5. BIOLOGICAL PROCESS MONITORING IN HOME COMPOST BINS

5.1 Temperature

Temperature of the decomposing materials in the compost bins was monitored at regular intervals throughout the controlled HC experiment. The experimental procedures are detailed in Section 2.2. The temperature of three distinct layers that developed as the material added to the bins decomposed with time was monitored; this included fresh input waste (layer A), decomposing waste (layer B) and decomposed composted waste (layer C). Detailed temperature profiles were also measured manually with an insertion probe on five occasions during the monitoring period.

5.1.1 Manual temperature monitoring

Temperature measurements were performed at a regular frequency during the experimental period using an electronic thermometer probe (Figure 5.1). Monitoring commenced on 8 February 2005 until 6 March 2006, for a period of 392 days, and therefore included both cool winter and warmer summer ambient conditions. As would be expected, considerable variation in temperature conditions was observed in the decomposing waste materials within the bins, which followed the underlying seasonal ambient temperature. However, the temperatures of the decomposing wastes were consistently above the ambient air temperature due to the generation of metabolic heat from microbial activity. Thus, biological degradation processes were active throughout the monitoring period, including the winter period when ambient temperatures were low. In general, temperature values were in the mesophilic range (15-45 ^{o}C) from mid-April for all treatments with the exception of Treatment 1, which reached the mesophilic range in late May. On one occasion, in mid-September, temperatures measured in three treatments (Treatment 4 (Milko and Blackwall bins), 5 and 6) exceeded 45 ^{o}C, indicative of thermophilic microbial activity. During cold ambient conditions (February – mid-April 2005 and late November 2005 – early March 2006), temperatures of the decomposing materials in the compost bins were in the psychrophilic range (5-10^{o}C) or fell below this range in all treatments. Bin temperatures rarely exceeded 15 ^{o}C during the winter period December 2005 - February 2006.

The lowest temperatures were recorded for Treatment 1 with the addition of only garden waste, which may be explained by moisture limitation of microbial activity in this experimental treatment. In contrast, compost temperature was raised with increasing proportion of kitchen residues in the waste input to the bins. The highest temperatures were measured for Treatments 3 and 6 (see Table 2.3 for experimental details), which received the most kitchen waste (80 % of the input mass). The addition of paper waste (Treatments 4, 5 and 6), in combination with food waste, also had a positive influence on temperature conditions in the home compost bins. Identical waste input regimes were added to Treatment 4, using the standard Milko bin, and the alternative Blackwall bin, to test the effects of bin type on composting conditions. Warmer temperature conditions were recorded for the Blackwall bin compared to the Milko type. A possible explanation for this observation is the black colour of the Blackwall bin may be more efficient at absorbing heat from sunlight compared to the green coloured Milko bin.

