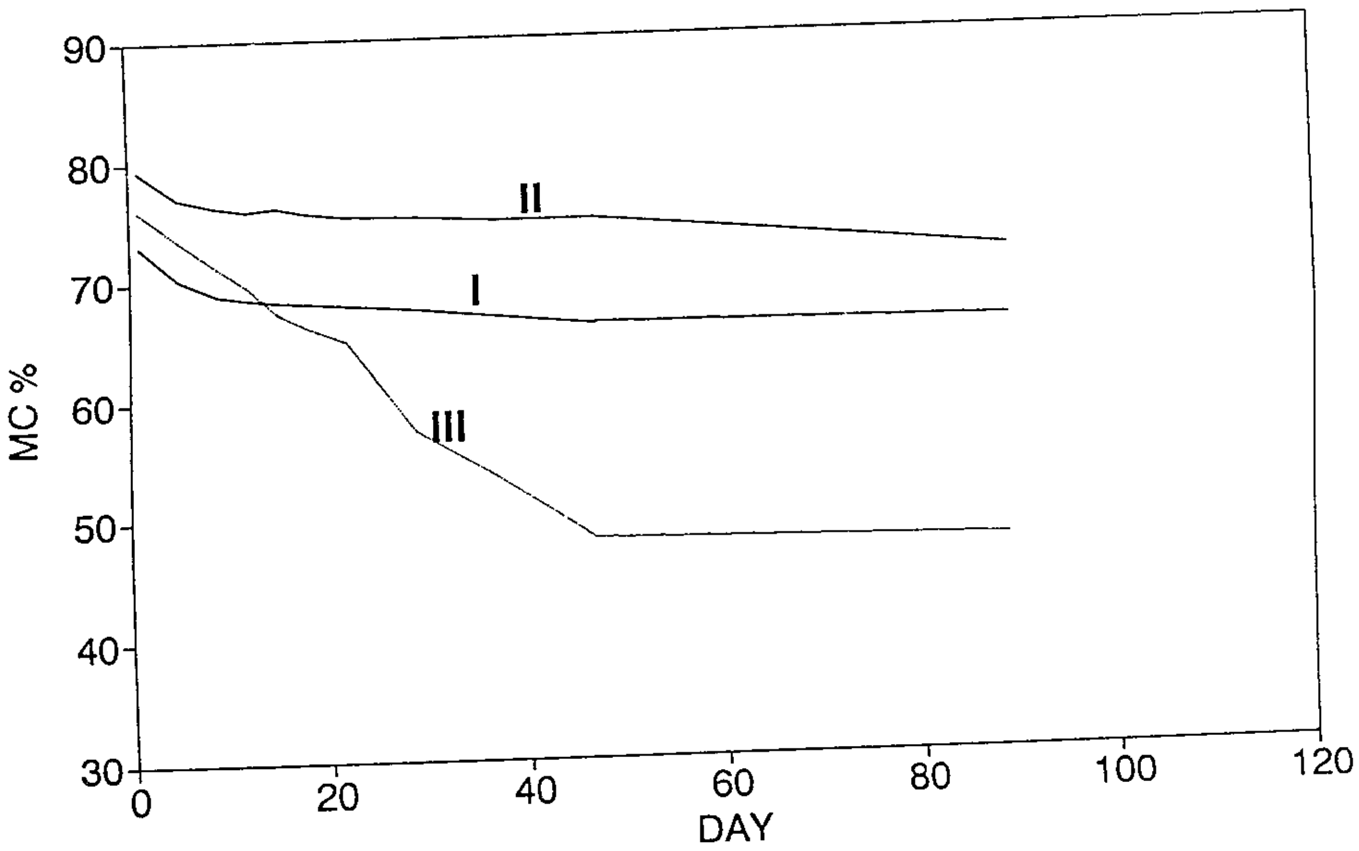

Fig.4.15 Moisture content variation during composting, Treatments I, II and III

There were differences in reduction of MC within the compost piles. As displayed in Fig.4.16, in Treatments I and II MC was reduced most in the pile top part and least in the bottom, the maximum difference was about 8% in Treatment II. This could be due to the lower temperature in the lower parts and higher temperatures in the upper parts of the piles. It can be seen from this figure that MC variation from top to bottom was smaller in Treatment I than in II, which indicates a more uniform aeration in the former than in the latter. For Treatment III, the straw treatment, Fig.4.17 shows that the highest MC was in the top, and the variation was as high as about 25%. This large MC divergence suggested that aeration condition was different in the straw piles from the top to the bottom. In comparison to the straw treatments, the smaller MC variation in the peat treatments suggests that aeration was more uniform in the latter. A possible factor related to the wet top situation in the straw compost was water vapour condensation at the interface, where rising warm and wetted air from inside the composting piles met with ambient cool dry air. However, it seems that further study is needed to put this scenario into a clearer perspective.

Moisture content is important during composting since it is essential for microorganisms to survive and grow. According to Golueke (1977), if MC is lower than 50%, microorganisms would not function appropriately. Therefore, if the MC is low in the compost products, there would be no guarantee that the

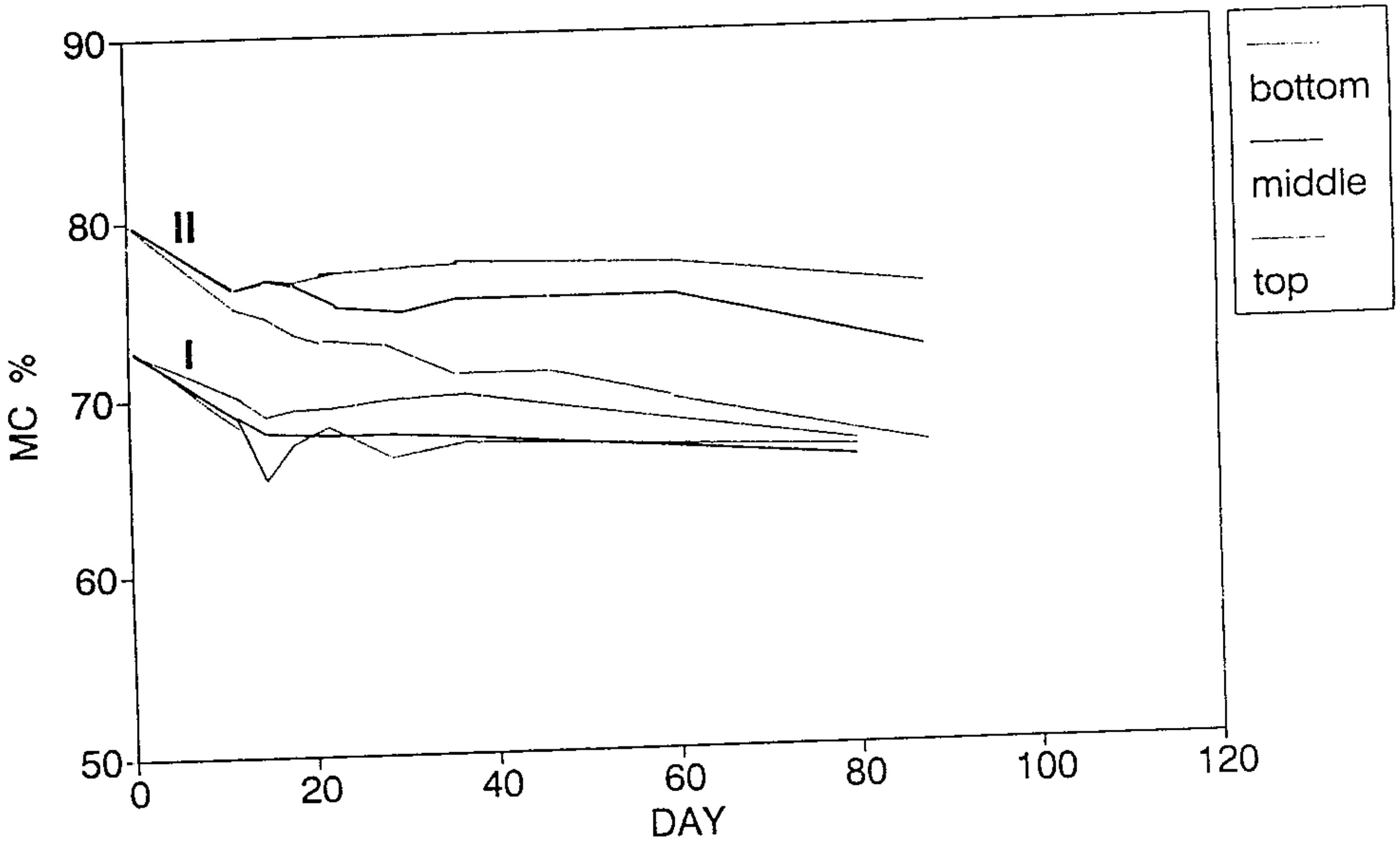

Fig.4.16 Moisture content variation within compost piles of Treatments I and II

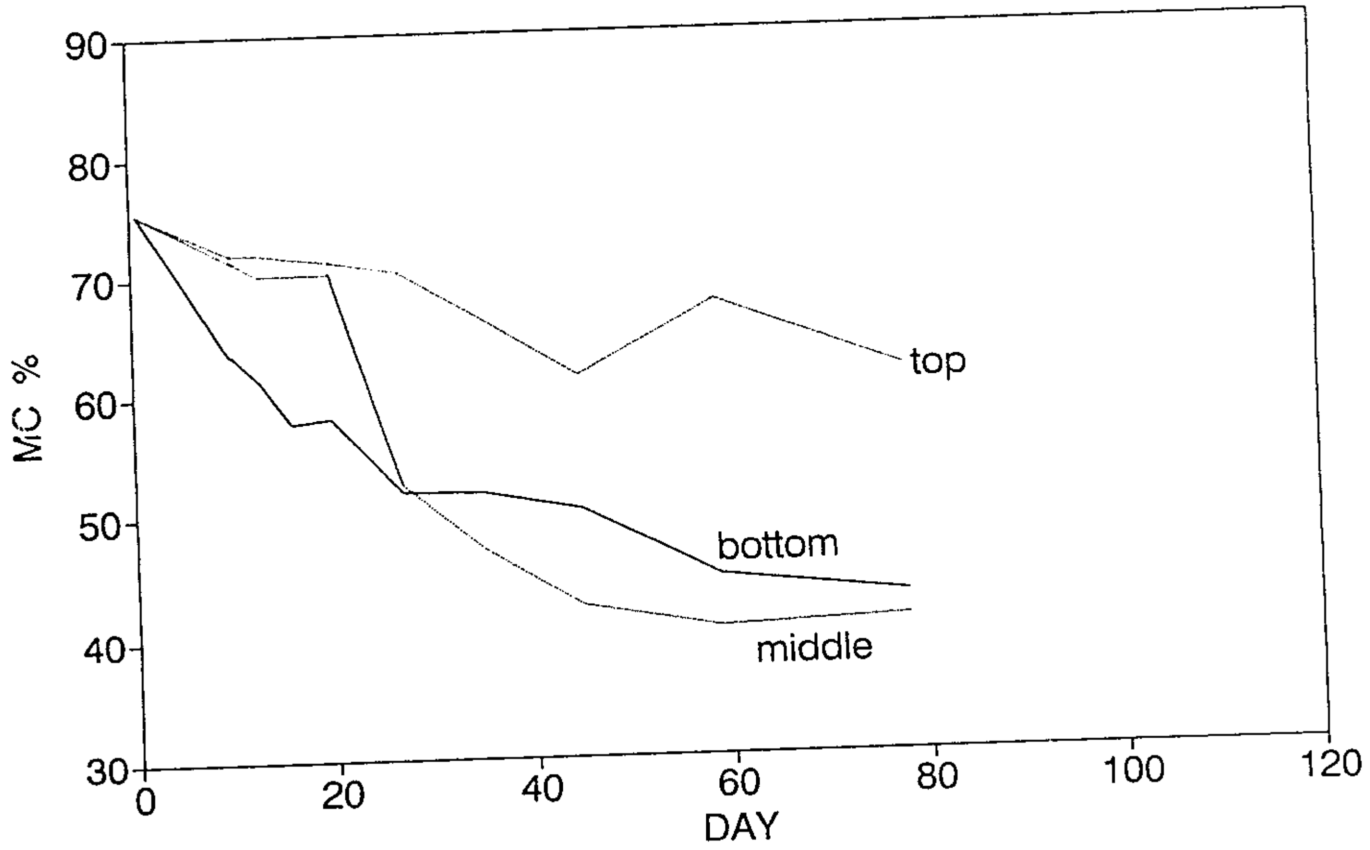

Fig.4.17 Moisture content variation within compost piles of Treatment III

composting process will be completed or the product matured. As a matter of fact, experience of compost reheating due to rewetting was reported by Haug (1980). In this regard, compost MC during the process should not drop below a certain level, for example 50 to 60%, so that the process may not be terminated by the limiting MC factor. Accordingly, the author suggests that final MC should be considered as a parameter for evaluating the overall performance of composting operations.

4.2.2 Mass Balance

Compost mass balance was calculated with phosphorus (P) data and material weight of each treatment. A necessary assumption is that P loss during the composting process was negligible. It is a valid assumption under the conditions of this study since (A) P compounds are not volatilized during composting, (B) there was no seepage from the composting piles that might have contributed to P loss in the water phase, and (C) after the compost pile were set up, there was no further material addition to them. Therefore, all the P should remain in the final compost. The rationale of mass balance based on P results is presented as follows.

Knowing initial total compost weight (Wt_{ini}, kg) and P concentration ($\%P_{ini}$) for each treatment, the total weight of P (P_{total}, kg), can be calculated as,

$$P_{total}(kg) = [\%P_{ini}]\ [Wt_{ini}] \tag{4.1}$$

If the change in P_{total} (kg) is negligible during the composting process as assumed above, the final total compost weight (Wt_{fnl}, kg) can be estimated with known final P concentration ($\%P_{fnl}$) using equation 4.1,

$$Wt_{fnl}(kg) = \frac{P_{total}(kg)}{P_{fnl}} \tag{4.2}$$

Therefore, the total compost weight loss (Wt_{loss}, kg) can be calculated with equation 4.3.

$$Wt_{loss} = Wt_{ini} - Wt_{fnl} \tag{4.3}$$

An example of moisture mass balance for Treatment I is given as follows

P concentrations and other necessary measurements for Treatment I were:

$\%P_{ini} = 0.9\%$ (dry matter)

$\%P_{fnl} = 1.2\%$ (dry matter)

$MC_{ini} = 73\%$

$MC_{fnl} = 67\%$

$Wt_{ini} = 1203$ kg (total weight)

Calculate the total phosphorus, P_{total} (kg), with equation 4.1,

$$P_{total} = 0.9\% \text{ x } (100\%\text{-}73\%) \text{ x } 1203 = 2.92 \text{ kg}$$

Based on the assumption, this P_{total} remained unchanged throughout the composting process. Since the final P concentration was 1.2% (dry matter), the final total compost weight is estimated using equation 4.2,

$$Wt_{fnl} = 2.92/(1.2\% \times (100\%-67\%)) = 737 \text{ (kg)}$$

With the analyzed results of $MC_{ini} = 73\%$ and $MC_{fnl} = 67\%$, moisture mass balance for Treatment I can be calculated as follows. First, calculate the initial moisture weight, $MC_{ini\text{-}wt}$ (kg),

$$MC_{ini\text{-}wt} = 73\% \times 1203 = 878 \text{ (kg)}$$

Secondly, determine the final moisture weight, $MC_{fnl\text{-}wt}$ (kg),

$$MC_{fnl\text{-}wt} = 67\% \times 737 = 494 \text{ (kg)}$$

The moisture mass balance is then calculated with equation 4.3,

$$MC_{loss} = MC_{ini\text{-}wt} - MC_{fnl\text{-}wt}$$

that is,

$$MC_{loss} = 878 - 494 = 384 \text{ kg}$$

The percentage MC loss is,

$$MC_{loss}\% = (384/878)100\% = 44\%$$

Table 4.4 presents the mass balance results for MC, VS, and ash (the initial and final concentration of these properties can be found in Tables 3.3 and 4.6). MC loss was much higher in Treatment III, 83%, than that in Treatments I and II, 44 and 52%, respectively. This result might be mainly related to the high temperature, over 70°C in most parts of Treatment III. VS loss was also the highest in Treatment III, 57%, while it was 25% in Treat-

Table 4.4 Mass Balance for compost Treatments I, II and III

TREATMENT		Moisture Content(M)	Volatile Solids(V)	Ash (A)	M+V+A (T)	Total Nitrogen(N)	Total Carbon(C)
I	Initial(kg)	878	282	38	1198	9	151
	Final(kg)	493	211	32	730	6	106
	Loss(kg)	384	71	6	468	3	45
	Loss/Initial	44%	25%	16%	39%	37%	30%
II	Initial(kg)	1379	272	63	1714	12	142
	Final(kg)	660	208	56	924	9	102
	Loss(kg)	718	64	7	790	4	40
	Loss/Initial	52%	24%	11%	46%	29%	28%
III	Initial(kg)	1044	259	57	1359	7	132
	Final(kg)	174	110	47	331	4	58
	Loss(kg)	870	149	10	1029	4	74
	Loss/Initial	83%	57%	17%	76%	50%	56%

TREATMENT	Ratios of loss (kg) of M, V, and A to T, and C, N to V				
	M/T	V/T	A/T	N/V	C/V
I	84%	15%	1%	5%	63%
II	91%	8%	1%	6%	63%
III	85%	14%	1%	2%	50%

ment I and 24% in II. Most likely, peat was hardly biodegraded due to its high biological maturity, while the chopped straw was new biologically unstable, hence it was partly decomposed. Since VS is largely composed of organic matter, decomposition of carbon-hydrogen organic compounds is the main driving forces for VS loss. In Treatments I, II and III ash loss was 16, 11 and 17%, respectively. This could be the result of the conversion of a fraction of ash (defined as the solids fixed at 550°C) from non-volatile to volatile during the process. Similar result was reported by Patni and Jui (1987).

The combined loss of MC, VS and ash (the M+V+A column in the table) can be regarded as the total compost loss. The M/T, V/T and A/T ratios in the lower part of Table 4.4 show that out of the total compost weight reduction, MC loss made up of over 80%. The highest MC loss of 83% occurred in Treatment III, and so did the highest total compost reduction, 76%. While the lowest MC loss of 44% eventuated in Treatment I, so did the lowest total compost weight decline, 39%. Ash made up only 1% of the total loss because most components in ash are stable during composting.

4.2.3 Carbon and Nitrogen

For microorganisms in a composting system carbon is the source of energy and nitrogen is one of the most important nutrient. C/N ratio is often used as a parameter for evaluating the speed of composting reactions (Schuchardt, 1987).

A proper starting C/N ratio is indicated by a fast process start. For the specific conditions of this study the quick temperature rise in each treatment revealed that the initial C/N ratios, ranging from 13 to 20, were appropriate for the composting process. Listed in Table 4.4 are carbon and nitrogen loss, which is mainly due to CO_2 and NH_3-gas emission. As part of VS loss, C comprised over 50%, and N up to 6%.

Nitrogen loss from Treatments I, II and III were 37, 29 and 50%, respectively. The comparatively lower N loss from the peat treatments could be associated with the lower pH (6.3 and 7.2) of the compost, whereas the higher pH (7.9) in Treatment III could be one of the factors for the higher N loss. Chemically, lower pH is favourable for retaining ionized ammonia nitrogen in the aqueous state, while higher pH tends to cause release of NH_3-N from the system in the gaseous form. Therefore, the peat used to cover the piles of Treatments I and II would be capable of absorbing significant amount of NH_3-N because of its low pH of 3.8, thus, reducing N loss from the compost. Higher temperature also stimulates N loss, which could be the case for Treatment III. C/N ratio is another factor influencing N loss. A rule of thumb is that the lower the C/N ratio, the higher the N loss. However, among the three compost treatments the lowest N reduction, 29%, occurred in Treatment II, which had the lowest C/N ratio, 13. Hence, C/N appears to have little effect on N loss for this case. A possible reason for this result was that NH_3-N was mostly in the ionized form under the low pH condition in Treatment II rather than being released from the pile as ammonia gas. Furthermore, N loss is reduced when most of the ammonia nitrogen (NH_3-N) is nitrified to NO_3-N later in the process.

Nitrogen loss was lower in Treatment II than that in Treatment I, although pH was lower in the latter, 6.3. The higher MC was most likely the reason behind this occurrence. This can be supported by the results shown in Fig.4.18. Both NH_3-N and NO_3-N were higher in the parts of each treatment where MC was higher. For example, the ratios of $(NH_3\text{-}N)_{max}/(NH_3\text{-}N)_{min}$ and $(NO_3\text{-}N)_{max}/(NO_3\text{-}N)_{min}$ were computed to be 13 and 15 for Treatment III, in which the largest MC variation occurred as shown in Fig.4.17. The same ratios were not higher than 1.8 and 3.3 in Treatments I and II, which were in agreement with their smaller MC variation (Fig.4.16). This result indicates that higher MC conditions for animal waste composting would be potentially beneficial for N conservation.

As expected both NH_3-N and NO_3-N concentration increased significantly, refer to Tables 3.3 and 4.6. In Treatment II NH_3-N augmented from 0.5 to 2.8%, and NO_3-N 0.001 to 0.32%. These results demonstrates that most of NH_3-N and NO_3-N (the inorganic forms of nitrogen) resulted from conversion of organic N. The calculated ratio of NH_3-N plus NO_3-N to total N for Treatments

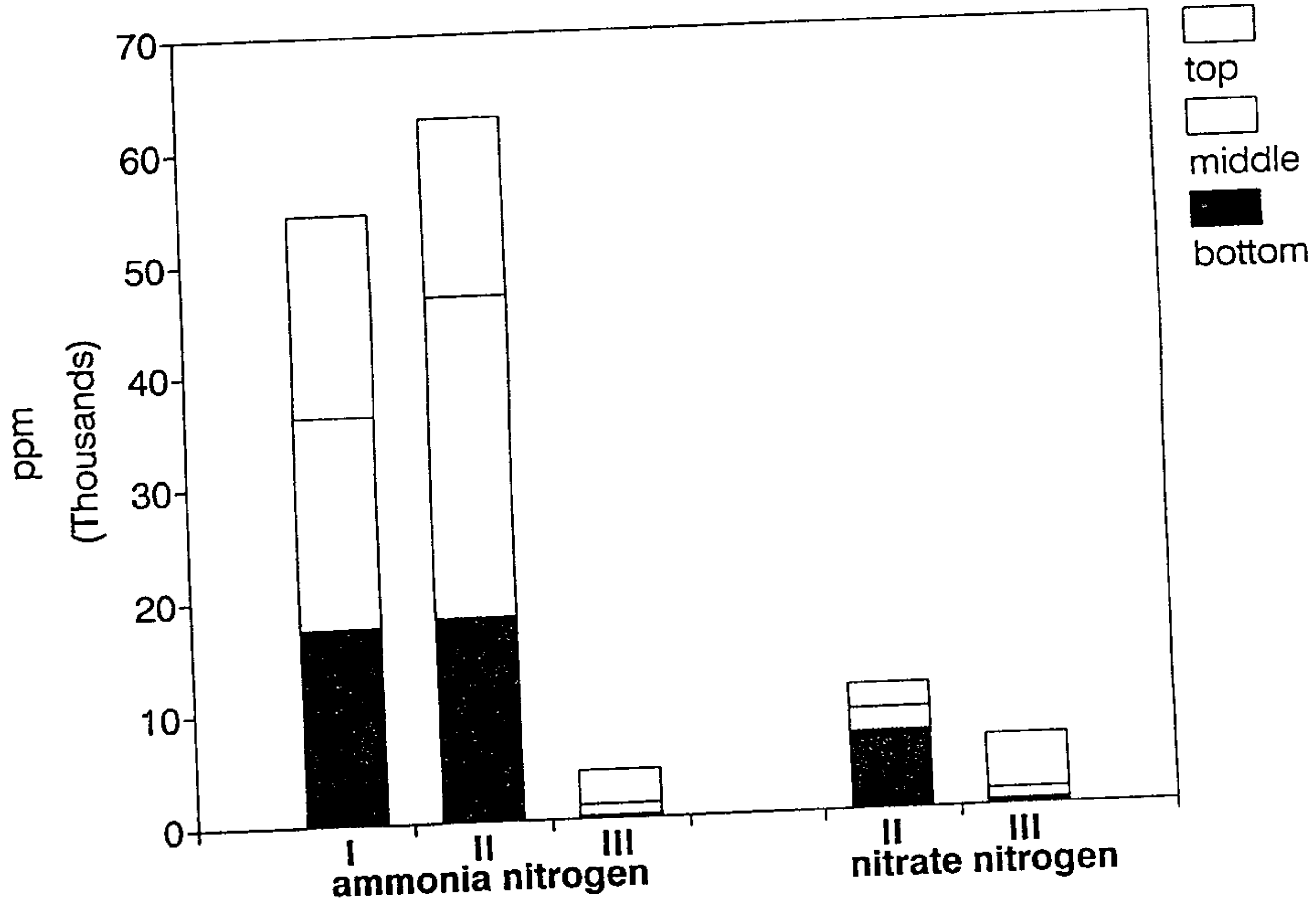

Fig.4.18 Ammonia and nitrate nitrogen variation in compost piles of Treatments I, II and III (final values)

I, II and III increased from 5, 16 and 3% to 75, 79 and 13%, respectively. The higher increase in Treatments I and II indicate that more NH_3-N and NO_3-N were conserved in the peat treatments than in the straw treatments, possibly as a result of NH_3-N loss. Fig.4.19 shows that NH_3-gas released from Treatment III was as high as 210 ppm, and it was much higher than that from Treatments I and II, where the maximum value was 10 and 60 ppm, respectively. Fig.4.20 shows that NO_3-N actually started building-up only after about 37 days when temperature had dropped below 40°C, similar results were attained by Finstein *et al.* (1980). It appears that nitrification microorganisms are most active in the mesophyllic temperature range.

4.2.4 pH

As Fig.4.21 shows, there was a sharp pH increase, over 8.5, within the first 5 days. According to Golueke and McGauhey (1953), pH increase in the early stage of composting is mostly due to decomposition of amino acids, production of NH_3/NH_4^+, and release of CO_2. In Treatments I and II pH levelled off around 8.7 for a period of about 35 days followed by a gradual drop to 7.6 and 7.3, respectively. The pH of Treatment III kept consistently increasing and reaching the alkaline level of 9.6. Sustainable pH situation is important for composting microbes to grow. Apparently, the initial pH range of 6.3 to 7.9 in the treatments were suitable for microbial activity so that the process could have a fast start.