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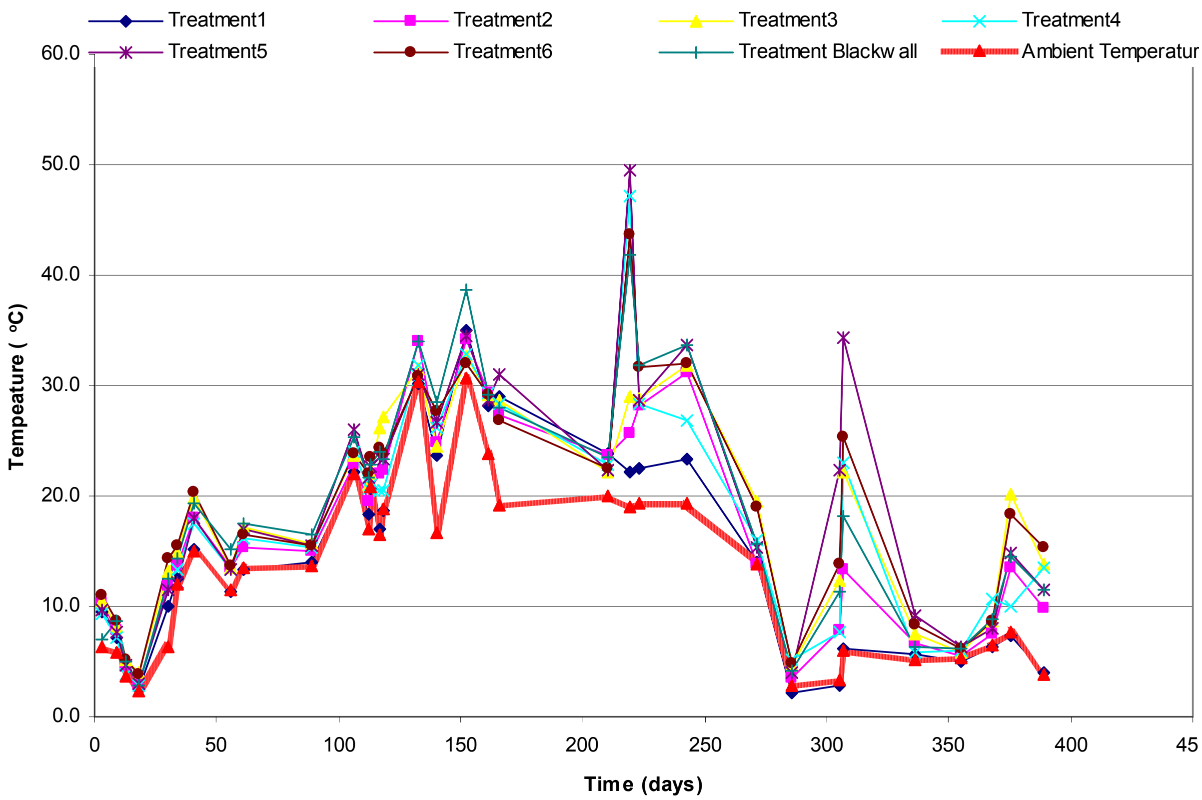


Figure 5.1 Mean temperatures recorded in home compost bins supplied with different waste input regimes (see Table 2.3 for description of Treatments)

5.1.2 Continuous automatic temperature monitoring

Temperatures of the three waste layers (A, B and C) in the compost bins were monitored continuously using a datalogger during two periods from 27 July to 4 November 2005 and 12 January to 6 March 2006. Temperatures followed the seasonal pattern in ambient conditions, but in most cases were higher than ambient values (Figures 5.2-5.6). The warmest conditions were measured in recently deposited waste, associated with higher rates of microbial activity in this layer, compared to cooler temperature conditions in more stabilised material at increasing depth. Temperature readings of the upper (A) and middle (B) layers of decomposing wastes were approximately similar throughout the monitoring period. Maximum temperatures were recorded in the A and B layers after 4-5 days following the addition of fresh waste inputs to the bins. The temperature of the lower C layer was not generally affected by the input of fresh waste, except when the waste mass in the bins was mixed. During the July-November 2005 monitoring period, maximum temperatures in the warmest regions of the bins reached the thermophilic range (45-70 ^{o}C) for short periods. In general, however, temperature profiles were in the range 12-55 ºC and, therefore, typically mesophilic. As ambient temperatures decreased during November, waste temperatures declined to the psychrophilic range (5-15 ^{o}C). During the winter period, temperatures did not exceed the mesophilic range, even after depositing fresh waste in the bins. The maximum values recorded during January-March 2006 were in the range 35-40 ^{o}C, but the temperature of fresh and decomposing materials was usually <20 ^{o}C. The temperature of the lower layer (C) during the winter was consistently within the psychrophilic range.

The overall mean temperatures for the different compost layers within the bins are listed for each Treatment in Table 5.1 for both monitoring periods. These confirmed the manual monitoring data and show the lowest temperatures were recorded for the garden waste treatment (Treatment 1) and the highest values were measured with the largest rate of food waste addition, equivalent to 80 % of the total waste input, for Treatment 3 and 6 during the July-November period. During this period, the mean temperature of home compost bins receiving food waste was approximately twice the ambient value (15 ^{o}C). Temperature conditions in all treatments with food waste were similar (10 – 11 ^{o}C) during the winter period (Jan-March), and were more than 3 times higher than ambient (3.2 ^{o}C). These data emphasise that biological degradation processes are active in home compost bins including the winter period when ambient temperatures are lowest.

5.1.3 Temperature profiles in compost bins

Temperature profiles of the compost bins were also measured manually on five occasions during the course of the experiment (Section 2.2.5.1, Table 2.6) using a probe inserted to a maximum depth of 40 cm (within layers A and B) (Figure 5.7). These data represent the overall mean values of three temperature profiles recorded for the three replicate bins of each experimental treatment. Temperatures varied from 5-45 ^{o}C and during warmer ambient summer conditions (July, September and October) were typically in the mesophilic range. During colder ambient conditions, temperatures decreased below 15 ^{o}C and were in the psychrophilic range during the winter period. The lowest temperatures were recorded for Treatment 1, supplied only with garden waste. Increasing the proportion of food waste added to the bins generally increased the profile temperature and there was also evidence for Treatment 5, for example, that paper inputs also raised bin temperature. As expected, temperatures declined with increasing depth as the waste became progressively more aged stabilized and, at the 40 cm depth, the variation in temperatures between the experimental treatments was relatively small. The profile depth monitoring showed that the temperature of composting materials in the Blackwall bin was consistently warmer than the equivalent waste input regime (Treatment 4) added to the Milko bin. This suggests that waste degradation processes in the Blackwall bin may be marginally accelerated compared to the rate of biological activity in the Milko type composter.

5.2 <u>Gaseous phase investigations</u>

Methane (CH_4), oxygen (O_2) and carbon dioxide (CO_2) in the compost bins were sampled and measured using a portable gas analyser (Section 2.2.5.2).

Only traces of CH_4 were occasionally detected in the interstitial gas of the materials in all compost bins, in the range 0.0-0.2 %, but no CH_4 accumulated or was detected in the void space surrounding home compost bins using the gas flux chamber (Figure 2.11). In general, O_2 concentrations were in the range 18 - 21 % and showed that the home compost bins were well supplied with O_2 through diffusion processes from the atmosphere and that waste biodegradation was predominantly aerobic (Figure 5.8). However, the presence of traces of CH_4 in the interstitial gas suggested that anaerobic zones may develop within the composting mass. This is plausible given the heterogeneity of the input materials and variations in densities and moisture contents of input wastes. However, CH_4 releases to the environment from home composters are probably controlled and minimised due to the microbiological oxidation of CH_4 in the mainly aerobic environment within the bin. Microbial CH_4 oxidation is accomplished by methanotrophic bacteria that are ubiquitous in water and soil environments (Hilger and Barlaz, 2002), they are abundant at the interface regions of aerobic and anerobic zones and would therefore also be expected to be part of the microbial community in composting wastes. Consequently, HC is unlikely to be a significant source of CH_4 emissions to the environment.

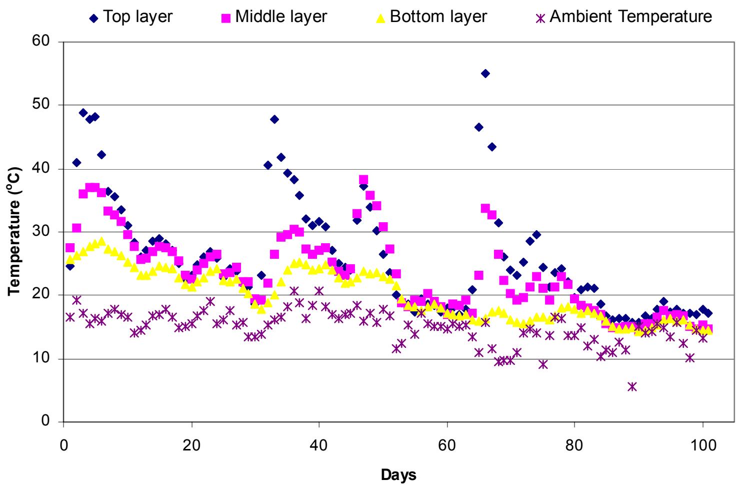
In most cases, the CO_2 concentration in the interstitial gas was small and in the range 0 to 4% (Figure 5.9). As expected, high CO_2 concentrations were associated with reduced concentrations of O_2 in response to active microbial biodegradation. The smallest CO_2 and largest O_2 values recorded for Treatment 1 indicating a lower rate of microbial activity compared to the other waste input regimes tested. Indeed, this behaviour was consistent with the low temperature conditions (Table 5.1) and reduced degradation of waste (Table