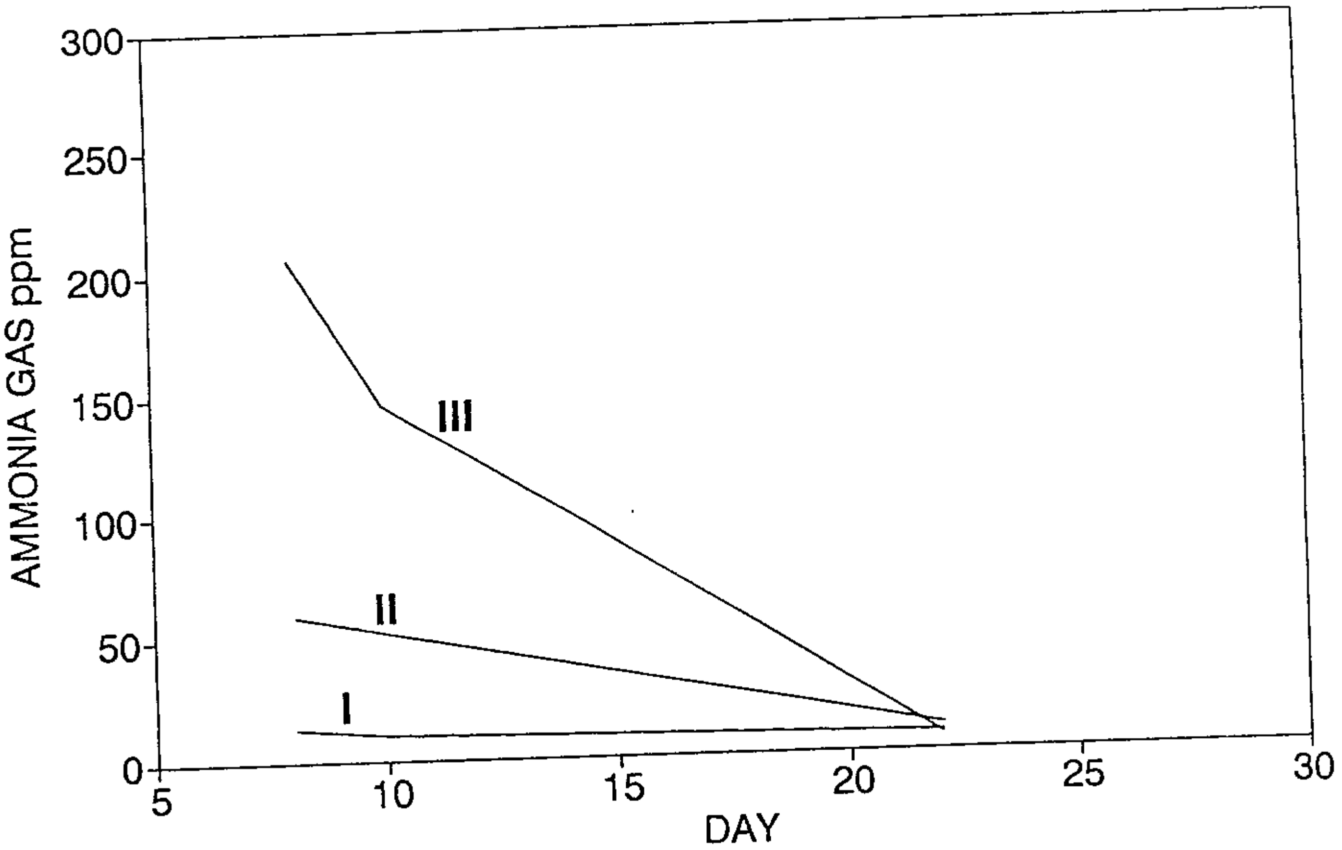

Fig.4.19 Released ammonia gas from compost piles of Treatments I, II and III

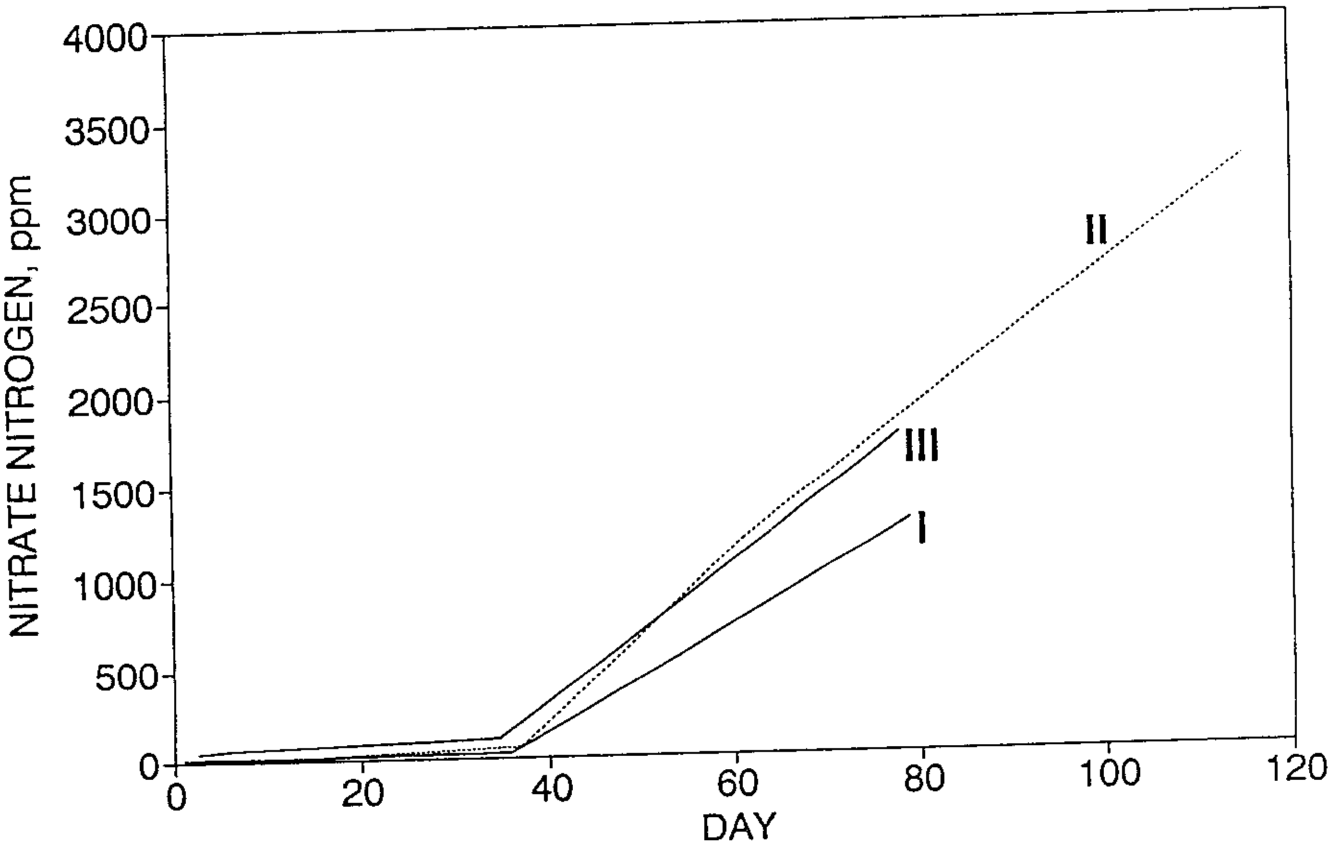

Fig. 20 Nitrate nitrogen variation in Treatments I, II and III

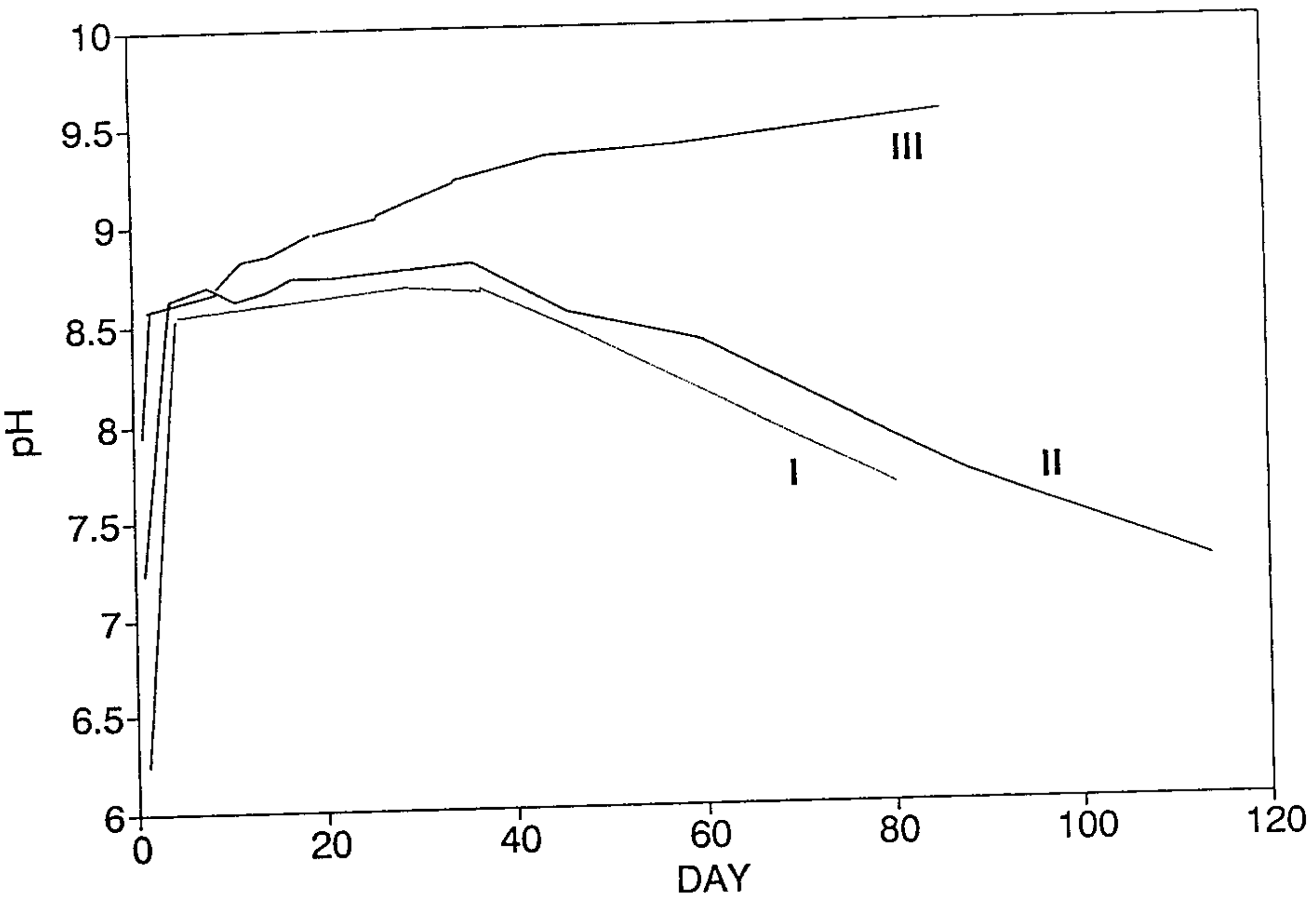

Fig. 21 pH variation in compost Treatments I, II and III

4.2.5 Correlation Analysis

Correlation coefficients between the parameters monitored and measured over the entire composting period are calculated by linear regression using the data in Appendix C. The significant correlations with 99% confidence are listed in Table 4.5, the plus sign refers to positive correlation, and the minus sign negative correlation. For the following discussion, the results in Tables 3.3 and 4.6 should be referred to.

MC is positively correlated to VS, NH_3-N, and total N concentration. This is because that higher MC essentially resulted from larger amount of poultry manure slurry in the compost, which in turn provided a higher proportion of VS and N as well as NH_3-N in the compost. The positive correlation between VS and C indicated that the carbon reduction during composting was mainly related to the part of VS that was biodegraded. Due to relatively higher reduction of VS in comparison to ash, the latter showed an increase in its concentration, which was the reason for the significant negative correlation between these two components. Similar to ash, during composting, the phosphorus concentration increased due to the decrease of total dry matter, therefore, P and ash are positively related to each other. The correlation between ammonia nitrogen concentration, NH_3-N, and pH as well as temperature is negative. This is an indication that NH_3-gas release was mainly under the condition of high pH and high temperature.

Table 4.5 Significant correlations among compost propreties

	Moisture Content	pH	Temperature	Total Carbon	Ash
Ammonia nitrogen	+	-	-		
Volatile solids	+			+	-
total nitrogen	+				
total phosphorus					+

\+ positive correlation

\- negative correlation

4.2.6 Compost Product

The characteristics of the end compost products from each of the treatments are listed in Table 4.6, the initial values are reported Table 3.3. The required minimum nitrogen-phosphorus-potassium (NPK) nutrient value for finished compost is 1.05% according to the MOE (1991) guideline. Comparatively high NPK values were observed in the compost products of this study, minimum 4.7% in Treatment I and maximum 10.5% in Treatment III. The fertilizer ratio in the last line of Table 4.6 is the standard expression of N-P_2O_5-K_2O results in terms of the lowest common denominator (Janick *et al.*, 1981). It is 3-3-1 in the compost from Treatments I and II, which is relatively rich in nitrogen and phosphate, and 1-2-2 in the compost from Treatments III and IV, which is comparatively rich in phosphate and potash. Application of the compost for any soil improvement or plant production purposes should be based on this ratio.

The difference among the products can be discussed by comparing the two bulking agents, peat and straw. In many aspects peat performed as a better bulking agent than straw. These include higher MC, 66 and 73%, lower pH, 7.6 and 7.3, and less N loss. In addition, compost products from the peat treatments have dark-brownish colour, earthy smell and loose structure, which are physically superior to that from the straw treatments. The efficiency of the bulking agents, defined as the amount of poultry manure slurry that can be added per unit weight of dry matter bulking agent favours the peat. Refer to

Table 4.6 Characteristics of the compost products for each treatment

PROPERTY	TREATMENT I	TREATMENT II	TREATMENT III	TREATMENT IV
Moisture Content %	66	73	48	34
Volatile Solids % dry matter	86	76	69	74
Ash % dry matter	13	20	30	25
pH water extract	7.6	7.3	9.4	9.6
Carbon % dry matter	43	39	36	38
Nitrogen % dry matter	2.8	4.0	3.0	2.3
Phosphorus % dry matter	1.2	1.9	2.2	1.5
Potassium % dry matter	0.7	1.2	5.3	4.2
ammonia nitrogen % dry matter	1.97	2.80	0.22	0.14
nitrate nitrogen % dry matter	0.13	0.32	0.17	0.09
Fertilizer Ratio* dry matter	3-3-1	3-3-1	1-2-2	1-2-2

* nitrogen - phosphate - potash in terms of the lowest common denominator

Table 3.2, the highest peat efficiency of 9.5 in Treatment II could still be increased according to water holding capacity test (Section 3.1.1). While the straw efficiency of about 4.5 was nearly at the maximum level.

The final pH of Treatment III product was 9.4, which maintains an uncertainty in terms of its effect on microbial activity. It might be too high because many microorganisms would have difficulties growing under such alkaline conditions. However, Beaudet *et al.* (1990) reported that thermophilic aerobic microbes could grow well even at pH 9.5. Nevertheless, detailed pH changes during composting has not yet been investigated.

Safety aspect is a common concern about the use of compost products. It is mostly related to deactivation of pathogens and increase of metal concentration. In general, pathogens are eliminated very quickly under thermophilic temperatures (Golueke and Gotaas, 1952). However, there is limited information for setting up technical standard for destruction of pathogens during composting. The only mandatory standard by USEPA (1981) requires raising temperature to 55°C and maintaining it for 3 days. The temperature results from each treatment (Section 4.1.1) show that in most parts of the compost piles, this standard was complied. However, additional perforated pipes are needed for the bottom central portion of the pile of Treatment II.

Table 4.7 includes the results of Cd, Cr, Cu, Mo, Ni, Pb, and Zn for the compost products as well as the guidelines for Ontario, Canada (MOE, 1991), Austria (Lau and Wu, 1987) and Switzerland (Obrist, 1987). It can be seen that metal levels in the final compost products are below the maximum level of these guidelines. Therefore, the produced compost may be considered as safe for applications.

The volume of the compost piles was reduced significantly. 26, 35 and 56% reduction was observed for Treatments I, II and III, respectively.

4.2.7 Process Duration and Stability

Process duration can be estimated as the period of time during which temperature stayed above the ambient level. Although this measure tends to be longer than the true processing time because of the time required for naturally cooling down the heated compost, it is acceptable for safety reasons. Temperature drop back to ambient level is an indication of compost maturity. Fig.4.22 shows the profiles of the average temperature in each treatment. Between the two peat treatments, I and II, the composting process lasted longer in II, about 90 days were taken for temperature to return to ambient levels. While it was much shorter, about 30 days, for Treatment I. Reasons for this variation could be multifold, but essentially, it was the different amount of poultry manure slurry processed in each treatment. Based on the data in

Table 4.7 Metals in the compost products

metal (ppm) dry matter	Treatment I	Treatment II	Treatment III	Treatment IV	GUIDELINES	
					Austria*	MOE***
Cd	0.2	1	-	0.2	1	3
Cr	3	-	6	5	50	50
Cu	14	34	30	21	100	60
Mo	2	4	-	3	5**	2
Ni	3	8	8	5	30	60
Pb	4	-	-	0.3	50**	150
Zn	113	289	207	161	300	500

* Austria guideline, Lau and Wu (1987)
** Switzerland guideline, Obrist (1987)
*** Ontario guideline, MOE (1991)

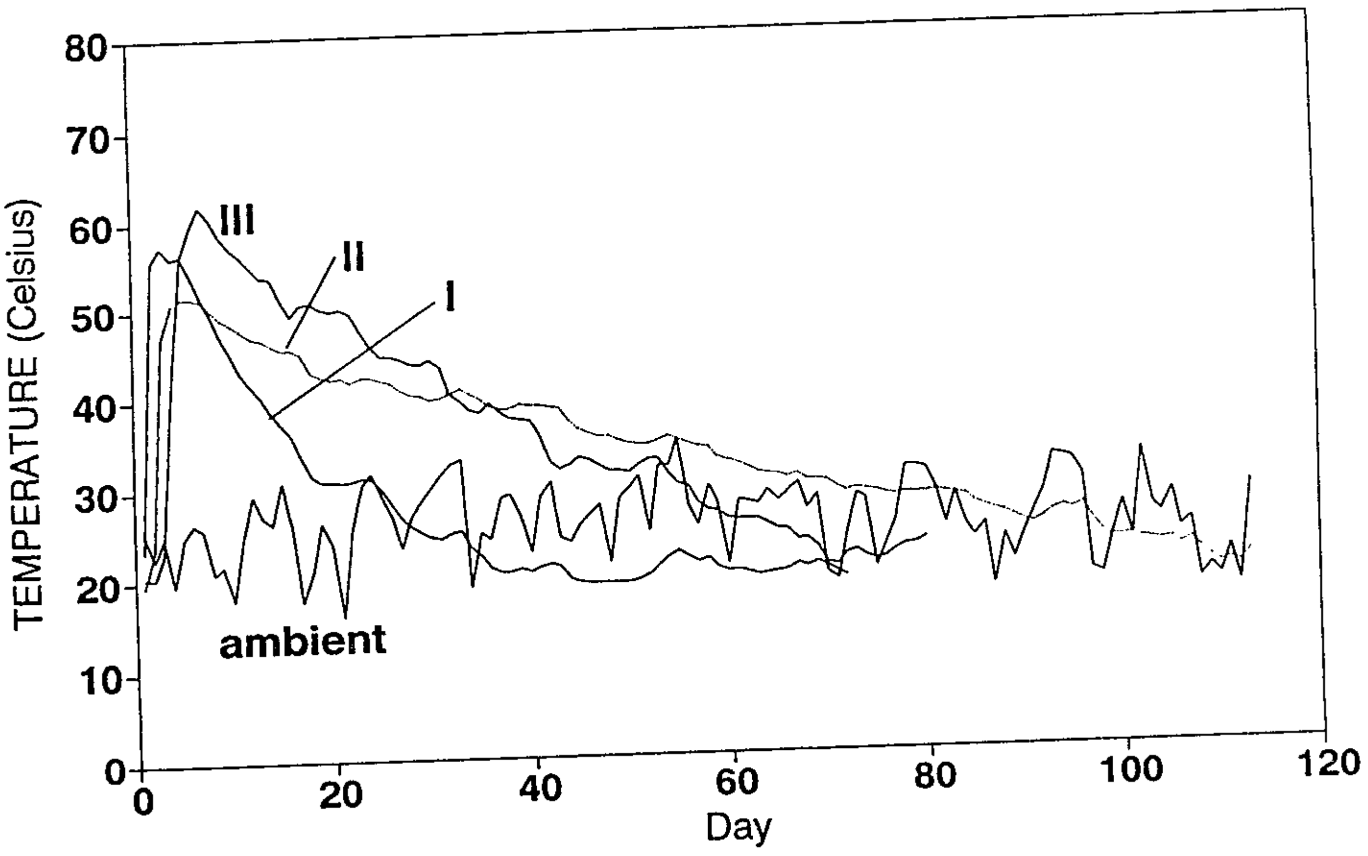

Fig.4.22 Average temperature profiles for Treatments I, II, III and ambient

Table 3.2 the ratio of poultry manure slurry to peat in Treatment II was 4.5, while it was 1.5 in Treatment I. That is to say that 3 times more poultry manure slurry (4.5/1.5=3) was treated in Treatment II than in I. Because of this, Treatment II compost would need longer processing time or higher aeration rate to accomplish the same degree of stabilisation as that in Treatment I. However, its higher bulk density, 513kg/m^3, and lower compost porosity should have resulted in a lower aeration rate, which was compensated by a longer process duration, about 3 times longer than that for Treatment I. It may be assumed that a higher aeration rate for Treatment II would shorten the process duration.

The average temperature above the ambient level in Treatment III lasted about 65 days. Nevertheless, it needs to be addressed that for the straw treatments temperatures in most parts of the piles were higher than 70°C for some time, which might have caused a process slow-down because of the possibly restrained activity of microorganisms under such high temperatures. Schultz (1962) and Golueke (1977) reported similar observations in their studies. Yet this is still an uncertainty as far as this study is concerned.

Three replicates for each composting treatment were tested in parallel during the same period and monitored with the same properties. This was done to confirm the process stability. An examples of the visual similarities among the average temperature of the three replicate piles of Treatment II is shown in Fig.4.23. The average correlation coefficient among the three profiles is calculated to be 0.977, similar calculation for Treatments I and III results in 0.999 and 0.978. All of these values are 99% significant confirming the close similarity among the replicates. Visual similarity can also be seen from other measured compost properties, for instance, MC, VS and pH as shown in Figs.4.24, 4.25 and 4.26. These results suggest that the performance of the SPPAC system is reproducible, and the outcome of this study are reliable and may be used to predict composting performances under similar operational conditions.