4.2) in the treatment only receiving garden waste. By comparison, the lowest concentrations of O_2 and highest values for CO_2 in the interstitial gas, indicating rapid microbial activity, were measured for Treatments 3 and 6 and for the Blackwall bin type. This was also consistent with the increased temperature (Table 5.1) and degradation of waste inputs (Table 4.2) to these treatments associated with the high rate of food waste addition and the warmer temperature conditions in the Blackwall bin compared to the Milko bin type.

Table 5.1 Overall mean temperatures at three depths (fresh input waste (A), decomposing waste (B) and decomposed/composted waste (C) in home compost bins receiving different waste input regimes (see Table 2.3 for description of Treatments)

Monitoring period and position in compost bin	Temperature (°C)					
27July-4Nov 2005						
	Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4**	**Treatment 6**	**Ambient**
Layer A	26.7	31.9	31.8	29.0	33.1	15.0
Layer B	23.8	31.4	34.6	30.9	32.5	
Layer C	20.2	23.3	26.4	24.2	27.1	
Mean	23.6	28.9	30.9	28.0	30.9	
12Jan-6Mar 2006						
	Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4**	**Treatment 6**	**Ambient**
Layer A	5.6	12.0	14.4	11.4	13.3	3.2
Layer B	4.4	13.2	11.7	11.4	11.5	
Layer C	4.7	5.6	6.2	6.5	8.0	
Mean	4.9	10.3	10.8	9.8	10.9	

(a)



(b)

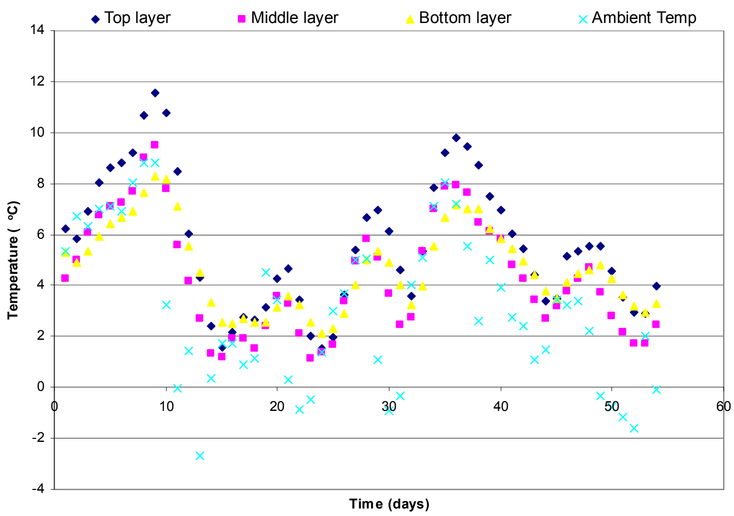
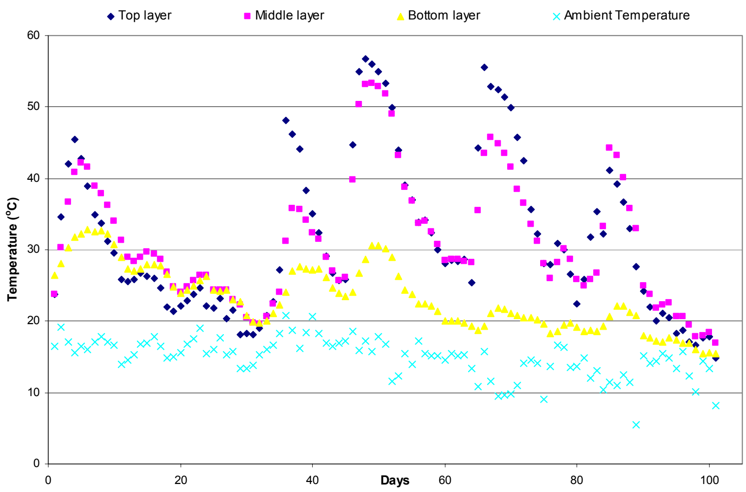