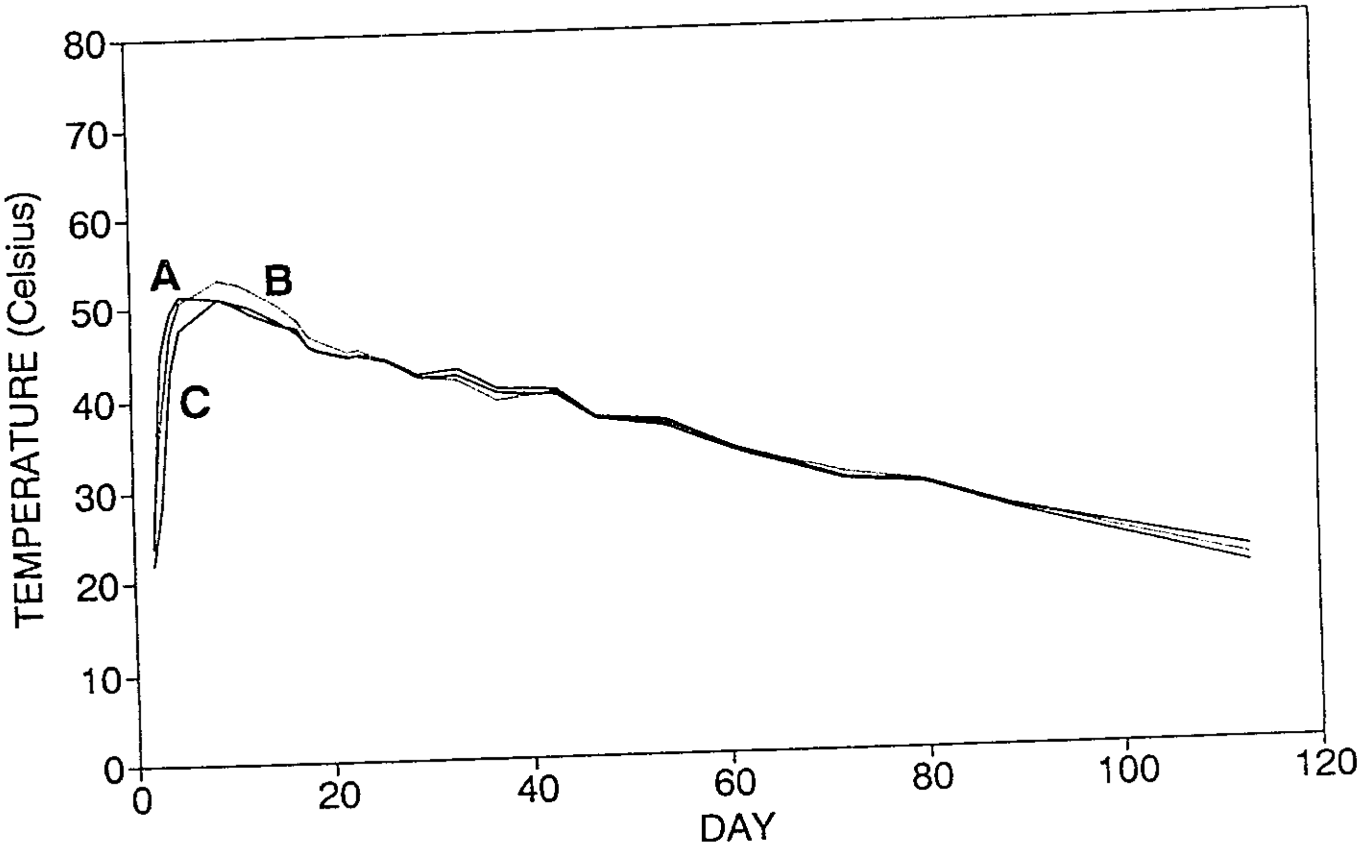

Fig.4.23 Average temperature profiles for the three replicate compost piles (A, B and C)of Treatment II

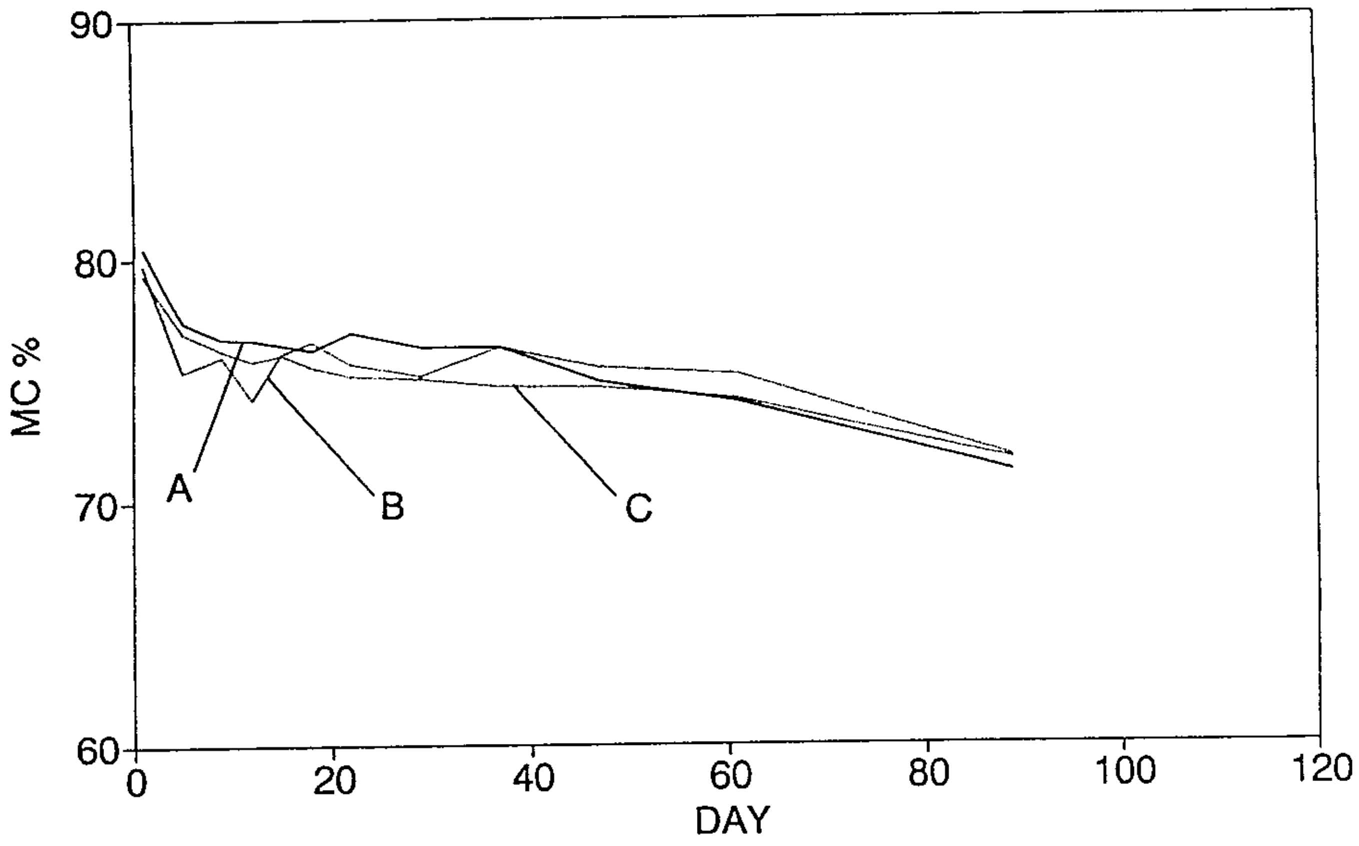

Fig.4.24 Moisture content results from the three replicate compost piles (A, B and C) of Treatment II

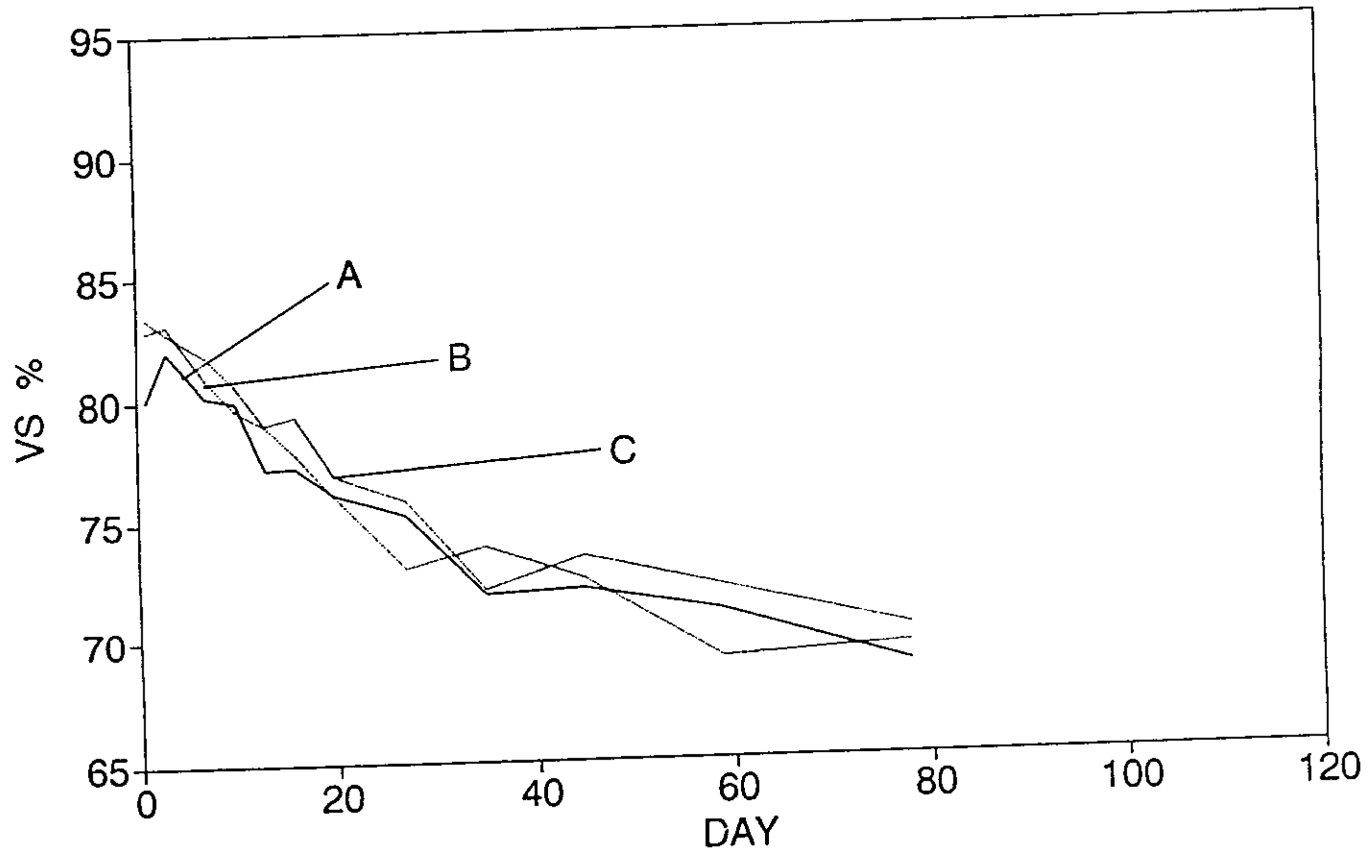

Fig.4.25 Volatile solids results from the three replicate compost piles (A, B and C) of Treatment III

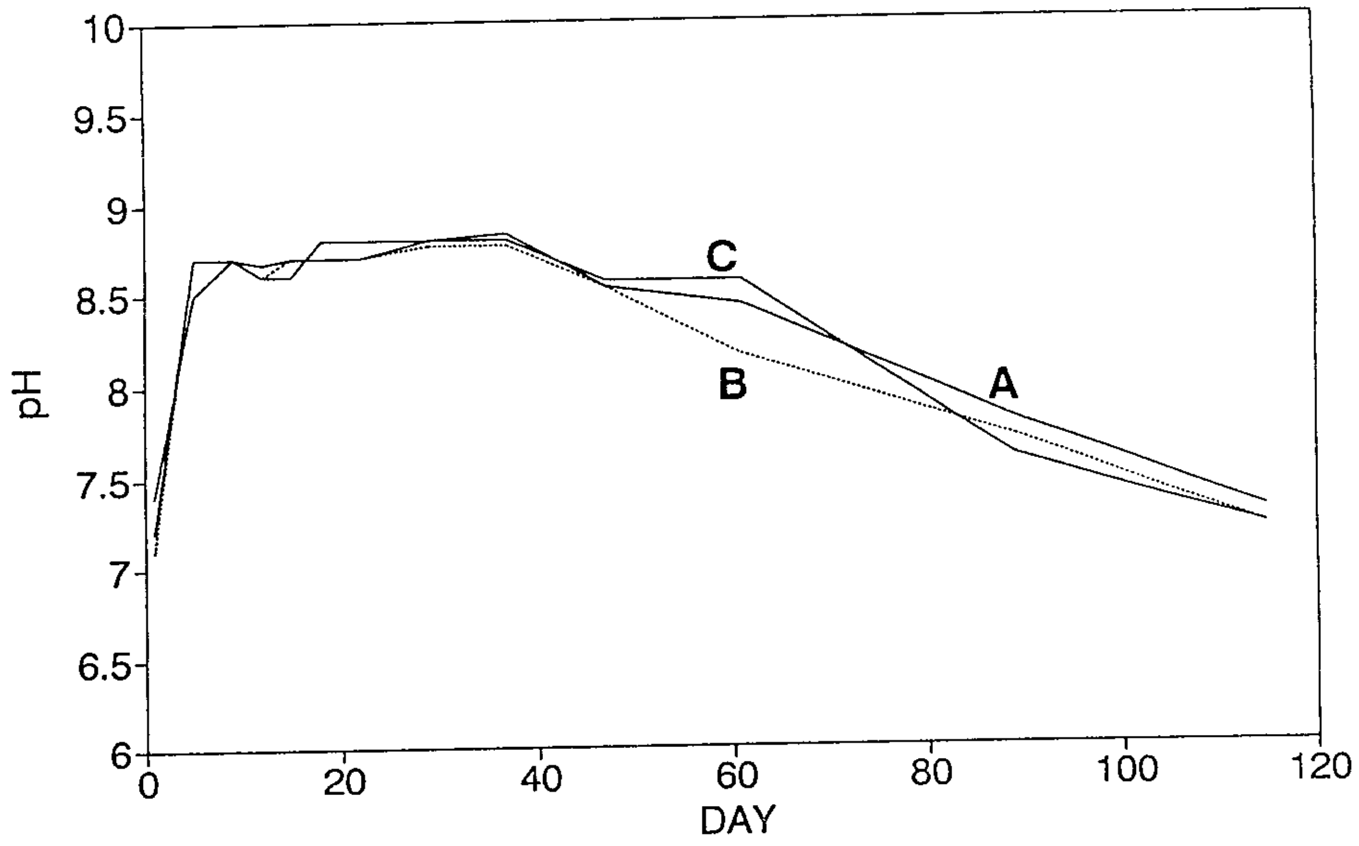

Fig.4.26 pH results from the three replicate compost piles (A, B and C) of Treatment II

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Static pile passive aeration composting was successfully used in treating poultry manure slurry under high moisture content conditions between 72 to 80%. The temperature monitoring results were used to derive information on the passive aeration method. The SPPAC process started fast, progressed stably, and ended with high quality compost products.

High temperatures up to 70°C occurred within the first 2 to 5 days in the peripheral parts of the compost piles and later in the interior parts. This result was an indication that the passive aeration was effective and air diffusion and convection through compost pile were important aeration factors. The aeration effect from the pipes was limited to their vicinity. There were signs of limited air supply in the bottom centre of the Treatment II piles, where temperatures could not rise over 45°C, and it was compensated by a long processing time, over 100 days.

Distinctive two-peak configuration temperature profiles were recorded in the compost piles with chopped straw used as the bulking agent. This occurrence was most likely due to partial decomposition of the chopped straw during composting.

Cluster analysis classified the recorded temperature profiles, 33 from each pile, into 3 temperature development zones, *i.e.*, the pile core, the region that surrounds the core and the lower periphery region of the piles. These results depict the phenomenon that the cooler ambient air diffused into the compost piles mainly through the lower parts to fill the void created by the convective movement of heated air in the compost.

The quick start of the composting process in each pile confirmed that the initial conditions including moisture content, 72 to 80%, C/N ratio, from 13 to 20, and pH, 6.3 to 7.9, were in the appropriate range.

The peat was a better bulking agent than the chopped straw in terms of higher water holding capacity, lower nitrogen loss, and superior product quality with respect to neutral pH, dark-brownish colour, earthy smell and loose structure.

Initial total compost mass was reduced by 39, 46 and 76% for Treatments I, II and III, respectively. 99% of the total reduction was due to loss of moisture and volatile solids. As part of volatile solids reduction, carbon comprised over 50% and nitrogen was lower than 6%. The volume reduction of the compost piles was 26, 35 and 56% for Treatments I, II and III, respectively.

The duration of the composting process was related to the amount of poultry manure slurry in each treatment. It was 30, 90 and 65 days for Treatments I, II and III, respectively.

The final compost product contained high nutrient values, the total of nitrogen-phosphorus-potassium concentration was between 4.7 and 10.5%. The product from Treatments I and II was relatively rich in nitrogen and phosphate, while the product from Treatment III was comparatively rich in phosphate and potash. The concentration of metals including Cd, Cr, Cu, Mo, Ni, Pb, and Zn in the final compost products are below the guideline levels.

The reproducibility of the performance of the composting process in each treatment was confirmed by the significant correlations and similarities in terms of the observed temperatures, moisture content, volatile solids and pH among the three replicate compost piles.

5.2 RECOMMENDATIONS

Based on the results from this study, optimum working conditions of the static pile passive aeration composting process still need to be examined in terms of the perforated pipe layout in accordance with the initial moisture content. Shorter processing time may be achieved along with an improved aeration set-up improvement. Lower nitrogen loss may be achieved by using a thicker peat cover compost piles.

The following studies are recommended for future work on the SPPAC method. (A) To evaluate the feasibility of using SPPAC method for large scale operations, different types of wastes and bulking materials under various initial MC conditions; (B) to determine the correlation between moisture level and composting reaction rate to estimate the limiting moisture condition; (C) to compare the operational costs and nitrogen loss among the SPPAC, forced aeration, and windrow methods; (D) To test SPPAC operation under cold weather conditions.

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Appendix A

Thermocouple Layout, Type B

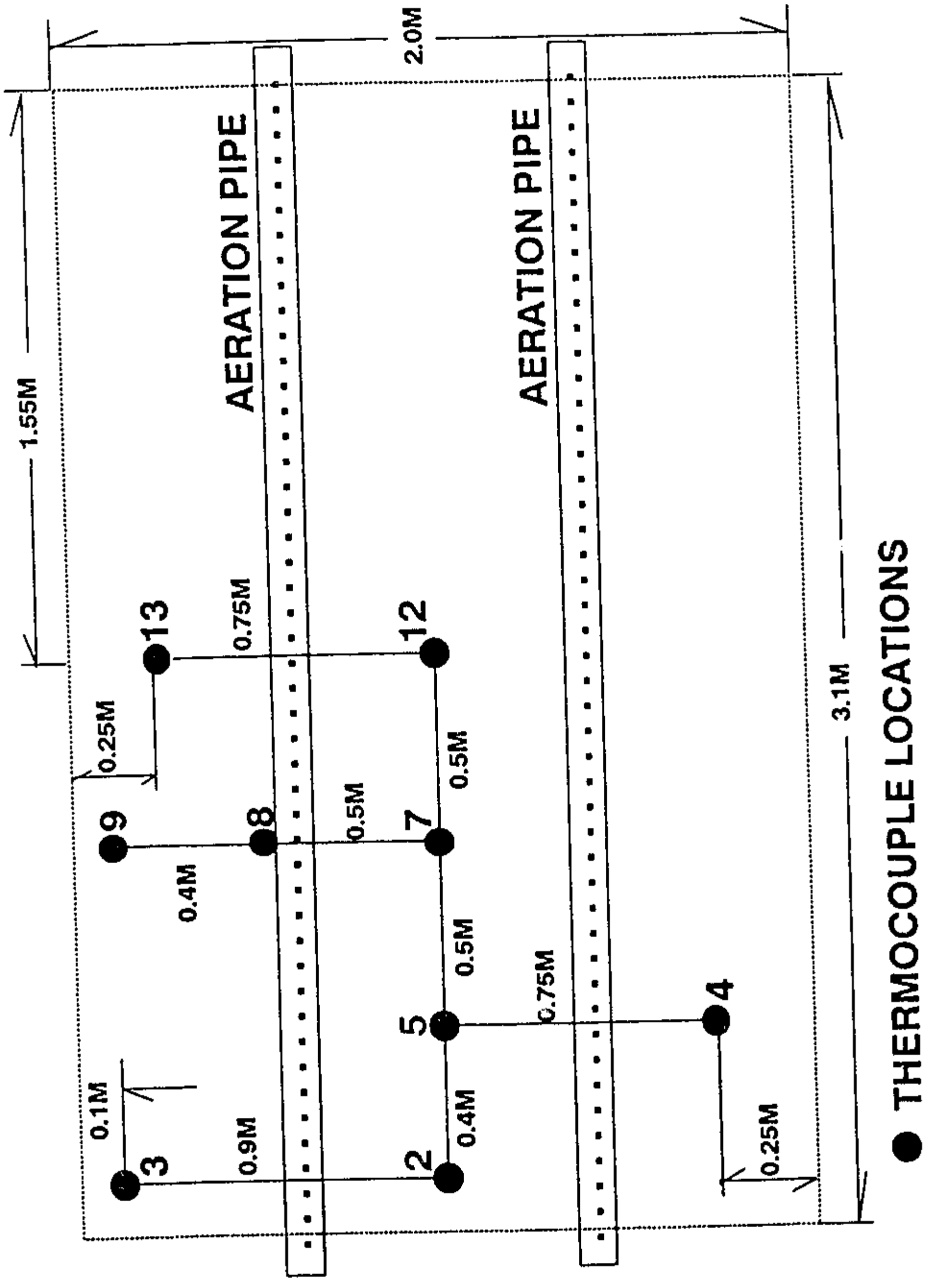

Fig. 1 Thermocouple layout, Type B, bottom frame

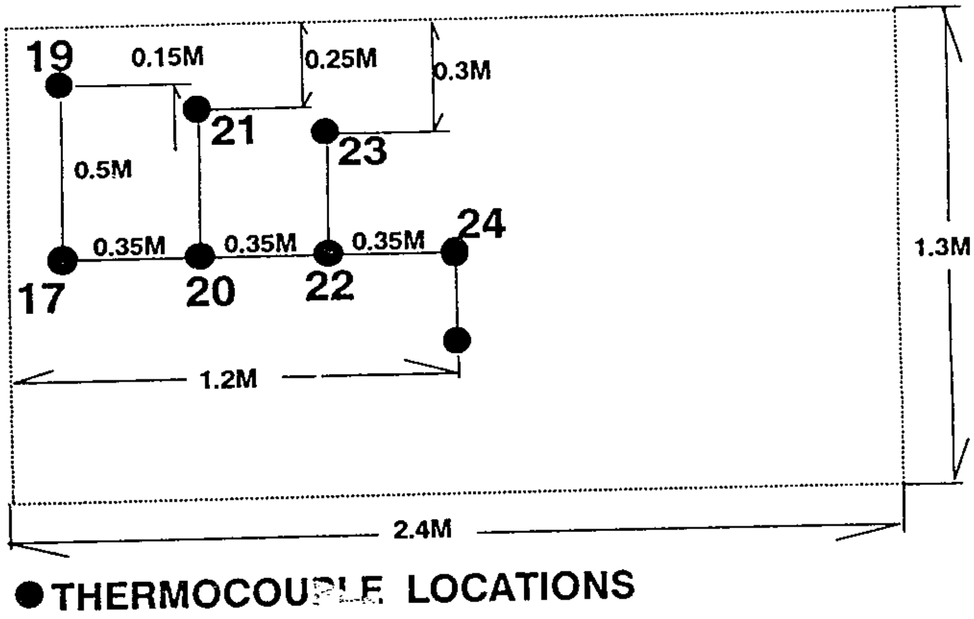

Fig. 2 Thermocouple layout, Type B, middle frame

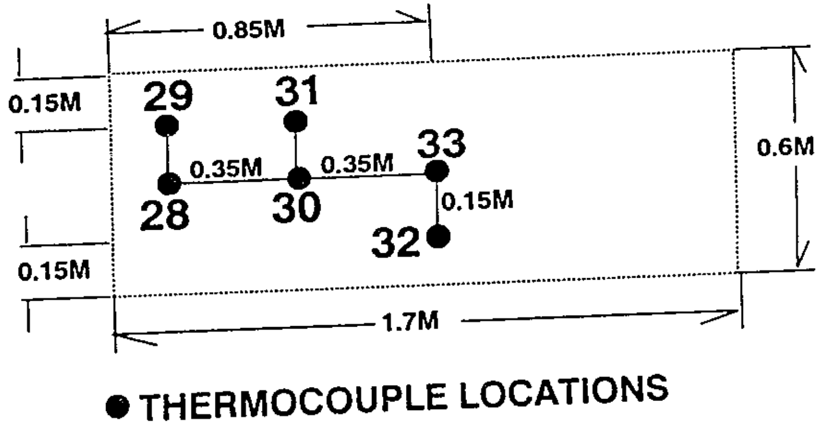

Fig. 3 Thermocouple layout, Type B, top frame

Appendix B

TEMPERATURE DATA

bottom (bot), middle (mid) and top (top) locations: (1)-(34)

Treatment I

	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)	(11)	(12)
day	bot	bot	bot	bot	bot	bot	bot	bot	bot	bot	bot
1	22.1	15.7	20.7	21.5	18.9	18.8	13.9	18.7	21.7	20.8	20.2
2	20	18.7	19.1	19.9	18.5	18.7	17.2	18.5	19.9	20.1	19.6
3	21.7	20.3	20.4	22.8	20.5	20	19	19.8	22.4	24.2	21.6
4	29.4	43.3	30.8	44.8	36.8	22.6	38.7	40.3	41.8	45.7	24.2
5	30.3	64.5	31.5	53.2	48.8	27.7	50	52.5	49.5	50.7	29.6
6	23.9	50.5	22.9	40	62.1	41.4	61.9	37.7	38.1	70	39.7
7	22.1	42.6	20.6	33.6	62.2	48.7	61.4	33	32.8	63.4	46.8
8	19.5	37.9	18.3	29.7	60.5	52.2	57.2	29.9	29	58.3	52.6
9	19.4	34.3	17.9	27.7	56.4	54.4	53.6	28.1	27.2	54.6	54.7
10	18.7	31.6	18	25.9	52.1	55.3	50.5	26.7	25.5	51.3	-
11	20.4	29.7	18.2	25.2	48	-	47.8	25.9	24.9	48.9	-
12	22.5	28.7	19.9	24.6	44.6	61.5	44.1	25.4	24.5	46.3	-
13	21.6	27.7	19.7	24.2	41.9	59.3	41.2	24.8	24.2	43.7	61.6
14	21.6	25.9	19.4	22.9	40	55.9	39.7	23.2	22.9	41.4	62.5
15	25	25.2	22	23.6	37.7	52	36.7	23.5	23.7	38.8	58.7
16	22.6	25.3	20.5	23.9	35.7	48.7	35.1	23.5	23.8	37.1	54.4
17	16.6	23.8	16.5	22	34	46.1	33.7	21.7	21.8	35.1	50.9
18	17.8	21.4	15.9	19.4	32	43.7	31.7	19.3	19.8	32.8	47.9
19	21.2	20.8	18.1	19.4	30.2	41.8	30.6	19.4	20.2	31.8	46.2
20	22.4	21	20.2	20.1	29	40.3	29.7	20.2	20.9	31.4	45.5
21	17.4	21.4	17.3	20.1	28.6	38.7	29.8	20	20.7	31.6	44.9
22	21.6	21.2	20	21.2	28.3	37	29.8	20.7	21.6	31.3	44.2
23	22.2	21.9	21.6	22.2	28.5	35.8	29.9	21.7	22.5	31.4	43.2
24	23.5	22.5	22.6	22.5	28.8	35	29.8	22.2	22.7	31.3	41.7
25	22.2	22	21	21.8	28.6	34	29	21.5	22	30.6	39.7
26	19.4	21.6	18.6	20.4	27.9	33	28	20.1	20.7	29.6	37.8
27	19.3	20.2	18	19.2	26.6	32	26.4	18.9	19.6	28.5	36.3
28	20.6	19.4	18.9	18.9	25.2	31	25.8	18.6	19.4	27.3	35
29	21.7	19.3	19.8	18.9	24.1	29.9	24.8	18.6	19.4	26.4	33.7
30	22.1	19.3	20.6	18.9	23.3	28.8	24.1	18.8	19.3	25.7	33.2
31	23.6	19.5	21.8	19.3	22.6	27.7	23.4	19.2	19.6	25	32.7
32	25.5	20.5	24.1	21.4	22.2	26.8	23.5	20.7	21.2	24.9	31.9
33	26.5	21.3	25	22.2	22.3	26	23.7	21.4	22	25	30.7
34	18.1	20.5	17.7	19.3	22.5	25.5	23.5	18.9	19.1	24.9	29.6
35	22.6	19.3	19	18.8	21.9	24.8	22.4	18.4	18.9	23.9	28.3

36	22.2	18.4	18.4	17.5	21.2	24	21.6	17.3	17.8	23	27
37	23.5	18	19.5	17.6	20.5	23.1	20.8	17.3	18	22.2	25.8
38	25.4	18.2	21.4	18.4	19.9	22.3	20.2	18.1	18.6	21.7	24.7
39	24.1	18.9	21.6	19.3	19.7	21.7	20.1	18.9	19.5	21.6	23.8
40	20.6	19.1	19.7	19.1	19.8	21.3	20.1	18.8	19	21.7	23.2
41	25.2	19.4	22	20.1	19.7	21	20	19.6	20.1	21.6	22.7
42	25.9	20.1	22.8	20.7	19.8	20.8	20.3	20	20.5	21.9	22.4
43	22	20	20.4	20.2	20.1	20.8	20.5	19.3	19.8	22	22.3
44	20.7	17.7	18.4	17.7	20	20.7	20	17.4	17.8	21.5	22.1
45	22.8	17.5	19.5	17.6	19.5	20.5	19.4	17.3	17.8	20.8	21.9
46	24	17.7	20	17.7	19.2	20.2	19.1	17.3	17.8	20.4	21.5
47	23.5	18	20.7	18	18.9	19.9	18.9	17.7	18.2	20.2	21
48	20.8	18.3	19.6	18.2	18.8	19.6	18.8	17.9	18.2	20.2	20.9
49	23.4	18.5	20.2	18.3	18.7	19.4	18.7	17.9	18.5	20.1	20.6
50	25.2	18.5	21.2	18.3	18.7	19.2	18.6	17.9	18.4	20	20.4
51	26.4	18.7	22.8	18.6	18.7	19.2	18.9	18.2	18.5	20.1	20.3
52	23.2	19.6	22.1	19.8	18.9	19.3	19.3	18.9	19.4	20.5	20.4
53	27.6	20.6	24.4	21.4	19.1	19.4	19.5	19.7	20.4	20.9	20.6
54	28.9	21.5	25.9	22.4	19.7	19.7	20.3	20.4	21.5	21.8	20.8
55	29.5	21.9	25.5	22.7	20.1	19.8	20.7	20.8	22.1	22.1	20.9
56	24.6	21.3	22.7	21.2	20.6	20	20.7	20.5	21	22	21.1
57	23.7	20.7	21.6	20.3	20.7	20.3	20.5	19.8	20.2	21.8	21.4
58	26	20.8	22.8	21	20.6	20.6	20.6	20.4	20.8	21.8	21.1
59	24	19.8	21.3	19	20.5	20.5	20.4	19.1	19.1	21.5	21.4
60	20.5	19.3	20	18.8	20.3	20.4	20.1	18.8	18.9	21.1	21.5
61	22.5	19.6	20.1	19.2	20.1	20.3	19.5	19	19.3	21	21.4
62	22.1	18.9	19.7	18.1	19.9	20.1	19.7	18.1	18.4	20.8	21.3
63	24.2	18.7	21	18.4	19.7	20	19.4	18.2	18.7	20.5	21.2
64	25.3	18.9	22	18.8	19.4	19.9	19.3	18.5	19.1	20.4	20.7
65	24.5	19.2	21.8	18.9	19.5	19.8	19.4	18.8	19.2	20.6	20.9
66	24.1	19.4	21.4	19.1	19.5	19.7	19.5	19	19.3	20.7	20.8
67	25.9	19.9	22.8	19.9	19.7	19.9	19.9	19.6	20	21	20.9
68	24.1	19.5	21.8	19.1	19.9	19.9	19.9	19	19.3	21	21
69	26	19.9	23.4	19.9	19.9	20	19.8	19.5	20.2	20.9	21.1
70	19.9	19.6	19.7	19.3	20	20.1	19.9	19.2	19.5	21	20.9
71	18.8	18.8	18.4	18	20	20.1	19.7	18.2	18.3	20.8	21.1
72	16.4	18.3	16.6	17.1	19.9	20.1	19.6	17.4	17.5	20.6	21.1

day	(13) bot	(14) bot	(15) bot	(16) bot	(17) mid	(18) mid	(19) mid	(20) mid	(21) mid	(22) mid	(23) mid
1	16.4	21.3	18.8	21.5	20.9	19.8	22	20.1	21.7	21.8	21.1
2	19.1	19.4	19.6	20.2	21.5	21.3	21.6	20.5	21.7	21.9	21.6
3	21	20.5	23.4	23.8	24.5	24.4	24.4	23.8	24.7	25.1	24.9
4	46.4	41.4	51.1	52.6	48.1	48.6	48.2	43.4	49.2	42.6	49

5	68.8	55.1	59.3	59.4	68.9	69.7	62.9	59	69.9	56.3	70.6
6	56.4	40.3	45.2	45.8	69	66.9	56.9	67.4	66.6	66.6	69.5
7	49.6	34.8	37.2	38.6	66.2	63.8	52	67.5	63	67.7	66.7
8	44.7	31	32.2	34	63.8	61.1	47.5	67.2	60	68	64.3
9	40.9	28.4	29	30.6	61.1	57.8	43.9	66.3	57.2	67.6	62
10	38.2	26.5	26.7	28.2	57.8	53.9	40.4	65.3	54	66.9	59.4
11	35.9	25.7	25.3	26.6	54.2	50.3	37.7	63.7	51	65.9	56.8
12	33.7	24.8	24.5	25.7	50.9	47.3	35.3	61.6	48.1	64.5	54.3
13	31.7	24.3	24.7	25.3	48	44.8	33.2	59	45.6	63	51.9
14	30	22.9	24	24	46	42.3	30.8	56.5	43.2	61.3	49.5
15	28.7	23.3	23.4	23.7	44.1	40.4	30.1	53.9	41.2	58.6	46.9
16	28.2	23.2	23.9	24.1	42.6	39.1	29.7	51.6	39.9	55.4	44.9
17	26.8	21.1	22.5	22.7	40.4	37.2	28.1	49.6	38	52.5	43
18	24.6	19.1	19.9	20.2	37.3	34.2	25.2	47.5	35.1	49.9	40.2
19	23.7	19.3	19.1	19.4	35	32.2	24.7	46.1	33.6	48.2	38.7
20	23.7	20.2	19.4	19.8	33.8	31.4	25.2	45.1	32.9	48	37.9
21	24.2	19.8	20.1	20.3	33.7	31.8	25.8	44	33.3	48.5	38.2
22	24.2	20.8	20	20.2	33.4	31.6	26.5	42.2	33	47.8	37.8
23	24.6	21.7	20.7	20.7	34.1	32.1	27.3	41.1	33.5	46.6	37.7
24	24.8	22.1	21.1	21.2	34.5	32.3	27.4	40.6	33.3	44.8	37.2
25	24.5	21.3	21.1	21.1	33.8	31.7	26.7	39.9	32.4	42.6	35.9
26	23.4	19.9	20.4	20.3	32.2	30.1	25	38.6	30.9	40.5	34.3
27	22	18.7	19.1	18.9	29.8	28	23	36.7	28.8	38.5	32.4
28	21.1	18.6	18.5	18.3	27.8	26.2	22	34.7	27.3	37.2	30.7
29	20.7	18.9	18.5	18.2	26.3	24.9	21.5	32.8	26.2	36.3	29.5
30	20.5	18.8	18.5	18.3	25.2	24.1	21.1	31.2	25.2	35.7	28.5
31	20.4	19.1	18.6	18.6	24.4	23.4	21.1	29.6	24.5	35	27.5
32	20.9	20.6	19.8	19.8	24.2	23.5	22.4	28.6	24.6	33.4	27.1
33	21.4	21.2	20.9	21	24.5	23.9	23.2	27.9	24.8	31.6	26.9
34	21.2	18.7	20.2	20	24.5	24	21.6	27.5	24.3	30.3	26.4
35	20	18.4	18.9	18.5	23	22.4	20.3	26.2	22.8	28.5	24.8
36	19.1	17.3	17.8	17.6	21.8	21.1	18.8	24.8	21.5	26.9	23.5
37	18.6	17.8	17.5	17.4	20.8	20.1	18.5	23.4	20.6	25.2	22.3
38	18.5	18.4	17.9	17.7	20.2	19.7	18.8	22.4	20.3	23.9	21.6
39	18.9	19	18.7	18.5	20.3	20.1	19.8	21.8	20.6	23.1	21.5
40	19.3	18.9	19.2	18.9	20.6	20.5	19.9	21.7	20.8	22.6	21.6
41	19.3	19.5	19.5	19.2	20.6	20.4	20.5	21.5	20.8	22.3	21.3
42	19.9	19.6	20.2	20	20.9	20.9	21.1	21.5	21.2	22.1	21.5
43	20.3	19.4	20.4	20.1	21.3	21.2	20.9	21.7	21.3	22.2	21.7
44	19	17.5	18.3	18.1	20.5	20.1	18.6	21.4	19.9	22	20.7
45	18.3	17.5	17.6	17.5	19.5	19.1	18.1	20.7	19.2	21.3	19.9
46	18.1	17.6	17.5	17.4	19	18.7	17.9	20.1	18.8	20.7	19.5
47	17.9	17.9	17.7	17.6	18.8	18.6	18.2	19.6	18.8	20.3	19.3
48	18.3	18.1	18	17.9	18.9	18.7	18.4	19.5	18.9	20	19.3

49	18.3	18.2	18.1	17.9	18.8	18.7	18.5	19.3	18.9	19.8	19.2
50	18.1	18.1	17.9	17.8	18.7	18.6	18.5	19.2	18.8	19.6	19
51	18.4	18.4	17.9	18	18.7	18.7	18.5	19.1	18.8	19.6	19
52	19.2	19.2	19.2	18.9	19.2	19.3	19.8	19.3	19.5	19.6	19.5
53	20.2	19.7	20.5	19.7	19.9	20.1	21.2	19.7	20.4	20	20.1
54	21.3	20.2	21.8	20.8	20.9	21.3	22.3	20.5	21.4	20.6	21.1
55	22.3	20.9	21.9	21.4	21.6	22	22.8	21.1	21.9	21.1	21.7
56	22	20.4	21.1	21.2	21.9	22.1	21.3	21.7	21.6	21.7	21.8
57	21.5	19.5	20.4	20.4	21.6	21.6	20.7	21.5	21.1	21.9	21.5
58	21.3	20.2	20.8	20.7	21.3	21.2	20.9	21.6	21.2	21.9	21.3
59	20.4	18.7	19.3	19.5	20.8	20.7	19.5	21.4	20.5	21.7	20.9
60	20	18.5	19.1	19.2	20.3	20.2	19.2	21.1	20.2	21.5	20.6
61	20	18.7	19.3	19.3	20.2	20.1	19.4	20.9	20.2	21	20.6
62	19.4	17.8	18.5	18.6	19.8	19.6	18.5	20.5	19.7	21.1	20.2
63	19	18	18.3	18.3	19.3	19.1	18.4	20.4	19.3	20.7	19.9
64	19.1	18.3	18.6	18.5	19.2	19.1	18.7	20.2	19.4	20.7	20
65	19.3	18.5	18.9	18.8	19.4	19.4	18.9	20.2	19.7	20.7	20.2
66	19.5	18.8	19.1	19	19.6	19.6	19.3	20.4	20	20.9	20.5
67	19.8	19.5	19.6	19.5	20	19.9	19.9	20.6	20.3	21.2	20.8
68	19.5	18.9	19.1	19.1	20	19.9	19.4	20.9	20.2	21.6	20.9
69	19.6	19.5	19.5	19.4	20.1	20.1	19.9	21.1	20.5	21.8	21.1
70	19.7	19	19.5	19.4	20.5	20.4	19.8	21.5	20.7	22.2	21.4
71	19.2	18	18.6	18.4	20.3	20	18.6	21.6	20.2	22.5	21.2
72	18.9	17.2	18	18	20.1	19.7	17.9	21.6	19.8	22.5	21

day	(24) mid	(25) mid	(26) mid	(27) mid	(28) top	(29) top	(30) top	(31) top	(32) top	(33) top	(34) top
1	20.6	22	22.2	20.1	21.1	20.8	21.4	21.2	22.1	22.2	23.1
2	21.6	21.6	22	21.1	21.2	20.6	21.7	21	21.6	22.2	20.8
3	25.2	25.5	24.6	23.4	24.6	23.9	25.2	24.6	25.1	26	22.3
4	42.8	47.5	48.8	48	47.6	43.6	50	43.2	48.2	51	35.8
5	52.4	61.6	69.1	68.8	61.3	57.2	65.9	55.1	62.8	66.6	45.7
6	62.7	70.3	64.3	68.4	55.1	53.2	59.9	50.2	58.2	60.5	40.7
7	66.9	68.8	61.3	65.9	53	52.2	58.2	48.5	56.5	58.5	39.6
8	67.6	67.4	57.7	64	50.1	49.6	56	45.2	54.1	56.3	36.6
9	67.2	66.5	54.6	61.5	47.3	47.7	53.6	43	51.7	54.1	35.1
10	66.8	65.4	51.4	58.5	44.3	45.2	51	40.3	49.3	51.7	33.1
11	66.1	63.8	48.6	55.3	41.9	42.8	48.5	38.1	47.1	49.4	31.1
12	64.9	61.6	45.6	52.2	39.6	40.5	46	36.1	45.4	47.1	30.2
13	63.2	59.3	43.8	49.4	37.8	38.9	44.1	34.4	43.7	45.3	28.6
14	61	57	41.8	46.9	35.8	36.9	42	32.5	41.5	43	27.1
15	57.8	54	39.8	44.8	35.3	35.7	40.5	32.8	40.5	41.3	28.2
16	54.4	50.9	38.2	43.2	35.1	35.6	40	32.3	39.1	40.6	27.1
17	51.6	48.6	36	41.4	32.9	33.2	38.2	29.8	37	38.9	23.5

18	49.5	46.6	33.3	38.7	29.5	30.9	35.1	27	34.3	35.9	22.5
19	48.4	45.5	32.5	36.6	28.9	30.6	34.1	26.8	33.9	35.2	23.9
20	48.2	44.9	32.8	35.7	29.2	31	34.3	27.3	34.2	35.3	25.4
21	48.3	44.6	33.4	36	29.4	30.9	34.9	26.9	34.4	35.8	23.6
22	48	43.7	33.6	35.6	29.6	31.6	34.2	28.1	34.4	35.4	25.7
23	47.4	43	33.8	35.1	30.4	32.6	34.5	29.2	34.6	35.5	26.8
24	46	42	33.5	34.5	30.5	31.9	34.3	29.1	34.4	35.1	27.1
25	43.4	40	32.2	33.5	29.5	30.6	33.1	27.8	32.6	33.6	25.4
26	40.9	37.9	30.4	32	27.6	28.6	31.2	25.8	30.3	31.5	22.8
27	38.4	35.8	28.2	30	25.5	26.8	28.8	24.1	27.8	29	21.9
28	36.7	34.3	26.9	28.1	24.4	25.8	27.3	23.4	26.5	27.4	22.2
29	35.9	33.5	26.1	26.7	23.8	25.1	26.5	22.9	26	26.7	22.1
30	35.6	33	25.4	25.6	23.3	24.4	26	22.4	25.7	26.1	22.1
31	34.9	32.3	25.1	24.7	23.2	24.4	25.8	22.6	25.7	26	23.2
32	33.6	31.4	25.6	24.4	24.4	25.5	26.4	24.1	26.6	26.6	25.5
33	32	30.7	25.8	24.6	25	25.9	26.6	24.8	26.8	26.7	26.8
34	30.7	29.7	24.8	24.8	22.5	23.3	25.4	21.2	24.5	25.4	19.9
35	28.8	27.7	23.2	23.4	21.2	22.2	23.1	20.5	22.6	23.2	20.3
36	27.1	26.1	21.7	22.2	19.3	20	21.2	18.5	20.8	21.3	19.1
37	25.4	24.5	20.9	21.1	19.1	19.8	20.2	18.9	20.4	20.4	19.9
38	24.2	23.5	20.8	20.5	19.7	20.2	20.1	19.9	20.5	20.3	21.4
39	23.3	23	21.1	20.5	20.4	20.8	20.8	20.6	21.1	21	21.9
40	22.8	22.7	21.1	20.8	20.2	20.5	21	19.9	21	21.1	20.6
41	22.5	22.3	21.1	20.7	21.3	21.3	21.1	21.4	21.6	21.3	22.1
42	22.3	22.3	21.5	21	21.8	21.7	21.7	21.9	22.1	21.8	23.1
43	22.4	22.5	21.6	21.4	21.2	21.2	21.7	20.8	21.7	21.8	21.6
44	22.1	21.8	19.9	20.7	18.4	18.6	19.3	17.9	19.1	19.4	18.7
45	21.3	21	19.1	19.8	18.1	18.2	18.4	18.2	18.5	18.4	19.4
46	20.8	20.5	18.8	19.3	18	18.1	18.1	18.3	18.3	18.2	19.8
47	20.3	20.1	18.8	19	18.4	18.3	18.2	18.6	18.6	18.5	20.2
48	20.2	20	18.9	19.1	18.4	18.5	18.5	18.6	18.8	18.8	19.9
49	19.9	19.8	18.9	19	18.7	18.6	18.5	18.9	18.8	18.7	19.9
50	19.7	19.6	18.8	18.9	18.7	18.5	18.3	19.1	18.7	18.5	20.9
51	19.6	19.6	18.8	18.9	18.9	18.8	18.3	19.4	18.8	18.6	22.8
52	19.7	19.9	19.7	19.4	20	19.9	19.5	20.6	19.9	19.8	22.4
53	20.1	20.4	20.5	20.2	21.7	21.5	20.7	22.8	20.7	21	24.5
54	20.8	21.2	20.8	21.2	22.9	22.7	22	23.8	21.7	22.2	26.1
55	21.3	21.8	21.9	21.8	23.3	23.1	22.6	24.1	22.7	22.8	25.7
56	22.1	22.3	21.7	22.3	21.9	22	22	22.3	22	22	23.3
57	22.4	22.3	21.4	21.9	21	21.1	21.3	21.1	21.1	21.4	22.1
58	22.2	22.3	21.4	21.8	21.5	21.4	21.3	21.6	21.6	21.5	23
59	22	22.2	20.6	21.3	19.6	19.6	20	19.6	20	19.8	21.5
60	21.8	22	20.3	20.9	19.2	19.3	19.5	19.4	19.5	19.6	20.4
61	21.6	21.8	20.4	20.8	19.5	19.6	19.7	19.6	19.8	19.8	20.4

62	21.6	21.6	19.7	20.4	18.4	18.7	18.9	18.5	18.8	18.9	19.6
63	21.5	21.2	19.3	20	18.6	18.8	18.5	19.3	18.8	18.7	20.8
64	21.4	21	19.4	19.9	19	19.2	18.3	19.9	19.2	19.1	21.6
65	21.5	21.1	19.7	20.1	19.2	19.4	19.2	19.8	19.5	19.5	21.7
66	21.7	21.3	20	20.3	19.5	19.7	19.7	20	19.9	19.8	21.2
67	22	21.5	20.1	20.6	20.4	20.5	20.3	21	20.7	20.6	22.8
68	22.2	21.7	20.2	20.7	19.7	19.9	19.9	20.4	20	20.1	22.1
69	22.3	21.7	20.4	20.9	20.6	20.7	20.3	21.4	20.8	20.7	23.3
70	22.7	22	20.5	21.2	20	20.4	20.6	20.1	20.7	20.9	20.7
71	22.7	21.9	19.7	21	18.6	19.2	19.6	18.6	19.5	19.7	19
72	22.7	21.7	19.2	20.8	17.7	18.4	19.1	17.3	18.8	19.2	17.3

Treatment II

day	(1) bot	(2) bot	(3) bot	(4) bot	(5) bot	(7) bot	(8) bot	(9) bot	(10) bot	(11) bot	(12) bot
1	19.4	20.3	20.4	18.6	18.4	-	17.8	19.5	21.5	18	-
2	22.6	22.7	20.6	23.8	20.3	-	21.3	23.2	24.6	19.5	-
3	61.9	42.2	50.6	53.5	24.2	22.3	29	58.4	60.8	29.6	23.1
4	55	52.2	33.5	62.8	30.6	23.8	39.7	50.1	58.4	39.3	24.2
5	45.4	54.2	28.8	60.9	36.7	27.3	45.3	43.9	53.2	44.5	27.6
6	39.6	55.1	26	57.9	40.9	32.1	48.2	40.2	49.3	47.4	32.2
7	35	55.6	24.3	54.8	43.4	36.1	49.8	37.1	45.4	49.1	36.3
8	30.6	54.1	21.6	50.8	44.4	38.7	49.9	33.6	41.5	49.7	38.7
9	27.4	50.5	20.7	45.9	44.8	40.3	50.3	31.4	38.8	50.2	40.5
10	25.4	48	20.2	41.8	45.5	42	51.1	29.9	36.9	50.9	42.1
11	24.6	45.4	20.7	38.2	45.3	42.4	51.3	29.6	35.5	50.9	42.8
12	24.8	43.4	21.4	35.8	45.4	42.6	51.4	29.7	34.4	50.9	43.3
13	25.5	42.2	21.5	34.7	45.8	43.1	51.6	30.7	34.1	51.2	43.9
14	24.3	40.6	20.4	33.2	45.9	43.5	51.7	29.3	33.1	51.2	44.3
15	26.4	39.6	22.7	33.3	45.8	43.3	51.7	29.3	32.9	50.7	44.2
16	27.1	39.2	22.8	33.9	46	43.3	51.7	30	32.5	51.2	44.3
17	25.8	38.6	20.4	33.3	46.4	43.7	52.4	29.2	31.5	51.2	44.8
18	21.6	35.7	17.2	29.9	45.7	43.1	51.3	26.3	28.8	50.5	44.1
19	21.3	34.3	18.9	28.8	45.5	42.9	50.8	26.6	28.7	49.6	43.9
20	22.2	33.6	19.9	28.7	45.2	42.7	50	26.7	28.5	48.8	43.6
21	22.6	33.7	19.2	29.5	45.4	42.8	49.9	27.2	29.3	48.7	43.6
22	22.6	32.6	21.1	28.5	44.9	42.2	49.1	27.5	29.3	47.8	43.3
23	23.6	32.4	22.9	29.4	45	42.1	48.6	28.3	29.7	47.3	43.1
24	24.6	32.6	23.7	29.9	45.3	42.3	48.1	28.7	29.9	46.8	43.1
25	24.9	32.7	22.7	30.2	45.4	42	47.9	28.7	30.2	45.7	43.1
26	23.9	32.4	20.8	29.8	45.7	42.2	47.4	27.8	29.6	45.6	43.2
27	22.7	31.3	20.1	28.7	45.8	42.2	46.8	27.1	28.7	45.2	43.1
28	22.4	30.6	20.8	28.1	45.7	42.1	46.1	27.1	28.5	44.5	43.1
29	22.9	30.2	21.6	28	45.4	41.9	45.2	27.1	28.3	43.8	42.9

30	23.8	30.2	22	28.3	45.4	41.8	44.7	27.1	28.2	43.1	42.7
31	24.9	30.5	23.2	28.8	45.3	41.4	44.3	27.8	28.6	42.7	42.6
32	27.2	31.2	25.3	29.8	45.6	41.5	43.8	28.8	29.3	42.4	42.4
33	29.1	32.4	26.2	30.9	45.9	41.3	44.1	29.8	30.1	42.2	42.4
34	26.9	33.1	20.8	31.2	46	41.7	44.1	28	29.9	42.7	42.8
35	25.9	32.3	21.3	30.2	45.9	41.6	43.1	27.2	29.2	42.2	42.7
36	24.7	31.8	20.4	29.7	45.7	41.4	42.6	26.2	28.4	41.7	42.7
37	24.1	31.1	21.1	29.5	45	41.4	41.6	26.1	28.2	41.3	42.6
38	24.3	30.7	22.7	29.8	44.3	41.3	41	26.4	28.4	41.2	42.6
39	24.9	30.8	23.3	29.9	43.7	41.4	40.7	26.8	29.1	41.1	42.6
40	24.6	30.7	22.1	29.8	43.3	41.6	40.5	26.5	29	41.2	42.7
41	25	30.3	23.7	29.6	42.6	41.2	40.3	27.2	29.5	41.1	42.7
42	25.7	30.7	24.2	30	42.2	41.4	40.2	27.3	29.6	40.7	42.7
43	25.5	31	22.7	29.9	42	41.5	40.5	27.3	29.8	41.2	43.1
44	22.7	29.6	20.1	27.9	41.5	41.7	39.6	25.2	27.6	40.4	42.9
45	22.2	28.4	20.7	26.6	40.6	41.5	38.7	24.8	26.9	39.7	42.9
46	22.1	27.8	20.8	25.9	39.8	41.4	38.1	24.6	26.4	39.1	42.8
47	22.4	27.4	21.4	25.7	39.1	41.3	37.3	24.6	26.2	38.6	42.7
48	22.6	27.4	21.1	25.9	38.7	41.3	36.9	24.7	26.4	38.7	42.8
49	22.3	26.9	21.1	25.3	37.7	40.7	36.3	24.5	26.2	38.2	42.3
50	22.4	26.7	21.7	25.3	37.2	40.7	35.8	24.4	25.8	37.9	42.2
51	23.1	26.7	22.7	25.4	36.9	40.9	35.3	24.2	25.6	37.3	42.1
52	24.1	27	22.9	25.9	36.4	40.6	35.3	25.2	26.3	36.9	42.2
53	25.1	27.3	24.8	26.5	35.9	40.4	34.9	25.9	26.9	36.9	41.9
54	26.2	28.1	25.9	27.4	35.9	40.6	35.1	26.7	27.7	36.9	42
55	26.4	28.1	25.8	27.7	35.5	40.3	34.8	26.7	27.9	36.7	41.8
56	25.1	28.1	23.5	27.3	35.3	40.4	34.8	25.9	27.4	36.6	42
57	24.3	27.8	22.6	26.9	35.3	40.7	34.7	25.3	26.9	36.7	42.2
58	24.7	27.4	23.1	26.6	34.7	40.6	34.3	25.6	27.1	36.1	42.1
59	23.4	26.9	21.7	25.8	34.2	40.8	33.6	24.1	25.7	35.3	42
60	23	26.5	21.3	25.5	33.8	40.8	33.3	24	25.4	35.2	42.3
61	23.2	26.3	21.3	25.2	32.8	40.2	33	24.3	25.7	34.7	42.1
62	22.1	25.8	20.6	24.7	32.4	40.1	32.4	23.3	24.7	34.2	41.8
63	22.2	25.4	21.6	24.3	32.1	39.8	32	23.4	24.7	33.9	41.7
64	22.3	25.2	22.2	24.2	31.6	39.5	31.6	23.4	24.7	33.4	41.4
65	22.7	25.4	22.1	24.3	31.3	39.5	31.4	23.4	24.8	33.1	41.3
66	22.8	25.3	21.8	24.5	30.8	39	30.9	23.4	24.8	32.4	41
67	23.8	25.8	22.8	25	30.8	38.9	31.1	24.1	25.3	32.3	41
68	22.8	25.5	22.5	24.7	30.7	38.9	30.6	23.3	24.6	31.8	40.8
69	23.2	25.4	23.5	24.6	30.4	38.7	30.3	23.7	24.8	31.9	40.7
70	22.7	25.4	21.3	24.7	30.2	38.7	30.2	23.7	24.7	31.8	40.7
71	21.6	24.8	19.4	23.9	29.8	38.4	29.9	22.6	23.8	30.8	40.6
72	21.4	24.2	20.7	23.4	29.3	38.3	29.4	22.4	23.4	30.6	40.4
73	22.3	24.3	22.3	23.8	29.1	38.1	29.1	23.1	24	30.5	40.3