Figure 5.2 Continuous temperature monitoring of the top, middle and bottom layer of home compost bins for Treatment 1 (a) July-November 2005 and (b) January-March 2006

(a)



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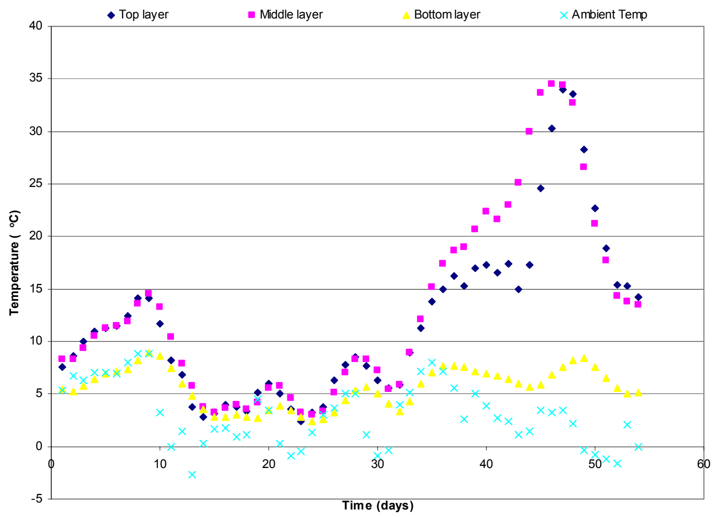
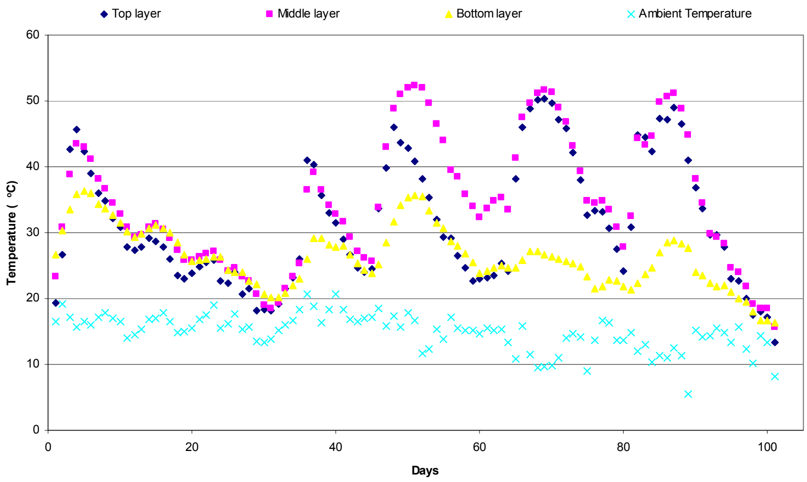


Figure 5.3 Continuous temperature monitoring of the top, middle and bottom layer of home compost bins for Treatment 2 (a) July-November 2005 and (b) January-March 2006

(a)