74	22.3	24.2	22.7	23.8	28.8	37.9	29.1	23.2	24.1	30.5	40.2
75	21.8	24.2	21.2	23.8	28.7	37.9	28.8	22.8	24	30.4	40.2
76	21.4	23.8	21.2	23.5	28.4	37.6	28.5	22.5	23.7	30.1	40
77	21.6	23.6	21.7	23.4	28	37.2	28.3	22.7	23.7	29.8	39.8
78	22.2	23.6	23.2	23.6	27.8	36.8	28.1	23.1	23.9	29.6	39.5
79	22.6	23.8	23.6	23.8	27.6	36.2	28.1	23.3	24.3	29.6	38.8
80	22.7	24.1	24	24.2	27.9	36.1	27.8	23	24.2	29.4	37.7
81	23.2	24.4	24.8	24.7	28.1	35.8	27.9	23.4	24.8	29.5	37.2
82	22.8	24.2	23.3	24.5	27.9	35	27.9	23.4	24.6	29.3	36.5
83	22.8	24	23.6	24.3	27.7	34.4	27.7	23.3	24.3	28.9	35.7
84	22.3	24.1	22.3	24.3	27.7	34.2	27.7	23.1	24.2	28.7	35.3
85	20.7	23.4	20.6	23.3	27.4	33.6	27.5	22.1	23.6	28.6	34.7
86	20.4	22.9	21.2	22.7	27.2	33.2	27.2	21.8	22.9	28.4	34.3
87	19.9	22.7	19.5	22.5	26.9	32.8	26.8	21.5	22.7	28.2	33.9
88	20.8	22.6	21.9	22.4	26.6	32.3	26.6	21.8	22.7	27.6	33.3
89	19.7	22.3	19.6	22.1	26.2	31.4	26.4	21.3	22.5	27.3	32.9
90	18.8	21.5	20.3	21.2	25.9	30.9	25.8	20.6	21.6	27	32.3
91	19.2	21.1	21.4	20.8	25.4	30.4	25.4	20.6	21.4	26.6	31.8
92	21.8	21.8	24.4	21.9	25.1	29.8	25.2	22.2	22.8	26.5	31.2
93	23.1	22.6	26.1	23	25.1	29.4	25.1	22.8	23.6	26.7	30.7
94	23.7	23.1	26.6	23.7	25.4	29.2	25.4	23.4	24.2	26.8	30.6
95	22.6	23.1	25.3	23.3	25.6	28.9	25.7	22.8	23.8	26.9	30.5
96	23.8	23.4	27.4	23.7	25.9	29.1	25.8	23.5	24.1	27.3	30.5
97	19.7	22.9	18.7	22.7	25.8	28.7	25.9	21.3	22.4	26.7	30.4
98	17.7	21.3	18.4	20.6	25.7	28.6	25.4	19.6	20.4	26.2	30.2
99	17.4	20.4	19.5	19.6	25.1	28.3	24.9	19.1	19.7	25.4	29.9
100	18.9	20.2	21.9	19.7	24.4	27.8	24.2	19.8	20.3	25	29.4
101	19.4	20.8	20.7	20.6	24.1	27.3	24	20.3	21	24.6	28.9
102	18.8	20.3	20.4	19.9	23.7	26.7	23.8	19.8	20.4	24.4	28.4
103	19.1	20.3	21.3	19.9	23.6	26.4	23.6	19.8	20.5	24.2	28.1
104	18.8	20.3	20.1	20.1	23.5	26.2	23.5	19.6	20.3	24.1	27.7
105	19.8	20.1	22.7	19.8	23.2	25.7	23.4	20.1	20.8	23.9	27.3
106	17.9	19.9	20.3	19.4	23	25.3	23.1	19.1	19.8	23.7	26.8
107	20.1	20	22.4	19.9	22.8	25.1	22.8	20.2	20.7	23.4	26.4
108	17.1	19.9	16.8	19.4	22.8	24.8	22.9	18.6	19.3	23.3	26.2
109	16	18.9	16.8	18.1	22.6	24.4	22.6	17.6	18.2	22.9	25.8
110	15.7	18.2	16.8	17.5	22.1	24.1	22	17.2	17.8	22.3	25.3
111	17.2	18.2	19.3	17.8	21.7	23.7	21.6	18	18.7	22	24.9
112	16.8	18.4	17.3	17.8	21.2	23	21.4	17.9	18.4	21.8	24.3
113	20.7	18.9	23.6	19.2	20.9	22.6	21.2	20.2	20.7	22.1	23.8

day	(13) bot	(14) bot	(15) bot	(16) bot	(17) mid	(18) mid	(19) mid	(20) mid	(21) mid	(22) mid	(23) mid
1	20.5	20.7	19.2	-	-	-	-	-	-	-	-

2	23.7	21.9	24.5	22	24.8	24.9	24.6	24.5	24.7	24.4	24.6
3	51.8	54.1	59.1	57.8	43.5	45.3	59.1	29.2	39.9	27	33.2
4	58.4	46.6	64.3	57.2	55.1	56.3	63.6	41.6	52.3	36.6	45.1
5	57.3	40.9	61.6	48.7	58.8	59.6	62.7	48.8	56.4	44.2	50.4
6	54.6	37.5	57.4	43.4	60.9	61.5	61.4	53.2	58.7	49.2	53.8
7	51.6	34.7	52.7	39.2	61.8	62.4	59.9	55.8	60.1	52.6	55.9
8	48.1	31.2	47.2	35.6	61.7	62.4	58	56.9	60.5	54.4	57
9	44.9	29.3	42.8	33.4	61.7	62.1	56.3	57.6	60.8	55.5	57.5
10	43.3	28.3	39.5	31.6	61.7	61.3	54.7	58.3	61.3	56.6	58.4
11	41.3	27.7	36.2	30.6	61.6	60.4	52.8	58.4	61.2	56.8	58.4
12	39.8	27.4	33.3	29.6	61.1	59.5	50.8	58.6	60.6	57	58.4
13	39.3	27.7	32.2	29.7	60.3	58.8	49.3	58.9	60.2	57.3	58.7
14	38.3	26.7	31.9	29	58.9	57.6	47.3	58.9	59.6	57.4	58.9
15	37.3	27	29.3	28.1	57.9	56.2	46.1	58.6	58.7	57.2	59.4
16	37.2	27.6	29.7	28.3	57.2	55.6	45.1	58.8	58	57.2	59.1
17	36.7	26.2	29.2	27.8	56.6	54.9	44.2	59.1	57.4	57.4	59.1
18	34.4	24	27	24.1	54.2	52.6	41.1	58.1	55.4	56.6	57.9
19	33.6	24.8	24.7	24.1	52.9	51.3	39.7	57.8	54.3	56.2	57.3
20	33.4	25.4	24.9	24.1	51.7	50.2	39.2	57.7	53.5	56.1	57.1
21	33.9	25.6	26.4	24.7	51.4	49.9	39.4	57.9	53.3	56.3	56.8
22	33.4	26.1	26.1	24.7	50.2	48.8	38.4	57.6	51.9	55.8	56
23	33.7	27.1	26.9	25.2	49.8	48.5	39.1	57.8	52.9	56.1	56
24	33.9	27.3	27.3	25.8	49.6	48.4	39.7	58.1	53.3	56.4	56.3
25	33.7	26.8	26.8	25.7	49.3	48.1	39.8	58.3	53.1	56.4	55.7
26	33.1	25.6	26.4	25.1	48.6	47.4	39	58.4	52.6	56.6	55.3
27	32.2	24.8	25.7	24.5	47.4	46.2	37.6	58.2	51.6	56.3	54.6
28	31.8	24.8	25.8	24.6	46.2	45.2	36.7	57.9	50.6	56.1	53.9
29	31.8	24.9	26.2	24.9	45.3	44.3	36.4	57.7	49.8	55.9	53.4
30	31.8	24.3	25.9	25.2	44.8	43.9	36.7	57.1	49.2	55.8	53
31	32	25.1	26	25.7	44.5	43.6	36.9	56.5	48.6	55.8	52.3
32	32.7	26.8	27	26.7	44.4	43.7	38.1	55.8	48.2	55.7	52.2
33	33.3	27.5	26.9	27.6	44.9	44.2	39.1	55.6	48.2	55.8	51.9
34	33.3	24.2	27.2	26.9	44.9	44.2	38.2	55.3	48.1	56.1	51.6
35	32.6	24.4	26.6	26.1	43.7	43.1	36.9	54.5	47.1	55.9	50.8
36	31.9	23.2	25.2	25.4	42.9	42.3	35.9	53.8	46.2	55.8	50.2
37	31.7	24.4	25.3	25	42.1	41.6	35.4	53	45.5	55.6	49.6
38	32.2	25.2	25.9	25.3	42	41.5	35.5	52.5	45.2	55.7	49.3
39	32.3	25.6	26.9	25.9	42.4	41.9	36.3	52.2	45.2	55.8	49.4
40	32.3	25.2	27.3	25.7	42.7	42.2	36.8	52.1	45.3	55.9	49.6
41	32.1	26	27.7	25.8	42.2	41.6	36.3	51.6	44.8	55.9	49
42	32.1	26.1	27.4	25.9	41.9	41.3	36.4	51.4	44.7	55.8	48.9
43	31.9	25.4	26.9	26	41.9	41.2	35.8	51.2	44.5	55.6	48.6
44	30.4	23.3	24.7	23.7	40.3	39.6	33.4	50.4	43.4	54.8	47.9
45	29.5	23.3	23.9	23.2	38.9	38.3	31.8	49.4	42.2	53.8	46.9

46	29	23.1	23.4	23.2	38.1	37.5	30.8	48.6	41.4	53.1	46.3
47	28.8	23.3	23.8	23.2	37.7	37.1	30.4	47.9	40.9	52.5	45.9
48	28.9	23.6	23.9	23.5	37.7	37.1	30.3	47.7	40.9	52.2	45.8
49	28.3	23.2	23.4	23.3	37.2	36.4	29.7	46.8	40.2	51.4	45
50	28.1	23.4	23.1	23.2	36.6	35.8	29.3	46.4	39.9	51.1	44.7
51	27.8	23.5	22.3	23	36.1	35.3	29.4	46.1	39.5	50.8	44.5
52	28.1	24.3	23.3	23.7	35.8	35.2	29.7	45.6	39.2	50.2	43.8
53	28.4	25.7	24.6	24.4	35.7	35	30	45.1	39.2	49.8	43.6
54	28.9	26.3	25.4	25.4	36.1	35.3	30.8	45.1	39.5	49.7	43.8
55	29	26.4	25.7	25.3	35.8	35.2	31.1	44.7	39.4	49.3	43.6
56	28.7	25	24.6	24.6	35.6	34.9	30.4	44.6	39.2	49.1	43.3
57	28.3	24.2	24.7	24.1	35.1	34.4	29.8	44.2	38.8	48.9	43.1
58	27.9	24.4	24.1	24.4	34.4	33.9	29.6	43.5	38.2	48.2	42.4
59	27.1	22.9	22.2	22.8	33.5	32.9	28.7	42.8	37.4	47.7	41.7
60	26.9	23	22.7	22.7	32.8	32.4	28.1	42.2	36.8	47.2	41
61	26.7	23.1	22.6	23	32.5	31.9	27.7	41.3	36.1	46.1	40.1
62	26	22.2	22	21.9	31.8	31.2	26.8	40.7	35.4	45.5	39.7
63	25.7	22.6	22.1	21.8	31.1	30.6	26.3	39.9	34.7	44.7	38.9
64	25.6	22.7	22.4	22.1	30.8	30.2	26.2	39.4	34.3	44.1	38.5
65	25.6	22.7	22.5	22.4	30.7	30.1	26.4	39	34.1	43.5	38.2
66	25.4	22.7	22.1	22.3	30.3	29.8	26.3	38.4	33.7	42.7	37.6
67	25.7	23.3	22.6	22.9	30.4	29.8	26.8	38.2	33.7	42.3	37.3
68	25.3	22.8	22.2	22.1	29.8	29.3	26.2	37.8	33.2	41.8	37
69	25.3	23.4	22.8	22.6	29.5	29.1	26.2	37.3	32.9	41.2	36.6
70	25.4	22.9	23	22.6	29.4	29.1	26.2	37.1	32.8	40.8	36.5
71	24.7	21.4	21.6	21.6	28.8	28.4	25.3	36.5	32.1	40.1	35.9
72	24.3	21.8	21.3	21.2	28.1	27.7	24.7	35.8	31.4	39.5	35.3
73	24.6	22.7	22.2	21.9	27.9	27.6	24.9	35.2	31.2	38.9	35
74	24.6	22.7	22.3	22.1	27.8	27.5	25	34.9	30.9	38.5	34.8
75	24.6	22.3	22.4	22	27.7	27.4	24.9	34.7	30.8	38.3	34.7
76	24.2	22	21.9	21.6	27.3	27.1	24.5	34.2	30.4	37.9	34.4
77	24.1	22.1	21.8	21.6	27.1	26.7	24.3	33.7	30	37.4	33.8
78	24.2	22.9	22.3	22	27	26.7	24.6	33.6	29.9	37.1	33.6
79	24.4	22.9	22.6	22.3	27.2	26.9	24.9	33.4	29.9	36.9	33.4
80	24.4	22.9	22.7	22.2	27.2	26.9	25.1	33.4	30	37.1	33.7
81	24.7	23.6	23.2	22.7	27.4	27.2	25.4	33.4	30.1	37.1	33.6
82	24.7	23.2	23.3	22.5	27.4	27.2	25.5	33.2	29.9	36.8	33.2
83	24.4	23.1	23	22.5	27.2	27.1	25.3	32.8	29.7	36.4	32.8
84	24.4	22.8	23.1	22.2	27.2	27.1	25.3	32.7	29.6	36.3	32.7
85	23.7	21.3	22	21.3	26.7	26.6	24.3	32.3	29.1	36	32.3
86	23.3	21.2	21.6	20.8	25.9	25.8	23.6	31.7	28.5	35.4	31.8
87	23.2	20.7	21.3	20.7	25.7	25.6	23.3	31.2	28.2	35	31.5
88	22.9	21.3	21.1	20.8	25.3	25.2	23.3	30.5	27.7	34.3	30.9
89	22.8	20.2	20.9	20.4	25.2	25.1	23.1	30.1	27.3	33.7	30.4

90	22.1	20.2	20.3	19.6	24.3	24.2	22.1	29.4	26.7	33.2	29.9
91	21.8	20.4	20	19.6	23.7	23.6	21.6	28.7	26	32.3	29.2
92	22.5	22.5	21.7	21.2	23.9	23.9	22.7	28.2	26	31.8	28.9
93	23.2	23.4	23.1	22.1	24.7	24.7	24	28.2	26.5	31.7	29.1
94	23.8	24.2	24.1	22.6	25.3	25.4	24.8	28.6	27.1	31.8	29.6
95	23.6	22.9	23.4	22.2	25.6	25.6	24.6	28.8	27.1	31.8	29.5
96	23.8	24.3	24.4	22.9	25.8	25.8	25.1	28.9	27.3	31.9	29.8
97	23.1	20.2	22.1	21	25.6	25.6	23.9	28.8	27.1	31.5	29.4
98	21.4	18.9	19.6	18.9	24	24	21.7	28.2	25.8	30.9	28.4
99	20.5	18.6	18.4	18.4	22.8	22.8	20.4	27.1	24.7	29.8	27.3
100	20.6	19.9	19.3	19.2	22.4	22.4	20.6	26.3	24.1	29.1	26.7
101	21.3	20.1	20.4	19.6	22.7	22.7	21.4	25.9	24.3	28.5	26.5
102	20.7	19.6	19.5	19.1	22.3	22.3	20.7	25.6	23.8	28.1	25.9
103	20.6	19.8	19.8	19.1	22.1	22.1	20.7	25.3	23.6	27.8	25.7
104	20.7	19.4	19.7	18.9	22.1	22.1	20.7	25.1	23.5	27.4	25.7
105	20.5	20.4	19.9	19.3	21.8	21.8	20.6	24.7	23.1	26.9	24.9
106	20.1	19.1	19.2	18.4	21.7	21.6	20.1	24.5	22.9	26.6	24.8
107	20.5	21.1	20.5	19.6	21.6	21.6	20.7	24.2	22.8	26.2	24.6
108	20.1	17.6	18.4	18.1	21.7	21.6	20.1	24.2	22.8	26	24.4
109	18.9	16.8	16.8	16.9	20.7	20.6	18.7	23.6	21.8	25.4	23.5
110	18.4	16.7	16.7	16.5	19.8	19.7	17.8	22.9	21.1	24.7	22.8
111	18.7	18.2	17.8	17.3	19.6	19.5	18.1	22.3	20.8	24.1	22.4
112	18.7	17.7	17.4	17.4	19.7	19.7	18.3	22	20.6	23.5	22
113	19.7	21.4	20.3	19.4	20	19.9	19.6	21.7	20.7	23.1	21.9

day	(24) mid	(25) mid	(26) mid	(27) mid	(28) top	(29) top	(30) top	(31) top	(32) top	(33) top	(34) top
1	-	-	-	-	-	-	-	-	-	-	-
2	24.5	24.6	24.2	24.8	26.4	24.3	25	24.7	23.7	24.9	21.2
3	27	34.6	61	33.4	67.9	66.8	62.7	63.3	63.6	60.4	59.4
4	35.3	46.1	60.3	46.4	63.1	64.7	67.3	66.3	61.3	66.4	56.1
5	43.1	51.3	59.1	52.4	60.6	62.2	67.1	65.1	60.4	67.3	54.7
6	48.6	54.7	57.8	55.7	58.7	60.2	64.5	63.4	59.8	66.9	52.7
7	52.2	56.6	56.6	57.7	57.2	58.8	62.8	62.4	58.4	64.4	51.3
8	53.8	57.3	54.8	58.3	55.1	56.8	61.1	60.9	56.3	62.3	49.2
9	55	58.2	53.3	58.7	53.4	55.3	59.7	59.6	54.9	60.8	47.7
10	56	58.9	52.3	59.2	52.1	54.1	58.7	58.8	54	59.8	46.6
11	56.6	59.2	51.2	59.3	50.8	52.7	57.4	57.4	53.2	58.7	45.6
12	56.8	59.3	50	59.4	48.8	51.2	56	55.9	52.1	57.4	44.6
13	57.2	59.6	49.3	59.7	48.9	50.5	55.2	55.3	51.4	56.6	43.6
14	57.1	59.5	47.9	59.6	47.6	49.1	54.1	54.2	50.1	55.2	-
15	57.1	58.9	46.9	59.7	47	48.6	53	52.7	49.8	54.6	43.3
16	57.4	59.2	46.8	60	46.4	47.3	52.7	52.6	49.4	54.1	41.9
17	57.6	59.7	46.1	60.2	45.4	46.8	51.9	51.7	48.5	53.6	38.9

18	56.7	58.5	44.1	59.1	42.6	43.8	49.5	49.3	46.1	50.8	37.2
19	56.3	57.9	43.7	58.6	41.9	42.9	48.8	48.7	45.8	50.2	37.1
20	55.8	57.2	43.4	57.8	41.8	42.7	48.6	48.6	45.4	49.8	37.1
21	55.9	57.2	43.6	57.5	42.1	43.1	48.9	49	45.6	50.1	37.2
22	55.7	56.7	43.3	56.8	41.7	42.3	48.1	47.7	45.3	49.4	37.6
23	55.7	56.6	43.5	56.6	41.9	42.7	48.1	47.9	45.4	49.2	-
24	55.9	56.3	43.4	56.3	42.2	43.2	48.1	47.7	45.3	49.1	38.8
25	56.2	56.3	43.1	55.9	41.7	42.8	47.4	47.3	44.5	48.3	32.4
26	56.2	55.9	42.2	55.3	40.6	41.8	46.5	46.3	43.4	47.4	-
27	56.1	55.3	41.3	54.4	39.2	40.4	45.1	45.2	42.3	46.1	-
28	55.9	54.7	40.9	53.7	38.6	39.7	44.2	44.4	41.7	45.3	-
29	55.6	54.1	41	52.9	38.4	39.4	43.8	43.9	41.4	44.7	-
30	55.6	53.9	41.5	52.4	38	38.8	43.4	43.1	41.3	44.2	34.1
31	55.8	53.8	41.7	52	37.8	38.6	42.9	42.7	41.3	43.9	34.6
32	55.6	53.4	41.9	51.7	38.8	39.2	43.3	42.5	41.7	44	-
33	56.1	53.5	42.1	51.6	39.3	39.7	43.4	42.4	42.2	44.5	40.7
34	56.4	53.7	41.8	51.4	38.3	39.4	43.3	42.9	41.2	44.5	-
35	56	52.8	41	50.3	37.6	38.7	42.2	42.3	40.4	43.3	-
36	56.1	52.4	40.3	49.7	36.6	37.7	41.2	41.2	39.7	42.5	-
37	55.8	51.6	39.9	48.8	36.2	37.3	40.7	40.8	39.6	41.7	-
38	55.9	51.6	39.9	48.4	36.5	37.5	40.9	41.1	40.4	42.2	34.4
39	56.2	51.6	40.2	48.4	37.1	37.9	41.5	41.4	41	42.7	-
40	56.4	51.5	39.9	48.4	37	37.6	41.6	40.9	40.8	42.6	-
41	56.5	51.1	39.9	48.1	37	37.7	41.3	41.1	40.7	42.3	-
42	56.7	50.8	39.6	47.7	36.8	37.4	41.2	40.7	40.2	42	-
43	57.2	50.8	39.4	47.4	36.3	37.1	40.8	40.4	40.1	42	-
44	56.5	49.8	37.5	46.2	33.9	34.8	38.9	38.7	37.8	39.8	-
45	55.7	48.8	36.7	44.9	33.1	33.8	37.7	37.7	36.9	38.7	-
46	54.7	48.1	36.2	43.9	32.6	33.4	37.1	37.1	36.4	38.2	-
47	53.9	47.4	35.9	43.2	32.7	33.3	37	36.9	36.1	37.8	-
48	53.6	47.1	35.9	43.1	32.8	33.6	37.2	37.2	36.1	37.8	-
49	53	46.4	35.4	42.6	32.6	33.3	36.7	36.7	35.8	37.4	-
50	52.6	45.9	35.1	42.2	32.3	32.9	36.3	36.2	35.3	36.8	-
51	51.9	45.3	34.5	41.6	32.3	32.7	35.9	34.9	34.8	36.6	-
52	51.7	45	34.7	41.1	32.3	32.9	35.9	35.4	35.2	36.5	-
53	51.1	44.4	35	40.6	33.3	33.8	36.4	36.3	35.6	36.8	-
54	51	44.4	35.3	40.6	34.1	34.4	37.1	36.9	36.3	37.5	-
55	50.4	43.9	35.1	40.3	34	34.5	37	36.7	35.9	37.2	31.5
56	50.3	43.7	34.3	40.1	32.8	33.6	36.3	36.1	35.1	36.6	30.3
57	49.9	43.2	33.7	39.7	32.1	32.9	35.8	35.8	34.2	36.1	29.4
58	49.5	42.5	33.4	38.9	32.2	32.7	35.3	35	34.1	35.7	-
59	48.6	41.5	31.8	37.8	30.3	30.8	33.8	33.2	32.2	34.1	-
60	48.1	40.9	31.5	37.1	29.7	30.4	33.1	32.8	31.6	33.2	-
61	47.6	40.3	31.3	36.4	29.6	30.2	32.8	32.6	31.5	33.2	-

62	46.7	39.6	30.5	35.7	28.6	29.1	32	31.9	30.1	31.9	-
63	46	38.9	30.1	35	28.4	28.8	31.4	31.4	29.9	31.4	-
64	45.3	38.3	29.9	34.4	28.4	28.8	31.4	31.4	29.6	31.4	-
65	44.8	37.9	29.7	34.1	28.4	28.6	31.4	30.9	29.3	31.3	-
66	43.9	37.3	29.4	33.6	28.1	28.5	31	30.7	29	30.9	-
67	43.5	37.1	29.6	33.2	28.6	28.8	31.1	30.9	29.4	31.2	-
68	42.6	36.4	28.8	32.6	27.6	28	30.4	30.4	28.2	29.9	-
69	42	36.1	28.9	32.2	28	28.3	30.6	30.6	29.1	30.5	-
70	41.4	35.9	28.8	32	27.6	28.1	30.7	30.7	28.6	30.4	-
71	40.9	35.5	27.8	31.6	26.2	26.8	29.5	29.4	26.9	29.1	-
72	40.1	34.8	27.4	30.8	25.9	26.2	28.8	28.8	27	28.6	-
73	39.3	34.4	27.7	30.4	26.6	26.8	29.2	29.2	27.8	29.1	-
74	39	34.3	27.7	30.3	26.7	26.8	29.2	29.2	27.9	29.2	-
75	38.7	34.2	27.4	30.2	26.1	26.4	29.2	29.2	27.3	29.1	-
76	38.2	33.8	27	29.9	25.7	26.1	28.8	28.7	26.9	28.6	-
77	37.7	33.4	26.8	29.5	25.7	25.9	28.4	28.4	27.1	28.4	-
78	37.4	33.3	27.1	29.4	26.3	26.4	28.7	28.6	27.8	28.7	-
79	37.3	33.2	27.2	29.3	26.6	26.7	28.9	28.7	27.9	29.1	-
80	36.9	32.9	26.9	29.1	26.4	26.6	28.9	28.8	27.3	28.8	-
81	36.9	32.9	27.1	29.1	26.8	26.8	29.1	29	27.9	29.2	-
82	36.8	32.8	27.1	29	26.6	26.8	29	28.9	27.8	29	-
83	36.4	32.4	26.8	28.7	26.6	26.7	28.8	28.6	27.4	29	-
84	36.3	32.3	26.6	28.7	26.1	26.4	28.8	28.6	27.2	28.7	-
85	36.1	32	25.8	28.4	24.7	25.1	27.6	27.5	25.8	27.7	-
86	35.5	31.3	25.2	27.9	24.2	24.4	26.8	26.8	25.3	26.9	-
87	35.2	31	24.9	27.5	23.6	24	26.6	26.6	24.9	26.7	-
88	34.6	30.5	24.8	27.1	23.9	24.1	26.2	26.2	25.3	26.5	22.4
89	34.2	30.2	24.5	26.7	23.2	23.6	25.8	25.7	24.6	25.9	21.2
90	33.5	29.4	23.7	26.2	22.4	22.6	24.8	24.8	23.8	24.8	-
91	32.8	28.8	23.3	25.6	22.2	22.1	24.1	24.2	23.7	24.4	-
92	32.3	28.6	24.3	25.3	24	23.8	25.2	25.3	25.4	25.7	-
93	32	28.6	24.9	25.5	25.2	25.1	26.3	26.3	26.3	26.7	-
94	32.1	28.9	25.5	26.1	25.9	25.9	27.1	27.1	26.9	27.2	-
95	32.2	29.1	25.3	26.3	25.3	25.3	26.7	26.7	26.3	26.9	-
96	32.2	29.1	25.7	26.5	26.1	25.9	27.1	27.2	27.2	27.5	25.5
97	32	29	24.3	26.5	23.3	23.8	25.8	25.7	23.9	25.8	21.5
98	31.3	27.9	22.5	25.7	20.9	21.3	23.4	23.4	22.2	23.3	19.3
99	30.4	27	21.7	24.7	20	20.1	21.9	21.9	21.4	22.2	-
100	29.6	26.3	21.9	24	20.8	20.7	21.9	22.1	22.1	22.4	20
101	29	26.2	22.3	23.9	21.5	21.7	23	23	22.5	23.1	20.5
102	28.6	25.8	21.8	23.6	20.8	20.8	22.2	22.1	22	22.3	-
103	28.2	25.4	21.7	23.4	20.8	20.8	22	22.1	22	22.3	-
104	27.7	25.2	21.6	23.3	20.6	20.7	22.1	22.1	21.5	22.2	-
105	27.5	24.9	21.7	23.1	21.2	20.9	21.8	21.8	22.4	22.2	-

106	27	24.7	21	22.9	19.8	19.9	21.2	21.3	20.9	21.4	-
107	26.5	24.3	21.6	22.7	21.2	21	21.9	22	22.3	22.2	-
108	26.5	24.3	20.7	22.9	19.2	19.5	21.1	20.9	19.9	21	-
109	25.9	23.6	19.6	22.3	17.8	17.9	19.3	19.2	18.7	19.4	-
110	25.1	22.7	18.9	21.5	17	17.2	18.4	18.5	18.1	18.5	-
111	24.4	22.3	19.2	21.1	18.1	18	18.9	19	19.2	19.1	-
112	24.1	22.2	19.3	21	17.9	17.9	18.9	18.9	18.9	19.2	17.8
113	23.6	22	20.7	20.9	20.9	20.4	20.6	20.7	21.9	21	22

Treatment III

day	(1) bot	(2) bot	(3) bot	(4) bot	(5) bot	(7) bot	(8) bot	(9) bot	(10) bot	(11) bot	(12) bot
1	23.9	24.2	23.8	24.2	24.3	24.2	24.2	24.5	23.7	-	-
2	39.2	56.9	43.6	45.6	54.4	27.7	69.1	34.9	31.8	69.1	27.9
3	28.1	40.5	27.1	32.8	69.5	60.8	65.7	28	25.6	64.6	57.2
4	24.9	35.7	23.5	29.9	64.9	70.9	61.1	26.6	24.2	58.6	71.4
5	24.8	42.6	22.2	31.8	67	70.1	63.1	29.2	24.8	64.4	70.2
6	27.8	54.7	20.7	44.6	66.1	69.3	61.4	43.3	27.9	64.4	69.6
7	38.9	58.2	24.2	54.1	64.9	68.4	60.8	48.2	42.7	64.4	69
8	46.6	53.1	31.9	49.1	63.2	67.4	59.4	43	43.6	62.8	68.4
9	41.1	49.6	39.7	46.1	62.3	66.4	56.8	40.8	39.4	60.3	67.2
10	33.8	45.9	43.1	43.1	61.3	65.7	55	39.1	37.2	57.3	66.3
11	32	43.9	42	39.2	60.9	65.1	54.8	36.6	35.2	57.2	65.7
12	30.2	41.7	34.7	35.7	60.5	64.7	53.8	33.6	32	56.3	65.2
13	28.1	38.6	32.5	35.4	58	63.5	52.1	34.4	31.8	53	63.8
14	27.1	39.1	31.8	34.1	58.3	63.6	52.8	33	30.8	54.1	63.7
15	22.7	35.7	27.1	30.8	56.6	63.2	48.9	28.5	26.2	51.6	63.4
16	19.8	33.2	22.4	25.9	54.3	61.9	47.9	25.9	24.1	50.6	62.2
17	22.3	34.5	23.7	27.7	55.2	62.7	49.7	27.7	26.2	52.3	63.1
18	24.8	35.4	25	29.1	55	62.6	49.7	29.1	27.7	51.4	63.1
19	24.4	35.7	23.6	27.6	55	62.4	50.5	26.7	25.1	50.8	62.9
20	26	34.9	25.8	29.1	53.7	62	48.5	29.3	27.6	50.3	62.3
21	28	35.3	27.8	30.6	53.2	61.8	49.1	31.3	29.3	50.2	62.3
22	28.3	35.1	27.8	31.1	52.6	61.5	47.6	31.3	29.6	48.7	61.9
23	24.9	32.8	26.7	28.3	50.8	60.7	45.1	29.3	27.8	45.6	61.2
24	22.6	31.4	23.7	25.7	49.8	60.2	43.6	26.2	24.9	44.7	60.8
25	21.9	30.3	22.2	24.7	48.9	59.8	43.1	25.2	24.2	43.9	60.4
26	22.6	30.2	22.9	25.3	48.3	59.8	42.3	25.9	25	43.6	60.4
27	21.8	30.1	22.8	26.4	47.6	59.6	41.6	26.4	25.3	42.9	60.4
28	21.1	29.5	22.4	27.2	46.4	58.9	40.9	26.4	25.2	41.3	60
29	22	29.2	23.9	27.7	45.3	58.4	40.7	27.1	26.1	40.2	59.6
30	25.2	29.9	25.8	29.2	44.2	57.8	41	28.8	27.8	40.1	59.3
31	25.7	29.7	27	29.4	43.2	57	40.2	29.2	28.3	38.7	58.6
32	20	27.6	20.6	22.3	42.6	56.4	40.2	22.3	21.8	39.7	58.4

33	21	26.7	21.8	23.5	39.7	54.8	38.2	23.9	23.3	38.8	57.6
34	18.8	25.1	20.7	22.9	38.7	54.1	36.8	22.8	22	37.5	56.9
35	20.8	25.2	21.3	22.4	37.6	52.7	36.6	23.5	22.8	37.3	55.9
36	23.5	26.8	22.9	24.1	37.4	52	37.5	24.8	24.4	37.8	55.1
37	21.4	25.7	20.4	21.4	37.3	51.4	37.2	22.4	21.9	37.2	54.3
38	22.3	26	21.5	22.5	36.8	49.7	36	23.8	22.7	35.4	52.3
39	23.8	26.4	23.9	25.7	35.5	47.7	35	26.2	25	34.9	50.1
40	25.2	26.9	24.7	25.8	34.9	47	34.5	26.4	25.6	34.4	48.4
41	21.3	-	22.8	24.2	34.2	46.2	33.2	24.4	23.2	33.2	46.9
42	18.9	22.9	20.4	21.7	31.6	44.2	30.4	21.8	20.7	30.4	45
43	20.6	22.6	21.3	21.9	29.8	43.4	29.4	22.7	21.7	29.3	43.8
44	20.7	22.3	21.6	21.9	29	43.7	29.1	22.8	21.9	29.1	46.1
45	21.2	23.4	21.8	22.9	28.4	43.3	29.4	23.2	22.6	29.7	47.5
46	21	22.9	21.5	22.3	28.2	42.5	29.7	22.6	22	30.2	47.6
47	21.5	25.1	21.9	22.6	27.6	41.1	28.9	23.2	22.3	29.6	45.3
48	22.8	22.7	22.9	22.9	26.9	39.8	28.4	23.7	23.1	28.9	43.3
49	24.9	-	24.1	23.7	26.2	38.8	28	23.7	23.6	28	42.6
50	23.7	23.2	23.4	23.4	26.3	38.5	27.7	23.8	23.7	27.7	42.1
51	26.6	24.4	26.1	25.6	26 3	37.9	28.3	26.2	26.1	28.4	41.3
52	27.9	25.4	27.1	26.6	27	37.8	29.6	26.9	27.2	29.3	41
53	27.6	25.4	27.1	26.7	27.1	37.1	29.2	27.1	26.9	29.1	40.2
54	24	23.7	23.9	24.1	27.1	36.3	27.9	24.4	24.1	27.8	39.4
55	23.6	23.5	23.2	22.8	26.4	35.4	27.6	23.4	23.1	27.1	38.6
56	24.6	23.5	24.4	24.2	25.7	34.6	27.4	24.6	23.9	26.7	37.8
57	23.1	21.7	22.8	22.8	24.7	33.2	25.3	22.4	22.1	25.1	36.8
58	21.1	21.8	21.3	21.3	24.1	31.9	24.7	21.4	21.4	24.8	35.9
59	21.2	21.4	21.8	21.7	23.9	30.8	24.3	22.3	21.4	24.5	34.8
60	21.1	20.8	21.2	21	23.2	29.3	23.6	21.2	20.9	23.9	33.8
61	22.7	21	22.5	21.7	22.6	28.1	23.1	22.3	22.2	23.4	32.6
63	24.3	21.5	23.3	22	22.4	27.1	23.2	22.7	23	23.4	31.5
64	23.7	21.7	22.8	21.9	22.7	26.4	23.3	22.4	22.8	23.3	30.2
65	22.7	21.1	22.3	21.9	22.2	25.2	22.8	22.2	22.2	22.9	28.6
66	24.4	21.9	24.2	22.8	22.3	24.6	23.7	23.2	23.2	23.4	27.1
67	23.6	21.2	23.1	22.2	21.9	23.7	22.8	22.3	22.8	22.8	25.6
68	25.6	21.9	24.3	23.2	21.9	23.3	22.4	23.4	24.2	22.7	24.3
69	21	21.1	21.1	21.3	21.9	22.9	22.1	21.3	21.1	22.4	23.7
70	19.1	19.4	19.3	19.4	21.2	22.3	20.5	19.6	19.1	20.8	22.8
71	20.5	19.6	20.7	20.3	20.4	21.6	20.2	20.8	20.6	20.5	22.1
72	23.1	20.7	22.8	22	20.6	21.3	21.1	22.2	22.4	21.2	21.8
73	24.2	21	23.3	22.2	20.9	21.4	21.1	22.6	22.9	21.2	21.7
74	21	20.4	21	20.8	20.9	21.4	20.9	21	20.8	21.2	21.8
75	20.9	20	21	20.8	20.6	21.2	20.6	21.1	20.9	20.8	21.6
76	21.8	20.2	21.8	21.1	20.4	20.9	20.6	21.7	21.6	20.6	21.2
77	24.7	21.1	24	22.6	20.6	20.9	20.9	23.2	23.3	20.9	21.1

78	25.2	21.4	24.3	22.6	20.8	21	21.5	23.2	23.4	21.4	21
79	25.6	21.4	24.6	23.4	20.8	21.1	22.1	23.1	23.7	21.9	21.3
80	26.1	22	25.3	24.1	21.2	21.4	22.6	23.9	24.5	22.3	21.6

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
day	bot	bot	bot	bot	mid	mid	mid	mid	mid	mid	mid
1	-	25.9	28.2	21.6	23.3	19.8	17.6	23.7	24.1	25.8	16.9
2	62.1	36.4	55.4	35.3	68.8	72.2	71.7	45.1	72	40.6	67.6
3	38.6	26.7	34.1	28.5	72.4	71.8	65.1	73.3	71.1	65.9	72.6
4	34.4	24.2	30.8	27.4	70.3	68.6	52.6	73.6	67.2	74.3	70.7
5	38.2	24	34.2	29	69.6	68	53.4	73.1	64.1	73.6	69.5
6	53.6	28.8	44.2	37.3	70.5	69.7	63.3	72.9	68.4	73.4	70.8
7	61.2	44.9	56	50.9	69.2	68.4	63.8	72.2	68.1	72.9	69.8
8	56.1	48.3	54.2	46.5	67	65.2	58	70.9	66	72	68.3
9	52.7	43.9	50.1	43	65.9	62.8	52.9	70	62.8	71.4	66.6
10	51.2	41.6	46.7	40.5	64.6	61.5	52.6	69.3	61.9	70.4	64.6
11	47.9	38.3	42.5	38	64.5	62.4	50.7	69.8	62.6	70.2	65.1
12	44.9	34.7	37.5	33.9	63.8	63.6	49.9	70	63.1	70.2	65.3
13	43.9	34.3	38	34.5	61.8	60.8	47.9	69.2	61	69.4	62.9
14	42.6	33.1	37.6	34	63.7	61.7	47.6	69.5	61.7	69.4	64.7
15	39.4	28.5	34.4	30.6	61.8	59.2	44.3	69.7	59.8	69.9	64.1
16	35.9	26.4	29.3	27.3	61.1	57.3	39.9	68	57.8	68.5	63.2
17	37	27.8	30.1	27.7	62.5	58.3	42.2	69.4	59.8	69.4	65.4
18	37.7	29	31.9	28.4	62.4	58	42.7	69.7	58.6	69.7	64.4
19	37.1	-	-	-	-	-	-	-	-	-	63.4
20	37.1	28.7	31.5	27.9	60	55.7	42.2	68.7	56.5	68.8	63.1
21	38.1	29.7	34.4	29	59.6	55.3	42.4	68.4	55.7	68.6	62.7
22	37.9	30	35.2	29.3	58.3	54.3	42.2	68.2	54.6	68.4	61.4
23	36.2	28	33.9	29.1	55.8	51.2	38.6	67.4	50.4	67.8	58.5
24	34.2	26	30.5	27.3	54.2	50.1	36.6	66.8	48.7	67.5	57.6
25	32.2	24.6	26.8	25.3	52.6	49.1	35.9	65.9	47.4	67	57
26	31.9	24.8	26.2	25.1	51.8	49	36.8	65.9	47.2	67.2	56.8
27	32.2	25.1	26.4	25.3	51.2	47.8	36.8	66.2	46.7	67.4	56.1
28	32	25.2	26.9	25.7	50.1	46.9	35.7	65.8	46.5	67	54.8
29	31.7	25.7	27.8	26.3	49.2	46	35.2	65.6	45.8	66.8	53.4
30	32.9	27.3	29.6	27.6	49	46.3	36.4	65.3	46.6	66.7	52.9
31	32.7	27.5	29.9	28	47.3	44.1	35.2	64.2	44.8	66	50.7
32	28.4	21.8	25.1	24.2	45.9	40.8	30.2	63.6	42.4	65.8	49.5
33	28.4	22.8	24.3	24.1	43.2	37.4	28.4	61.9	40.4	65.1	48.3
34	27.1	21.6	23	23.1	42.1	36.2	27.1	61.3	39.1	65.2	47.1
35	27.1	22	22.7	22.9	41.6	35.4	26.8	60.3	38.8	64.4	46.2
36	28.6	23.3	24.1	23.8	42.4	36.9	28.8	61	40.1	64.4	46.6
37	26.6	21.7	23	22.7	42.4	36.7	27.5	61.1	39.6	64.4	45.9
38	27.2	22.7	23.4	23.1	41.4	36	27.4	58.9	38.1	62.8	43.8

39	28.6	24.6	25.2	24.4	39.9	35.3	28.9	56.1	37.8	61	43.2
40	29.3	24.8	26.4	25.2	39.3	35.2	29.5	54.8	37.6	59.8	42.8
41	27.1	22.8	24.7	24	38	33.6	27.2	54	35.8	58.4	41.1
42	24.6	20.4	21.8	22.2	34.5	29.6	23.5	52.2	31.9	55.4	37.8
43	24.5	21.3	21.9	22.2	32.5	28	23.1	52.1	31	53.1	36.9
44	24.3	21.4	21.9	22	31.7	27.5	23.1	52.2	30.9	55.9	37.7
45	24.8	22	22.3	22.2	31.2	27.7	24.1	51	32	58.6	39
46	24.6	21.4	22.2	21.9	30.7	27.8	24.4	49.6	32.1	58.1	39.3
47	24.6	22	22.3	22.1	29.7	27.2	24.3	48.4	31.1	55.4	38.2
48	25	22.2	22.5	22.4	29.1	26.8	24.3	47.2	30.3	53.7	36.9
49	25.1	22.8	23	22.5	28.8	26.8	24.5	46.3	29.6	54	36
50	25.2	23	23.8	23	28.8	27.1	25.4	45.4	30	53.9	36
51	26.7	24.8	25.4	24.2	29.2	27.9	26.8	44.8	30.8	53.3	36.6
52	27.6	25.3	26.3	24.9	30.2	29	28.1	44.6	32.1	53.1	37.5
53	27.7	25.6	26.6	25.3	30.9	29.7	28.4	43.8	32.6	52.5	37.5
54	25.2	23.5	24.2	23.5	30	28.2	25.7	42.5	30.6	51.8	35.7
55	24.4	22.5	22.4	22.4	28.8	27.1	24.4	41.1	29.6	51	34
56	25.2	23.1	23.2	23.2	27.7	26.6	25.2	39.3	28.5	48	33.1
57	23.4	21.5	21.7	22	25.8	24.7	23	37.4	26.1	46.1	31
58	22.7	20.7	21.4	21.6	25.2	24.2	22.4	35.5	25.8	45.5	30.4
59	22.7	21.4	21.6	21.7	24.7	24	22.4	33.8	25.2	45.3	29.9
60	21.8	20.4	20.8	21	23.8	22.9	21.5	31.8	24.1	44.8	28.9
61	22.2	21.3	21.1	21.2	23	22.3	21.6	29.8	23.7	44.2	28.1
63	22.3	21.8	21	21.2	23.1	22.7	22.1	28.8	24	43.5	27.8
64	21.9	21.5	21.1	21.1	23.5	22.9	22.1	28.2	24.1	41.9	27.4
65	21.9	21.4	21.1	21.3	23.2	22.7	22.1	26.8	23.4	38.6	26.3
66	22.7	22.1	21.4	21.9	23.4	23.2	23.1	25.8	23.9	33.8	26.1
67	21.9	21.5	21.2	21.4	22.6	22.3	22	24.9	22.8	29.5	25
68	22.5	22.4	22.4	21.9	23	23	23.1	24.5	23.5	27.1	25.1
69	21.4	20.9	21.4	21	23.2	22.8	21.9	24.6	23.2	26.6	24.6
70	20	19	19.4	20.1	21.3	20.6	19.7	23.2	20.8	24.9	22.3
71	20.1	20.4	20	20.2	20.5	20.2	20	22	20.5	23.3	21.6
72	21.5	21.4	21.6	21.3	21.5	21.6	22.1	22.1	21.8	23.1	22.5
73	21.5	21.6	21.8	21.3	21.9	21.9	22.3	22.5	22.2	23.4	22.8
74	20.6	20.5	20.8	20.4	21.9	21.7	21.1	22.9	21.9	23.7	22.6
75	20.5	20.6	20.7	20.3	21.3	21	20.8	22.3	21.3	23.1	21.9
76	20.7	20.8	21.2	20.7	21.2	21.1	21.2	22	21.3	22.6	21.8
77	21.7	22	22.4	21.6	21.7	21.8	22.6	22.1	22.1	22.6	22.4
78	21.8	22.2	22.7	21.8	22.4	22.5	23	22.8	22.7	23.2	22.9
79	21.9	22.4	22.6	21.7	22.7	22.8	23.7	23.2	23	23.6	23.2
80	22.3	22.9	23.1	22	22.9	23.1	24.1	23.3	23.5	23.8	23.5
	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)
day	mid	mid	mid	mid	top	top	top	top	top	top	top

1	19.4	25.1	22.7	23.3	25.2	24.5	23.9	23.3	24.8	25.2	25.4
2	40.5	62	70.6	66.1	67.6	63.6	65.9	68.4	71.3	65.2	70.9
3	68.4	73.1	61.8	72.7	67.9	66.9	73.1	70.6	71.8	73	72.7
4	73.6	72.3	52.8	71.9	67.5	65.7	73.2	69.8	70.2	73.4	71.3
5	73	71.8	53	71.6	66.2	64.1	72.4	68.7	68.6	72.7	70
6	72.8	71.9	61.5	70.7	65.9	63.7	72.1	68.3	69.1	72.4	68.5
7	72.1	71.3	64	68.2	64.8	61.7	70.8	67.1	68.5	71.4	66.2
8	71.2	70.2	59.7	67.1	63.5	59.5	69.7	66	66.8	70.2	65.3
9	70.3	69.1	56.9	68.1	61.8	57.6	69.1	64	65.8	69.1	66
10	69.9	69	56.2	68.1	60.6	56.4	67.5	61.8	65.4	67.9	66.1
11	69.7	68.9	54.9	67.4	61.1	58.9	67.4	63.1	64.6	67.7	65.1
12	69.5	68.6	54.2	66.5	60	60.1	67.3	63.8	63.8	67.1	64
13	68.8	68.5	53.8	67.6	58	57.1	66.4	61.1	63.6	65	65.2
14	68.9	68.4	52.9	66.6	59.7	56.1	66	61.2	62.3	65.4	63.5
15	69.3	67.6	49.7	66	58	53.4	66.3	60.3	57.8	65	64.4
16	68	66.3	48.3	64	56.5	52.2	64.4	58.9	57.8	64.2	61.4
17	68.8	67.1	49.6	64.5	58.4	55.1	65.6	61.1	59.4	65	61.3
18	69.1	66.8	49.1	64.3	58.4	54.5	65.2	60.3	57.1	64.6	60.7
19	69	66.1	47.7	62.4	57.8	51.4	64.7	58.2	55.3	64.2	59
20	68.2	66	47.5	62.1	56.4	52.1	63.5	58.2	55.2	62.8	58.3
21	68	65.5	47.6	61.8	55.9	51.1	62.6	57.7	54	62	57.9
22	67.9	64.8	47	61	53.8	51.6	61.9	57.1	53.8	61.1	56.9
23	67.3	64	44.6	60	52.1	47.2	60.3	53.3	52.5	59.9	55.9
24	67	62.9	42.3	57.4	50.5	45.8	59.6	53.6	50	59.3	54
25	66.4	62.1	40.4	54.3	48.4	43.9	58.2	53.1	48.7	58	50.8
26	66.5	61.7	40.2	53.4	48.4	44.4	57.8	53.2	49.2	57.6	50.1
27	66.7	61.3	40.2	53.6	47.9	44.5	54.5	49.3	49.4	57.4	51
28	66.5	60.3	39.9	53.7	46.8	44	54.2	49.3	49.2	56.1	50.8
29	66.2	59.6	39.8	52.9	45.5	42.6	54.1	49	49.7	55.4	49.6
30	66.1	59	40.8	53	45.1	43.1	53.6	49.2	49.5	55.2	49.9
31	65.5	57.8	40.1	52.5	41.3	39.7	51.4	47.3	49.8	54.4	49.4
32	65	55.3	36	48.1	42	38	50.6	44.8	43.8	54.1	44.9
33	64.1	54.5	35.5	44.5	40.1	37	50	45.4	44.8	53.9	42
34	64.1	53.5	34.2	43	37.2	34.4	49.7	44.7	45.1	54.5	40.9
35	63.3	52.2	33.9	42.8	37	35.1	49	44.1	44.1	53.4	40.5
36	63.4	52.3	35.3	43.8	39.4	36.9	50.4	44.5	44.2	53.3	41.5
37	63.4	51.6	33.8	44.2	38.3	35.8	50.2	43.3	42.5	53.2	41.1
38	61.8	49.6	33.3	43.9	36.7	35	48	41.7	41.1	51.2	40.2
39	59.9	48.4	34.4	41.9	35.8	34.7	46.3	41.7	42.1	49.8	38.4
40	58.7	47.3	34.5	42.2	34.6	34.3	45.3	41.3	40.8	49.3	38.3
41	57.2	45.8	32.4	41.1	33.5	32.1	43.5	38.6	39.6	47.8	36.7
42	53.8	42.8	28.9	38	30.5	28.8	39.9	34.7	36.4	44	33.4
43	51.2	41.4	28.5	36.2	30.1	28.5	38.6	33.9	34.9	41.2	32.2
44	54.5	43	28.4	35.6	30.1	28.5	40.7	35.6	35.9	42.8	32.5

45	57.3	45.4	29.4	35.1	29.7	29.7	41.6	36.6	38.3	46.4	32.9
46	57.7	46.3	29.4	34.2	28.4	28.3	40	35.1	38.9	46.5	32.5
47	54.9	44.8	29.5	32.9	27.8	27.4	38.2	34	37.8	43.3	31.3
48	52.4	43.2	29.3	32.1	27.6	27.1	37.1	33.4	36.2	40.7	30.5
49	53.3	42.7	29.1	31.7	27.5	27.2	35.8	32.7	34.8	39.7	30.4
50	53.4	42.2	29.1	32	27.3	27.5	36.3	33.1	34.7	40.3	31.1
51	52.8	41.8	30.5	31.4	29.1	29	36.7	34.6	35.9	40	31.3
52	52.8	41.8	31.3	32.3	29.8	29.9	37	35.2	35.3	39.9	32.1
53	52.1	41.2	31.5	32.2	30.2	30.1	36.3	34.9	35.9	39.2	32.1
54	51.2	39.8	28.8	31.2	28.1	27.8	34.5	32.2	33.6	37.7	30.1
55	49.1	38.2	27.6	28.9	27	26.5	33.2	30.5	32.8	36.6	28.1
56	47.3	37.6	27.9	28.4	26.3	25.9	31.8	30.3	31.6	35.2	27.6
57	45.2	36	25.6	27.5	23.7	23.7	30	28.5	29.1	33	26
58	44.4	34.9	24.5	26.1	23.2	23	29.8	27.9	28.9	32.9	24.6
59	44.7	35.1	24.8	25.2	23.2	22.6	29.5	28	30.2	33.2	24.1
60	44.2	33.6	23.6	24.1	22.1	21.6	28.8	27.2	29.8	33.5	22.8
61	43.4	32.4	23.9	23	22.3	21.9	28.2	27.2	29.9	33.1	22
63	42.2	31.3	23.9	22.8	22.7	22.3	27.8	26.7	29.4	32.5	22
64	40	30.1	23.2	23	22.6	22.2	26.8	26	27.8	31.2	22.1
65	37	29.4	23.4	23.4	22.1	21.8	24.9	24.4	27.3	29.4	22.4
66	33.4	28.4	24.1	23.7	22.8	22.4	24.4	24.3	26.7	28	23.1
67	29.3	26.3	22.8	23.2	21.6	21.4	22.5	22.6	24.1	24.6	22.1
68	26.7	24.8	23.3	22.8	23	22.8	23.3	23.7	23.8	24.1	22.5
69	25.9	24.2	22	22.9	21.6	21.5	22.5	22.1	22.2	23.4	21.9
70	24.4	22.8	20.1	21.9	19.2	19	20	19.7	20.2	20.8	20.1
71	22.8	21.6	20.5	20.8	19.6	19.4	19.6	19.9	20	19.9	19.4
72	22.6	22	22.1	21.2	21.5	21.4	21.2	21.7	21.8	21.3	21
73	22.9	22.2	22.2	21.6	22.1	22.1	21.8	22.3	22.2	21.8	21.5
74	23.2	22.3	21.1	21.7	20.9	20.7	21.1	21	21	21.6	20.9
75	22.5	21.7	20.9	21	20.4	20.3	20.3	20.6	20.7	20.7	20.3
76	22.2	21.6	21.5	21	21	20.7	20.6	21.1	21.2	20.8	20.6
77	22.1	21.8	22.7	21.3	22.4	22.3	21.7	22.5	22.5	21.6	21.6
78	22.8	22.5	23.1	22	22.9	22.6	22.3	22.9	23	22.4	22.4
79	23.1	22.8	22.9	22.4	22.8	22.8	22.5	22.8	23.2	22.7	22.6
80	23.3	22.9	23.3	22.4	23.3	23.3	22.9	23.3	23.5	23	23

Treatment IV

	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)	(11)	(12)
day	bot	bot	bot	bot	bot	bot	bot	bot	bot	bot	bot
1	27.8	26.9	25.6	27.8	26.7	26.1	27.4	28.6	27.2	25.5	25.5
2	49.4	62	35.2	69.5	52.4	32.7	63.9	57.7	58	65.9	29.4
3	31.5	44.8	26.5	53.8	72	67.5	61.5	40.8	39.7	62.2	59.6
4	26.5	34.9	24.2	38.4	66.4	73.3	58.7	32.7	33.6	60	72.8
5	23.9	31.5	21.7	33.1	58.2	71.2	55.8	28.8	32	56.1	71.6

6	25.1	32.2	22.9	36.5	63.4	71.3	59.4	31.7	38.6	59.9	70.8
7	30.5	46.3	26.6	47.8	68.5	70.8	58.4	41.7	56.4	59.5	70.3
8	45.2	62	38.6	60	68.5	69.8	58.3	55.9	60.4	59.7	69.2
9	51.1	62.1	44.7	66.2	67.5	68.9	57.2	55.6	55.1	58.7	68.3
10	49.6	54.5	39.5	57.7	65.5	68.2	54.2	50.3	52.1	57.6	67.5
11	43.3	51.9	34.6	54.9	63.9	67.4	52.5	46.4	49.2	55.5	67
12	39.6	49.5	32.7	52.9	62.6	66.4	51.7	45.4	47.4	54.9	65.8
13	40	48.2	30.7	50.3	62.6	66.2	53.1	42.7	44.9	55.9	65.6
14	31.9	43.8	24.5	46.5	60.9	66.4	47.8	38.4	41.4	51.5	66.2
15	26.9	41.1	22.2	42.8	59.5	65.3	49.1	35.2	38.9	51.7	65.1
16	28.6	41.4	24.8	42.6	60	65.5	50.6	35.6	38.7	53.8	65.3
17	29.8	40.9	25.7	42.5	59.5	65.3	49.9	35.3	38.2	53.3	65.4
18	28.8	39	23.2	41.1	56.4	64.8	48.8	32.8	36.6	52.4	65.2
19	29.3	38.9	26.1	40.7	57.6	64.4	49.2	33.9	37	52.8	64.7
20	30.6	39.1	27.2	40.8	57.2	64.2	49.2	34.2	37.3	52.8	64.3
21	29.9	38.3	27.5	40.2	56.3	63.6	47.5	33.8	36.7	51.5	63.9
22	28.3	37.2	26	38.4	55.4	63.1	46.6	32.3	35.5	50.1	63.3
23	25.9	35.4	23.6	36.6	54.4	62.7	44.7	30.3	33.9	48.9	62.9
24	24.7	33.7	23.1	34.6	52.9	62	43.9	29	32.4	49.3	62.1
25	24.9	33.4	23.9	33.9	52.1	61.9	43.5	29.2	32.1	49.3	61.9
26	24.2	33.4	24.2	33.2	51.5	62	42.7	29.3	31.9	48.3	62.1
27	23.4	33.1	24	32.8	50.6	61.9	41.4	29.1	31.9	46.9	62
28	24.6	33.2	25.5	32.1	50	61.8	41.4	29.6	31.8	47.1	62
29	27.3	33.4	27	33.6	49.4	61.8	41.3	31	32.6	46.3	62.1
30	27.7	32.5	27.9	31.8	47.7	61.3	39.8	31.6	32.1	45.1	61.7
31	22.1	30.4	21.7	28.3	48.1	61.3	38.2	26.1	29.1	43.7	61.7
32	23.4	29.5	23	27.8	45.8	60.8	37.4	26.5	29.1	43.3	61.3
33	21.7	28.2	22.2	26.3	45	60.3	35.7	25	27.9	42.3	61
34	22.9	27.8	23.1	26.5	43.8	59.8	35.6	25.3	27.7	42.1	60.6
35	24.8	28.7	23.9	28.2	43.2	59.5	35.9	26.2	28.7	42.2	60.5
36	22.8	27.5	22.2	26.9	43	59	34.7	24.4	27.3	41.5	60.1
37	23.2	27	22.7	27	41.6	57.2	32.1	24.2	27.1	38.8	58.2
38	25	27.8	25.2	27.9	40	56.6	32.9	26.7	28	39.3	57.8
39	25.8	27.9	25.2	28.4	40	55.9	33.7	27	28.3	38.5	57.3
40	23.3	26.7	23.7	26.4	39.5	54.7	31.8	25.5	26.8	37.5	56.2
41	21.1	24.5	21.7	23.8	37.4	52.8	29.8	23	24.8	35.3	54.4
42	22	24.4	22.8	23.8	35.6	51.5	29.4	23.6	24.7	34.8	52.9
43	22	24.2	23	23.5	34.8	50.9	29.1	23.5	24.4	34.6	52.1
44	22.7	24.2	23.4	24.2	34	50	29	23.8	24.6	34.5	51
45	22.4	24.1	22.6	24.1	33.6	48.9	29	23.4	24.4	34.6	50
46	22.6	24.1	23.2	23.9	32.6	47.5	28.7	23.7	24.4	34.2	48.8
47	23	24.1	23.9	23.9	31.8	46.7	28.5	23.8	24.4	33.7	48.1
48	23.5	23.9	24.5	24.1	30.9	46	28.2	24.1	24.3	32.9	47.5
49	24.1	24.4	24.4	24.7	30.5	45.2	28.4	24.5	24.8	32.5	46.9

50	26	25.6	27	25.8	30.8	44.8	29.3	26.5	25.7	33.3	46.4
51	26.6	26.4	27.5	26.6	31.3	44.4	30.5	27.1	26.3	33.7	45.9
52	27.1	26.7	28	26.9	31.8	43.5	30.7	27.4	26.4	33.6	44.7
53	24.4	25	25.3	24.9	31.5	43	28.8	25.3	24.6	31.7	44.4
54	23.5	24.6	24.4	24.3	30.7	42.1	28.4	24.4	24.1	31.1	43.4
55	23.6	24.7	25	24.4	29.4	41.3	28.7	25.1	24.2	30.6	42.8
56	22.5	22.8	23.2	22.7	28	40.4	26.9	23	22.9	28.7	42.1
57	22.2	22.8	22.4	22.6	27.7	39.8	25.8	22.5	22.7	28	41.4
58	22.4	23	23.3	22.5	27.1	38.9	25.8	23.3	22.6	28.1	40.6
59	21.4	22.4	22.3	21.8	26.6	37.8	25.2	22.2	21.9	27.4	39.7
60	22.3	22.5	23.6	22	25.8	36.6	24.9	23	22.2	27.1	38.8
61	22.8	22.8	23.9	22.4	25.5	35.5	25	23	22.4	26.9	37.8
62	22.6	22.8	23.5	22.4	25.5	34.1	24.6	22.5	22.2	26.3	36.6
63	22.3	22.6	23.2	21.9	25	32.8	24.5	23	22	26	35.6
64	23.2	23.3	24.5	22.6	24.7	31.8	25.2	24	22.6	26.2	34.6
65	22.8	22.4	23.5	21.9	24.2	30.6	24.7	23	21.8	25.2	33.4
66	24	23.3	24.8	23	24.2	30.1	24.5	24	22.6	25.3	32.2
67	22.2	22.4	22.2	22.4	24.3	29.2	23.8	22.6	21.9	25	31.1
68	19.9	20.7	20.5	20.3	23.2	27.6	21.6	21.2	20.5	22.9	29.5
69	21.1	21	21.9	20.7	22.4	26.5	21.9	21.8	20.5	22.8	27.9
70	22.7	22.2	23.5	22	22.5	26	22.9	23.3	21.7	23.5	26.9
71	23	22.3	24	22.2	22.7	25.6	22.8	23.3	21.9	23.5	26.1
72	21.7	21.6	22.2	21.6	22.8	25.1	22.5	22.1	21.2	23.3	25.3
73	21.6	21.4	22.3	21.3	22.4	24.3	22.1	22.3	20.9	22.8	24.2
74	22.2	21.6	23	21.5	22	23.5	22.2	22.6	21.2	22.6	23.5
75	23.8	22.4	24.7	22.4	22	23	22.2	23.8	21.8	22.5	22.9
76	24	22.8	25.3	22.7	22.3	23	22.6	24.1	22	22.7	22.8
77	23.8	22.8	25.1	22.7	22.4	23	23.6	24	21.9	23.4	22.8
78	24.4	23.1	25.6	23	22.5	23	23.7	24.5	22.2	23.6	22.8
79	23.6	22.8	24.3	22.8	22.8	23.2	23	23.9	21.9	22.9	22.9
80	23.8	22.9	24.7	22.8	22.3	22.8	23.3	24.1	22.1	23.1	22.5

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
day	bot	bot	bot	bot	mid	mid	mid	mid	mid	mid	mid
1	29.3	23.3	28.2	25.5	27.5	27.8	27.8	26.7	26.7	26.6	26.5
2	68.3	35.8	65.8	36.7	70.8	71.7	71	51.3	69	45.1	58.8
3	47.1	27.3	37.5	26.4	72.9	73.3	68.8	73.8	73.6	72.4	74
4	36.4	25.4	29.8	24.9	68.9	70.2	61.1	73.6	71.9	73.8	72.9
5	39.3	23.6	28.7	22.2	62	63.6	49.9	71.9	69.1	73	71.2
6	54.4	27.3	35.7	23.8	62	62.3	51.6	71.7	68.2	72.9	70.3
7	62.5	40.7	48.5	28.8	68.1	70.2	63.1	72.1	71.2	72.3	71.4
8	64	49.9	58.9	42	70.2	70.5	64.6	71.4	69.8	71.5	70.6
9	56.3	46.7	59.9	43.5	68.7	68.9	62.2	70.6	66.9	70.7	69
10	53.8	42.9	54.2	38	64.7	65.7	58	69.5	66.7	69.6	68.4

11	52	39.3	51.8	37.1	62.7	62.7	55.5	68.3	67.7	68.7	68.1
12	50	39.5	46.7	37.5	62.4	61.5	54.1	67.4	65.8	68.1	67.3
13	48.2	36.3	43.3	33.7	63.3	62.6	52.6	68.2	66.1	68.3	68
14	44.8	31.9	37.7	28.3	61.3	60.6	49.5	68.6	64.2	68.7	67.8
15	41.3	28.4	31.8	26.5	60.8	59.8	48.9	67.2	64.9	67.7	66.8
16	41.4	29.4	32.3	28.3	62.2	61.8	50	68.2	66.1	68.3	68.9
17	40.6	29.6	33.1	28.8	62	62	49.8	68.5	65.4	68.6	68.7
18	39.2	27.2	32.2	26	60.7	61.1	47.2	68.4	63.6	66.8	68
19	39	29.4	32.2	28.3	60.5	60.7	48.3	67.8	64.2	68.3	68
20	38.8	29.5	33.4	29.1	60.3	60.5	48.3	67.9	64.1	68.2	68
21	38.1	30.3	33.5	29.6	59	59.4	47	67.6	63.3	68	67.5
22	36.8	28.3	31.9	27.6	57.9	58	44.8	67.3	60.8	67.7	66.5
23	35.1	25.8	30	25.5	56.6	56.8	43.1	67	59.7	67.4	66.3
24	33.3	25.4	27.3	24.8	55.3	55.5	41.6	66.2	58.5	66.6	65.5
25	32.9	25.7	27	25.3	54.7	54.7	41.5	66.1	58.9	66.4	65.6
26	32.9	26	27.4	25.7	54	54	41.8	66.4	58.3	66.7	65.7
27	32.8	25.9	27.8	25.9	52.9	53	42.2	66.1	58.1	66.8	65.5
28	32.8	27.1	28	26.7	52.5	52.3	41.3	66.1	57.1	66.9	65
29	33.9	28.7	29.8	28	51.6	51.8	42.3	65.8	57.7	66.8	65.1
30	33.8	29.7	30	28.6	48.8	48.8	39.9	64	54.5	65.9	63.7
31	30.5	22.9	25.5	23	49.1	48.5	36.8	65.7	52.9	66.3	63.3
32	29.6	24.3	25	23.9	47.2	46.2	34.6	64.8	51.9	65.9	62.5
33	28.3	22.8	23.4	22.8	45.9	44.7	33.4	64.4	50.4	65.7	61.9
34	27.9	24	23.8	23.5	44.9	43.7	33	63.6	50.2	65.4	61.7
35	28.4	24.7	25.3	24.3	44.8	44.1	34.3	63.4	50.4	65.6	61.6
36	27.4	22.9	24.1	22.7	44.4	43.7	33.3	63.3	49.4	65.5	61.1
37	25.9	22.8	24.3	23.2	43.2	42.3	32.5	61.3	48.1	63.4	59.7
38	27.7	26.1	25.8	25.4	41.6	40.8	32.6	60.7	46.6	64.8	58.5
39	28.2	26.1	26.7	25.5	41.9	40.9	33.2	60.5	46.9	64.4	57.9
40	27.4	25	24.7	23.8	40.4	39.5	30.8	59.2	44.2	63.9	55.4
41	24.9	22.5	22.1	21.9	37.4	35.9	26.7	56.6	40.8	62.2	53.1
42	24.6	23.3	22.2	22.5	36.4	34.3	26	55.4	40.2	61.1	52.7
43	24.4	23.5	22.1	22.6	36	33.8	25.7	55.3	40.2	60.8	52.2
44	24.5	24.1	22.7	23.2	35.8	33.7	26.4	54.5	40.6	59.9	51.9
45	24.4	23.2	22.6	22.5	35.3	33.5	26.1	53.6	40.4	58.8	50.7
46	24.3	23.6	22.6	23	34.2	32.3	25.8	52.5	39.3	57.7	49.3
47	24.2	24	22.8	23.6	33.5	31.7	25.9	51.8	38.7	57	48.6
48	24.4	24.6	23	24.2	32.7	31.6	26	50.9	38.6	56.3	48
49	25.2	24.6	23.9	24	32.3	31.7	26.6	49.8	38.9	55.3	47.6
50	26	27	25.3	26.3	33.1	32.1	28.3	49.4	39.1	55.4	47.3
51	26.6	27.4	26	26.7	33.9	33.4	29.4	48.8	40.1	54.8	47.6
52	27	27.8	26.3	27.2	34	33.4	29.6	47.7	39.4	53.5	46
53	25.6	25.7	24.1	24.8	32.4	31.6	26.7	47.1	37.8	54	44.9
54	24.6	24.3	23	23.6	31.5	30.4	25.7	46	37	53.3	44.2

55	25.5	25.4	23.8	24.5	29.5	28.8	25.5	44.5	35.2	52.9	42.9
56	23.9	23.5	22.2	23.3	27.9	27.6	23.5	43.7	34	52.2	42.4
57	22.9	22.1	21.9	22.1	28	27.1	23.1	43.7	33.5	52	42
58	23.3	23	22	22.6	27.3	26.3	23	42.8	32.1	51.5	41.1
59	22.2	21.6	21	21.8	26.6	25.4	22.1	41.7	31.4	50.7	40.5
60	22.3	23	21.5	22.8	26	24.9	22.7	40.4	30.6	50.3	39.8
61	22.4	23	21.6	23	26	25	23.2	39.4	30.3	49.3	39.2
62	21.7	22.5	21.5	22.6	26.3	25.4	23.2	38.2	30.5	48	38.7
63	22.5	23.3	21.6	22.9	24.9	24.2	22.4	35.9	27.3	47.8	35.9
64	23.3	24	22.3	23.5	25.1	24.5	23.1	34.5	26.8	46.7	34.8
65	22.4	23	21.5	23.1	24.1	23.2	22.2	33.1	25.7	45.2	34
66	22.8	24	22.6	23.9	24.9	24.2	23.8	32.8	27.4	44.5	35.5
67	22.2	22.3	21.7	21.9	24.5	23.9	22.5	31.5	26.8	43	34.1
68	21.1	20.7	19.9	20.1	22.2	21.6	20	28.2	23.3	41.3	30.1
69	20.7	21.7	20.3	21.5	21.5	20.8	20.5	26.5	22.6	40.4	29.9
70	21.8	23.1	21.9	22.8	22.7	22.2	22.5	26.7	24	39.2	30.6
71	21.8	23.4	22	23	23	22.7	22.9	26.5	24.3	36.7	30
72	21.2	22	21	21.5	22.7	22.3	21.6	25.9	23.9	33.3	28.3
73	21	22.1	20.7	21.6	22	21.6	21.3	24.6	22.9	28.6	25.9
74	21.2	22.4	21.3	22.1	22	21.6	21.8	23.7	22.5	26	24.5
75	21.8	23.8	22.4	23.7	22.6	22.4	23.5	23.3	22.8	24.9	24.1
76	22.1	24.2	22.5	23.9	23.2	23	23.6	23.8	23.3	24.8	24.3
77	22.1	24.4	22.2	24.2	23.2	23.1	23.4	23.9	23.5	24.9	24.4
78	22.4	24.8	22.5	24.4	23.3	23.2	23.8	23.9	23.7	24.6	24.5
79	22.3	23.8	22.2	23.3	23.4	23.3	23.4	24.1	23.7	24.7	24.5
80	22.3	24.2	22.4	23.8	23	22.8	23.5	23.4	23.3	23.9	24

day	(24) mid	(25) mid	(26) mid	(27) mid	(28) top	(29) top	(30) top	(31) top	(32) top	(33) top	(34) top
1	27	28.3	28.9	27.5	28.2	28.4	28.4	28.1	28.9	28.6	26.1
2	48.2	69.8	71.9	70.4	70.1	70.1	64.1	63.7	69.5	65.2	64.1
3	73	73.5	68.1	72.4	72.1	72.6	74.1	73.9	71.2	74	62.7
4	73.8	72.1	55.3	69.9	70.8	71.3	73.5	73.3	70.1	73.5	61.8
5	72.9	68.7	47.2	67	67.9	68.5	72.5	72.1	67.8	72.5	58.3
6	72.8	70.7	57.7	66.8	66.1	65.9	72	70.8	67.9	72.2	57.5
7	72.2	69.7	62.1	68.3	68.2	69.5	71.1	71.5	65.2	70.9	57.9
8	71.4	69.1	63.5	68.1	66.7	67.2	70.1	69.7	64.4	69.9	55.2
9	70.4	67.1	56.9	65.7	64.5	64.2	69.1	67.9	63.8	69	54.6
10	69.5	65.8	55.5	63.3	63.8	64.3	67.7	67.4	61.6	67.7	51.4
11	68.8	65.6	54.7	62.6	61.4	63.3	66.6	67.2	60.7	66.9	52.7
12	68.5	66.8	54.5	62.4	58.6	60	66.5	65.8	63.4	67.4	54.4
13	69	67.2	53.6	62.2	64.9	63.7	67	65.9	63.1	67.9	50
14	69.1	66.5	51.2	60.4	63.1	63.1	67.6	66.5	61.4	68.1	48.2
15	68.1	66.3	50.6	59.8	62.2	62.1	66.4	66.1	55.9	65.6	44.6

16	69	67	51	61.1	62.1	63	67.2	67.7	59.9	67.6	48.4
17	69.1	66.1	49.6	60.5	61.2	62.3	66.9	67.7	58.7	66.9	47.1
18	69	65.2	47.3	58.6	60.2	60.9	66.8	66.8	56.9	66.5	43
19	68.5	65.5	48.4	59.1	59.5	60.5	65.9	66.4	57.4	65.9	45.8
20	68.3	64.7	47.7	58.9	59.5	60.8	65	66.3	55.9	64.8	46.5
21	67.9	64.1	47	57.3	57.9	59.7	64.9	65.8	55.9	64.8	45.9
22	67.6	63.4	44.9	55.7	57.7	58	64.7	64.5	55.1	64.8	42
23	67.2	61.8	42.7	55	56.5	57.6	64.4	64.6	52.6	64	39.6
24	66.4	60.8	41.4	53.8	55.3	56.2	63.8	63.5	52.5	63.7	38.3
25	66.2	60.3	41.3	53.4	55.2	56.2	63.4	63.3	52.6	63.3	38.9
26	66.5	59.9	41.1	52.9	54.2	54.8	62.8	62.3	52	63	39.8
27	66.6	59.1	40.5	52.2	52.2	53.5	62.2	62.3	51.3	62.6	39.8
28	66.6	58.8	40.6	51.3	53.5	53.7	63	61.9	52.9	63.2	39.8
29	66.6	58	41.1	51.7	51.2	53.1	62	62.6	51	62.1	41.3
30	66	56.8	39.7	51	47.8	49.4	60.5	60	52.5	62.3	40.8
31	65.9	54.2	35.6	46.8	51.8	51.7	61.9	60.4	47.4	61.5	33.6
32	65.4	53.3	34.8	45.4	51.4	50.4	61.5	59.8	49.1	61.3	33.7
33	65.3	52	32.6	44	49.6	48.2	61	59.5	48.6	61.1	32.4
34	65	50.8	32.2	43.4	48.3	47.1	60.2	59.4	48.1	60.4	33.2
35	65.4	50.9	32.8	44.1	48.1	47.1	60.4	59.5	48.7	60.7	35.2
36	65.2	49.5	30.9	43.3	47.1	46.3	60	59.6	46.6	60.2	32.8
37	63.1	44.7	27.5	42.3	45.7	45.6	56.3	58.3	42.1	56.4	32.7
38	64.6	47.7	31.2	41	44.6	43.5	59.4	57.6	49	60.7	34.1
39	64	47.4	31.6	42.2	44.6	44.2	59	58.3	46.8	60.1	34.3
40	63.2	46.5	30	40.9	42.2	41.4	58.8	56.2	47.1	60.3	32.1
41	61.3	43.6	26.7	37.9	39.1	38.2	56.3	54	44.8	58.7	29.1
42	60.2	42.6	26.8	36.2	38.9	38.1	55.2	53.3	45.1	58	29.4
43	59.4	42	26.6	35.6	38.9	38.1	54.8	53.3	44.2	57	29.2
44	58.1	41	26.7	35	39.1	38.7	52.9	51	42.8	55.8	29.5
45	57	40.5	26.2	34.3	38.6	38.4	52.2	50.7	42.1	54.3	29
46	56	40.1	26.6	33.3	37.6	37.1	50.4	49.2	42	52.5	28.6
47	55.5	40	26.7	32.8	36.9	36.6	49.2	48.1	41.9	51.5	28.8
48	54.7	39.5	26.9	32.6	36.5	36.5	48.3	47.1	40.4	50.4	28.6
49	53.9	39.1	27.1	32.9	36.2	36.8	47.1	46.5	39.3	49.2	29.1
50	53.7	40	29.3	32.9	36.8	37	46.9	46.1	41.2	48.8	30.9
51	53.2	40	29.8	33.8	37.5	38.2	46.4	46.2	39.5	47.8	30.9
52	52.2	40.4	30.5	33.9	36.4	36.8	44.7	44	40.6	46.8	31.7
53	52.3	39.5	28.1	32.5	34.4	34.5	43.7	42.2	39.3	46.3	29.1
54	51.4	38.5	26.9	30.6	33.9	33.5	43.1	41.7	38.9	45.7	27.5
55	51.4	39.1	28	30.6	31.9	32	42.3	40.3	37.9	44.6	27.2
56	49.9	36.3	24.7	29.1	30.8	31.6	41.6	40.4	34.5	43.2	25.5
57	49.3	35.6	24	27.5	31.7	31.7	41.5	40.2	35.2	43.3	24
58	48.6	35.6	24.9	26.5	30.8	30.4	40.9	39.2	37.2	42.9	24.2
59	47.3	33.8	23.4	25.1	30.2	29.7	39.9	38.5	35.6	41.9	22.9

60	46.6	32.9	24.1	24	29.5	29	39.2	38.1	36.2	41.4	23.2
61	45.5	31.9	24	23.9	29.2	28.8	38.8	37.9	35.2	40.8	23.3
62	43.9	29.3	22.8	24.2	29.3	29.4	38	38.3	30.7	38.4	22.9
63	44.2	31.2	23.9	24.4	26.7	26.1	37.4	35.2	35.3	40.2	23.3
64	43.4	31.7	25.2	24.9	26.8	26	37.2	34.9	35.8	39.6	24.1
65	42	30.5	24	24	25.1	24.4	36.1	34.2	33.3	38.3	23
66	40.7	29.4	24.7	23.7	26.7	26.5	36.2	35.8	32.5	37.6	23.8
67	39.3	28.2	23.1	23.5	25.7	25.5	35.6	34.5	31.4	37.4	22.1
68	37.4	26.6	21.1	22.2	22.3	21.9	32.9	31	29.3	35.6	19.9
69	34.7	25.4	21.7	21.3	21.9	21.6	31.8	30.7	29.2	34.4	20.7
70	32.6	25.9	23.6	22.2	23.5	23.4	32	31.4	29.2	33.5	22.5
71	30.2	25.3	23.6	22.5	23.8	23.8	30.5	30.3	27.7	31.1	23
72	28.2	24.2	22	22.1	22.8	22.7	28.1	27.7	25.3	28.4	21.4
73	26.2	23.5	22.1	21.4	21.8	21.6	24.9	24.6	24.1	25.3	21.2
74	24.9	23.1	22.5	21.6	21.8	21.8	23.4	23.3	23.1	23.7	21.7
75	24.1	23.3	23.9	22.1	22.9	22.9	23.4	23.6	23.9	23.5	23.5
76	24.3	23.6	24.2	22.8	23.6	23.4	24	24.1	24.3	24.1	23.8
77	24.4	23.7	24.2	23	23.5	23.6	24.1	24.1	24.3	24.2	23.9
78	24.2	23.7	24.5	23.1	23.8	23.9	24	24.2	24.2	24	24.4
79	24.4	23.8	23.9	23.1	23.5	23.5	23.8	23.9	23.8	23.9	23.5
80	23.7	23.3	24	22.8	23.4	23.4	23.5	23.7	23.7	23.5	23.7

Appendix C

COMPOST PARAMETER DATA

Samp: sample ID, (in the ID, the number is the sampling day, and the letter the sampling location: w-whole pile, b-bottom, m-middle and t-top).
MC:moisture content; VS:volatile solids; C:carbon; N:nitrogen; P:phosphorus; NO_3-N:nitrate nitrogen; NH_3-N:ammonia nitrogen; T:temperature.

Treatment I

Samp	MC%	VS%	Ash%	pH	C%	N%	P%	NO_3-N%	T	NH_3-N%
1w	73	87	11	6.2	47	2.8	0.91	0.002 20	-	
5w	71	87	11	8.6	44	2.9	-	0.001 56	-	
9w	69	87	12	8.4	44	3.1	1.01	0.001 47	-	
12b	70	87	11	8.5	44	2.5	-	-	32	-
12m	69	87	11	8.3	45	2.9	-	-	53	-
12t	69	86	13	8.3	46	2.8	-	-	41	-
15b	69	87	13	8.4	45	2.8	1	0.002 31	-	
15m	68	87	12	8.2	45	3.4	0.97	0.001 47	-	
15t	65	-	-	8.2	38	2.8	0.81	0.001 36	-	
18b	69	87	11	8.5	45	2.5	-	-	26	0.15
18m	68	87	11	8.1	45	2.8	-	-	40	0.14
18t	67	87	12	8.3	44	2.7	-	-	31	0.14
22b	69	84	14	8.6	46	2.5	-	-	25	-
22m	68	86	12	8.5	43	2.4	-	-	38	-
22t	68	87	11	8.5	45	2.6	-	-	31	-
29b	70	88	11	8.7	45	2.5	-	-	22	1.42
29m	68	87	12	8.7	44	2.4	-	-	29	1.46
29t	67	87	12	8.6	44	2.5	-	-	25	1.39
37b	70	86	12	8.6	45	3	-	0.002 20	1.33	
37m	68	87	12	8.7	45	3.2	-	0.001 22	-	
37t	67	86	12	8.7	45	3.2	-	0.002 20	-	
47w	67	87	11	8.5	45	2.6	-	-	19	1.02
80b	67	86	12	7.8	45	2.8	1.25	-	21	1.81
80m	66	87	11	7.8	45	2.6	1.23	-	22	2.1
80t	67	86	12	7.8	44	2.6	1.21	-	22	1.99
1w	71	89	10	6.1	46	2.7	0.79	0.001 22	-	
5w	68	89	11	8.5	46	2.8	-	0.001 51	-	
9w	68	87	11	8.3	45	2.8	0.84	0.001 50	-	
12b	67	89	10	8.1	45	2.4	-	-	34	-
12m	68	89	10	8.1	46	3	-	-	48	-
12t	67	86	-	8.1	43	2.4	-	-	49	-
15b	66	88	10	7.7	46	2.5	0.69	-	30	-
15m	67	88	10	8	45	2.9	0.92	0.001 43	-	

15t	68	88	10	8.2	44	3	0.95	0.002	45	-	
18b	68	88	12	8.4	46	2.5	-	-		25	0.36
18m	67	90	10	8.2	47	2.4	-	-		36	0.37
18t	67	87	13	8.4	46	2.5	-	-		38	0.41
22b	65	90	-	8.4	47	2.4	-	-		23	-
22m	67	89	10	8.3	46	2.5	-	-		29	-
22t	66	87	12	8.4	45	2.5	-	-		32	-
29b	67	84	15	8.7	46	2.4	-	-		20	1.38
29m	65	89	11	8.5	46	2.5	-	-		25	1.33
29t	67	83	-	8.6	45	2.5	-	-		25	1.39
37b	69	85	14	8.6	45	2.8	-	0.002	19	1.18	
37m	66	90	10	8.5	46	2.8	-	0.001	21	-	
37t	68	86	13	8.6	45	3.5	-	0.001	20	-	
47w	65	89	11	8.5	44	2.5	-	-		19	1.22
80b	65	90	-	7.3	45	2.3	0.94	-		21	1.7
80m	65	89	10	7.5	45	2.5	1.03	-		22	1.82
80t	64	81	-	7.8	40	2.2	1.01	-		22	1.61
1b	71	86	14	6.1	44	2.6	0.79	0.001	21	-	
1m	76	84	14	6.9	44	3.1	1.19	0.001	25	-	
1t	78	84	15	6.8	45	3.7	1.3	0.001	23	-	
4w	72	86	14	8.6	43	3	-	0.001	55	-	
8w	69	85	14	8.6	43	3.1	1.09	0.001	52	-	
11b	69	88	11	8.4	46	2.7	-	-		38	-
11m	67	82	17	8.6	41	2.9	-	-		55	-
11t	72	82	16	8.6	44	2.8	-	-		51	-
14b	68	86	11	8.4	45	2.9	0.91	0.001	36	-	
14m	68	86	12	8.4	43	3.3	1	0.001	51	-	
14t	72	84	16	8.5	42	3.6	1.3	0.001	48	-	
17b	68	87	12	8.5	45	2.4	-	-		31	0.37
17m	68	87	12	8.4	45	2.6	-	-		44	0.39
17t	71	83	17	8.5	43	3	-	-		40	0.43
21b	68	88	11	8.6	45	2.3	-	-		28	-
21m	70	84	-	8.6	44	3.1	-	-		40	-
21t	70	81	18	8.7	43	3	-	-		37	-
28b	67	88	12	8.7	44	2.4	-	-		24	1.41
28m	67	87	13	8.8	46	2.8	-	-		32	1.55
28t	70	83	17	8.8	43	3.3	-	-		30	1.49
36b	72	87	12	8.7	46	2.6	-	-		21	1.37
36m	67	88	12	8.8	46	2.6	-	-		27	-
36t	69	84	16	8.8	44	3.2	-	-		26	-
46w	67	87	12	8.3	43	2.8	-	-		21	1.21
79b	67	88	12	7.5	45	2.9	1.02	0.078	21	1.72	
79m	65	86	14	7.6	42	3.3	1.14	-		22	1.72
79t	68	79	19	8.1	41	3.9	1.59	0.177	22	1.85	

Treatment II

Samp	MC%	VS%	Ash%	pH	C%	N%	P%	NO_3-N%	T	NH_3-N%
1w	80	81	16	7.2	42	3.7	1.64	0.001 20	-	
5w	77	81	16	8.7	41	3.4	-	0.003 52	-	
9w	77	79	18	8.7	42	3.7	1.85	0.001 49	-	
12b	77	80	19	8.7	39	2.9	-	-	37	-
12m	77	81	19	8.6	40	3	-	-	57	-
12t	76	79	19	8.7	40	3.1	-	-	52	-
15b	76	77	21	8.7	43	4	1.83	0.001 36	-	
15m	77	79	21	8.7	40	3.8	1.9	0.001 56	-	
15t	76	78	20	8.7	39	3.8	1.89	0.001 50	-	
18b	75	81	19	8.7	41	3	-	-	34	0.2
18m	77	77	22	8.7	40	3.2	-	-	54	0.2
18t	76	79	19	8.7	39	3.1	-	-	46	0.52
22b	78	79	18	8.7	40	3.1	-	-	33	-
22m	77	81	18	8.7	41	3.3	-	-	52	-
22t	76	78	21	8.7	41	3.4	-	-	45	-
29b	77	79	21	8.8	40	2.9	-	-	32	2.37
29m	77	80	20	8.8	40	3.1	-	-	50	2.01
29t	75	77	21	8.8	41	3.5	-	-	42	1.82
37b	78	80	17	8.8	40	3.4	-	0.002 32	2	
37m	77	81	17	8.8	40	3.4	-	-	47	-
37t	74	77	22	8.9	40	3.7	-	-	39	-
47b	77	76	21	8.1	39	2.9	-	-	30	1.47
47m	75	79	18	8.7	40	3.3	-	-	43	1.34
47t	73	79	19	8.8	40	3.3	-	-	36	1.62
61b	76	79	21	7.8	39	4	-	0.13	28	1.5
61m	75	78	22	8.6	39	3.9	-	-	37	1.85
61t	72	79	18	8.9	38	3.8	-	-	32	1.76
89b	72	77	22	7.5	38	3.3	2.06	-	24	1.76
89m	73	77	22	8	39	3.3	2.04	-	28	2.24
89t	68	78	22	8	38	3.3	1.99	-	24	1.98
115b	75	79	20	7.1	38	4	2.02	0.341 21	1.18	
115m	74	77	22	7.6	38	4.2	1.8	0.216 21	1.7	
115t	72	78	22	7.3	39	3.9	1.89	-	21	1.42
1w	80	81	18	7.1	41	3.4	1.59	0.001 25	-	
5w	75	82	16	8.7	42	3.5	-	-	51	-
9w	76	81	17	8.7	40	3.4	1.7	0.001 53	-	
12b	76	80	20	8.6	41	3.1	-	-	41	-
12m	72	82	17	8.6	42	3.2	-	-	59	-
12t	74	79	18	8.6	41	2.9	-	-	60	-
15b	77	80	20	8.7	41	3.7	1.71	0.001 39	-	
15m	77	80	19	8.7	40	3.6	1.72	0.001 58	-	
15t	74	80	19	8.7	41	3.7	1.55	0.001 57	-	

18b	79	79	21	8.7	42	2.9	-	-		36	0.29
18m	77	79	20	8.7	42	3.2	-	-		55	0.24
18t	74	81	19	8.7	39	3.1	-	-		51	0.22
22b	77	81	17	8.7	37	2.9	-	-		35	-
22m	76	81	18	8.7	50	3.3	-	-		53	-
22t	74	82	18	8.7	41	3.1	-	-		49	-
29b	74	80	20	8.7	35	2.6	-	-		34	1.96
29m	77	81	19	8.8	46	3.5	-	-		49	2.01
29t	75	82	18	8.8	35	1.4	-	-		44	1.88
37b	78	81	17	8.7	41	3.6	-	0.026	33	1.84	
37m	76	80	20	8.8	41	3.8	-	0.001	46	-	
37t	75	83	17	8.8	42	3.9	-	0.001	39	-	
47b	80	81	18	8	41	3.1	-	-		32	1.52
47m	75	80	18	8.8	41	3.3	-	-		44	1.35
47t	72	82	18	8.8	40	3.1	-	-		37	1.62
61b	77	80	18	7.7	39	4.1	-	0.176	30	1.43	
61m	77	81	18	8	40	3.8	-	0.083	38	1.58	
61t	71	81	18	8.8	39	4	-	0.061	33	1.72	
89b	77	79	20	7.6	39	3.5	1.96	-		25	2.12
89m	73	77	21	7.7	39	3.4	1.99	-		29	2.03
89t	65	76	22	7.7	39	3.2	1.86	-		26	2.01
115b	75	81	19	7	38	4.8	1.94	0.681	20	2.01	
115m	75	80	20	7.3	39	4.1	1.8	0.206	21	2.38	
115t	70	79	21	7.5	39	4.2	1.89	0.221	19	1.71	
1w	79	80	19	7.4	43	2.9	1.54	-		22	-
4w	77	80	17	8.5	41	2.7	-	-		48	-
8w	76	79	20	8.7	41	2.9	1.65	-		51	-
11b	76	78	19	8.6	41	3	-	-		39	-
11m	76	79	19	8.6	42	3	-	-		55	-
11t	75	78	-	8.6	40	3	-	-		60	-
14b	77	77	20	8.6	42	3.1	1.69	-		38	-
14m	77	78	18	8.6	42	2.9	1.67	-		54	-
14t	75	78	18	8.6	41	3	1.71	-		56	-
17b	77	79	20	8.8	42	3	-	-		36	0.59
17m	76	80	20	8.8	41	3.3	-	-		52	0.49
17t	74	79	19	8.8	42	3.3	-	-		52	0.48
21b	77	80	18	8.8	40	3	-	-		35	-
21m	75	79	19	8.8	41	3.1	-	-		50	-
21t	73	78	22	8.8	40	3.1	-	-		50	-
28b	77	79	20	8.8	41	3	-	-		34	2.14
28m	75	80	20	8.8	41	3	-	-		48	1.88
28t	73	78	19	8.8	40	3	-	-		46	1.71
36b	78	79	20	8.7	42	3.1	-	-		33	1.7
36m	75	75	-	8.8	41	3.1	-	-		46	-

36t	71	73	-	8.9	42	3	-	-		42	-
46b	77	78	21	8.1	40	3.2	-	-		31	1.44
46m	75	79	20	8.8	40	3	-	-		43	1.58
46t	71	79	20	8.8	41	3.1	-	-		38	1.53
60b	77	81	17	8	41	3.2	-	-		30	1.52
60m	76	79	20	8.9	42	3.3	-	-		38	2.25
60t	70	79	21	8.8	40	3.2	-	-		33	1.64
88b	76	76	20	7.3	38	3.6	1.83	-		25	2.01
88m	72	72	24	7.8	40	3.2	2.03	-		28	1.97
88t	67	75	23	7.8	38	3	1.86	-		26	1.85
114b	76	79	20	6.7	38	3.9	-	-		19	2.23
114m	72	80	19	7.4	40	3.3	-	-		21	4.54
114t	69	80	20	7.4	40	3.3	-	-		19	1.64

Treatment III

Samp	MC%	VS%	Ash%	pH	C%	N%	P%	NO_3-N%		T	NH_3-N%
1w	76	80	18	7.9	40	1.8	1.32	0.002	24	-	
3w	74	82	16	8.5	41	1.6	-	0.003	57	-	
7w	72	80	18	8.7	40	1.9	1.29	0.007	62	-	
10b	64	78	20	8.7	40	1.8	-	-		49	-
10m	71	81	17	8.4	41	1.6	-	-		64	-
10t	72	81	17	8.6	41	1.5	-	-		64	-
13b	61	75	-	8.8	38	1.9	1.59	-		43	-
13m	70	76	21	9	39	1.7	1.04	-		63	-
13t	72	80	19	8.7	41	1.8	1.34	-		62	-
16b	58	77	22	8.9	40	2.1	-	-		36	0.1
16m	64	77	21	8.9	39	1.9	-	-		60	-
16t	78	78	21	8.8	39	1.9	-	-		59	0.07
20b	58	76	23	9	39	2.2	-	-		38	-
20m	70	76	24	8.8	40	2	-	-		60	-
20t	71	76	21	8.8	39	1.6	-	-		58	-
27b	52	73	25	9.2	38	2.2	-	-		34	0.01
27m	52	75	24	8.9	38	2.2	-	-		54	0.02
27t	70	77	22	8.9	39	1.9	-	-		51	0.51
35b	52	71	29	9.5	38	2.8	-	0.002	30	0.01	
35m	47	74	26	9.2	38	5.4	-	0.001	46	0.01	
35t	66	71	28	9	37	3.3	-	0.024	43	0.19	
45b	50	72	26	9.6	37	2.4	-	-		27	0.01
45m	42	73	26	9.6	37	2.2	-	-		38	0.02
45t	61	71	29	8.8	36	2.8	-	-		35	0.1
59b	45	72	26	9.6	36	2.3	-	-		24	0.02
59m	40	72	26	9.6	37	2.3	-	-		30	0.11
59t	68	70	29	8.9	36	3	-	-		27	0.26
78b	53	70	28	9.7	36	3.1	2.33	0.034	22	0.02	

78m	41	70	28	9.6	36	3.2	2.33	0.103	23	0.17	
78t	62	66	33	8.7	35	3.8	2.64	0.49		23	0.48
1w	76	83	17	7.9	41	2.3	1.14	0.001	24	-	
3w	73	83	15	8.5	41	1.7	-	0.002	61	-	
7w	70	81	17	8.8	39	1.7	1.3	0.002	64	-	
10b	66	78	22	9	40	1.7	-	-		55	-
10m	70	81	18	8.7	42	1.4	-	-		68	-
10t	67	79	20	8.6	41	1.5	-	-		66	-
13b	62	76	23	9	38	2	1.67	-		50	-
13m	69	79	20	8.7	41	2	1.37	-		67	-
13t	71	82	18	8.6	40	1.6	1.14	-		65	-
16b	62	76	24	9	40	2.1	-	-		45	-
16m	68	78	20	8.8	40	1.9	-	-		65	0.02
16t	72	80	19	8.7	41	1.6	-	-		63	0.14
20b	60	75	25	9.1	39	2.3	-	-		45	-
20m	62	77	23	8.9	40	2.1	-	-		64	-
20t	71	77	22	8.9	40	1.7	-	-		63	-
27b	56	72	26	9.2	38	2.4	-	-		39	-
27m	49	74	24	8.9	39	2.6	-	-		59	0.07
27t	66	73	26	9	37	2.3	-	-		57	0.39
35b	50	72	28	9.6	37	2.8	-	-		35	0.01
35m	47	74	26	9.1	39	3	-	0.012	52	0.04	
35t	66	76	-	8.7	38	2.7	-	0.031	51	0.1	
45b	51	73	26	9.3	37	2.3	-	-		30	0.01
45m	45	72	28	9.6	37	2.7	-	-		43	0.03
45t	51	73	27	8.9	38	2.6	-	-		41	0.18
59b	57	70	30	9.7	36	2.5	-	-		26	0.01
59m	41	69	31	9.3	36	2.7	-	-		34	0.16
59t	56	68	29	9	36	2.8	-	-		33	0.25
78b	45	69	30	9.7	36	2.9	2.05	0.011	22	0.02	
78m	46	69	31	9.5	35	3.1	2.18	0.125	23	0.07	
78t	51	70	29	8.8	37	3.3	2.04	0.28		23	0.2
1w	75	83	16	7.9	41	1.8	1.08	-		24	-
3w	73	83	15	8.7	42	1.4	-	-		60	-
7w	72	82	16	8.7	43	1.6	1.39	-		64	-
10b	66	80	18	9	40	1.7	-	-		52	-
10m	73	81	17	8.6	41	1.6	-	-		68	-
10t	76	81	18	8.5	40	1.7	-	-		68	-
13b	64	79	21	8.9	40	1.6	1.48	-		50	-
13m	66	79	21	9	40	1.6	0.98	-		68	-
13t	72	80	20	8.7	40	1.4	1.35	-		67	-
16b	59	78	21	8.9	40	2	-	-		44	-
16m	64	80	19	8.9	41	1.7	-	-		66	0.01
16t	71	80	19	8.8	41	2	-	-		66	0.11

20b	60	75	23	9.2	40	2.4	-	-	44	-
20m	57	76	22	9.1	40	2	-	-	66	-
20t	74	79	19	8.9	40	1.8	-	-	66	-
27b	50	73	26	9.2	39	2.3	-	-	39	0.02
27m	47	76	23	9.1	40	2.5	-	-	61	0.07
27t	75	78	21	8.8	41	2.1	-	-	62	0.08
35b	50	71	26	9.5	38	2.2	-	-	36	0.005
35m	43	71	26	9.2	38	2	-	-	54	0.01
35t	62	74	24	9.1	39	2.5	-	-	58	0.19
45b	43	73	27	9.6	37	2.3	-	-	31	0.01
45m	36	74	26	9.8	38	2.4	-	-	46	0.03
45t	54	74	26	8.8	38	2.8	-	-	48	0.14
59b	48	73	26	9.8	32	2.1	-	-	26	0.01
59m	34	72	27	9.5	38	2.1	-	-	35	0.04
59t	53	72	28	9	37	3.1	-	-	34	0.23
78b	50	72	28	9.7	37	2.7	1.95	-	22	0.03
78m	39	70	30	9.9	37	2.4	1.98	-	23	0.06
78t	42	69	30	9.5	37	2.7	2.04	-	23	0.27

Treatment IV

Samp	MC%	VS%	Ash%	pH	C%	N%	P%	NO_3-N%	T	NH_3-N%
1w	72	83	16	8	43	2.2	0.95	0.015	27	-
2w	71	84	14	8.4	43	1.8	-	0.004	59	-
6w	68	82	17	8.7	41	1.5	0.93	0.014	56	-
9b	62	80	17	8.9	41	1.7	-	0.01	57	-
9m	66	83	16	8.6	41	1.5	-	0.005	67	-
9t	69	82	17	8.4	42	1.8	-	0.005	65	-
12b	52	78	-	8.8	38	1.5	1.14	-	50	-
12m	67	82	18	8.8	40	1.4	1.02	-	64	-
12t	67	81	16	8.8	40	1.5	0.94	-	62	-
15b	48	71	-	8.8	38	1.8	-	-	42	-
15m	62	83	17	8.9	42	1.6	-	-	62	0.02
15t	64	82	18	8.7	41	1.5	-	-	60	0.05
19b	40	77	21	9.2	41	1.8	-	-	42	-
19m	56	80	18	8.7	41	1.8	-	-	62	-
19t	64	74	-	8.8	38	1.5	-	-	60	-
26b	39	79	21	9.3	41	1.9	-	-	37	-
26m	39	76	-	8.9	39	2.3	-	-	57	0.04
26t	55	79	21	9	40	2.2	-	-	56	0.29
34b	36	-	-	9.7	36	1.8	-	-	33	-
34m	38	77	22	9.3	40	2	-	-	50	0.004
34t	50	76	23	9.1	40	2.6	-	-	51	0.18
44b	36	76	23	9.7	39	2.1	-	0.005	29	0.01
44m	33	75	23	9.3	38	2.5	-	0.017	42	0.07

44t	45	78	-	9	39	2.5	-	0.017	44	0.01	
58b	37	76	23	9.7	38	2.1	-	-		26	0.01
58m	34	75	25	9.7	38	2	-	-		35	0.04
58t	46	73	26	9.7	38	2.6	-	-		35	0.17
86b	26	77	23	9.6	39	2.3	1.41	0.012	20	0.05	
86m	31	77	23	9.8	39	2.3	1.46	0.008	21	0.04	
86t	38	73	27	9.6	38	2.7	1.55	0.244	19	0.24	
1w	72	83	20	7.9	48	2.4	0.94	-		27	-
2w	71	83	16	8.6	41	1.6	-	-		51	-
6w	67	79	18	8.6	40	1.4	0.93	-		63	-
9b	58	77	20	8.9	40	1.4	-	-		56	-
9m	66	81	17	8.3	40	1.3	-	-		67	-
9t	68	78	19	8.5	40	1.6	-	-		69	-
12b	57	76	22	9	37	1.4	1.24	-		52	-
12m	61	77	22	8.9	40	1.6	1.09	-		65	-
12t	66	79	19	8.8	38	1.4	1.4	-		67	-
15b	54	79	21	9.2	40	1.4	-	-		46	-
15m	60	78	22	8.7	38	1.7	-	-		62	0.29
15t	66	78	21	8.4	40	1.9	-	-		64	0.06
19b	50	72	-	9	38	1.9	-	-		46	-
19m	54	78	21	8.9	40	1.9	-	-		63	-
19t	69	74	24	8.8	39	1.8	-	-		66	-
26b	44	76	24	9.4	39	1.6	-	-		41	-
26m	47	77	23	9.1	39	2.1	-	-		58	0.02
26t	61	75	25	8.9	38	2	-	-		63	0.44
34b	34	71	29	9.7	38	1.7	-	-		36	0.01
34m	37	68	-	9.2	38	2.1	-	-		52	0.05
34t	58	73	27	9.1	38	2.2	-	-		58	0.24
44b	39	72	28	9.8	42	2.9	-	-		31	-
44m	42	71	29	9.4	35	[illegible]	-	-		42	0.05
44t	-	68	32	9.1	36	1.9	-	-		49	-
58b	38	70	30	9.8	34	1.8	-	-		25	-
58m	29	71	29	9.5	41	3.2	-	-		33	-
58t	41	68	31	9.2	37	2.5	-	-		40	0.22
86b	35	71	28	9.8	36	2	1.46	-		20	0.03
86m	32	68	32	9.8	38	2.2	1.59	-		21	0.07
86t	43	68	31	9.4	-	2.4	1.63	-		19	0.26
1w	73	85	15	7.7	44	2.2	0.95	0.004	27	-	
2w	71	80	16	8.5	43	1.7	-	0.002	56	-	
6w	63	71	27	8.7	35	1.5	0.9	0.004	63	-	
9b	62	81	17	8.9	35	1.6	-	0.002	59	-	
9m	68	84	14	8.6	42	1.5	-	0.002	68	-	
9t	68	69	-	8.3	36	1.5	-	0.002	67	-	
12b	56	79	21	8.7	40	1.6	1.34	-		55	-

12m	62	76	-	8.9	39	1.2	1.05	-		66	-
12t	67	80	20	8.7	41	1.2	1.08	-		66	-
15b	53	81	19	9	41	1.5	-	-		52	-
15m	58	82	17	8.8	42	1.4	-	-		63	0.01
15t	69	84	15	8.5	43	1.4	-	-		63	0.16
19b	49	78	21	9.1	41	2.4	-	-		49	-
19m	52	80	18	8.7	41	1.6	-	-		64	-
19t	72	81	18	8.9	41	1.5	-	-		64	-
26b	40	79	21	9.1	41	1.9	-	-		43	-
26m	39	79	20	8.9	40	2.2	-	-		59	0.04
26t	70	80	20	8.8	40	1.8	-	-		59	0.4
34b	35	77	23	9.3	40	1.4	-	-		36	0.005
34m	34	76	24	9.1	41	2.4	-	-		51	0.02
34t	62	75	25	9.1	36	2.4	-	-		51	0.11
44b	34	78	22	9.7	39	1.6	-	0.003	30	0.01	
44m	29	77	23	9.4	38	2.5	-	0.012	44	0.03	
44t	43	78	22	8.9	38	3.3	-	0.01		42	0.08
58b	30	75	25	9.7	39	2.4	-	-		26	0.03
58m	26	74	23	9.4	40	2	-	-		36	0.12
58t	41	73	26	9.1	38	2.7	-	-		33	0.22
86b	34	76	24	9.7	40	1.8	1.55	0.008	20	0.03	
86m	31	79	21	9.8	39	2.1	1.33	0.01		21	0.05
86t	31	75	22	9.2	38	2.6	1.54	0.005	19	0.49	