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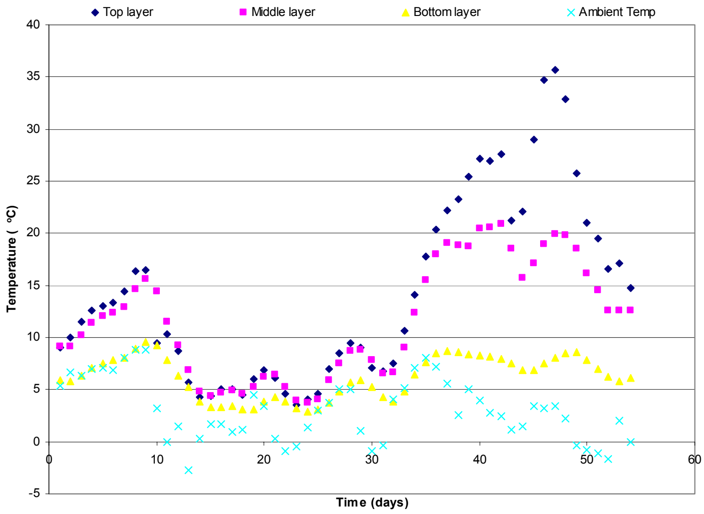
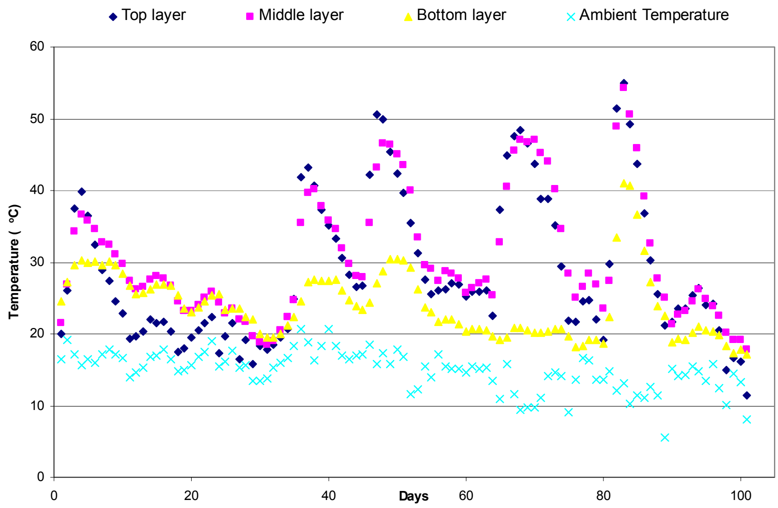


Figure 5.4 Continuous temperature monitoring of the top, middle and bottom layer of home compost bins for Treatment 3 (a) July-November 2005 and (b) January-March 2006

(a)



(b)

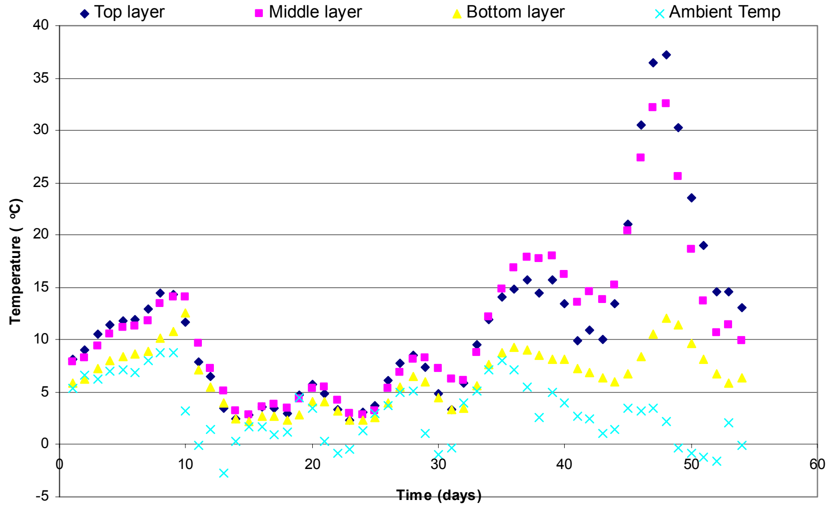
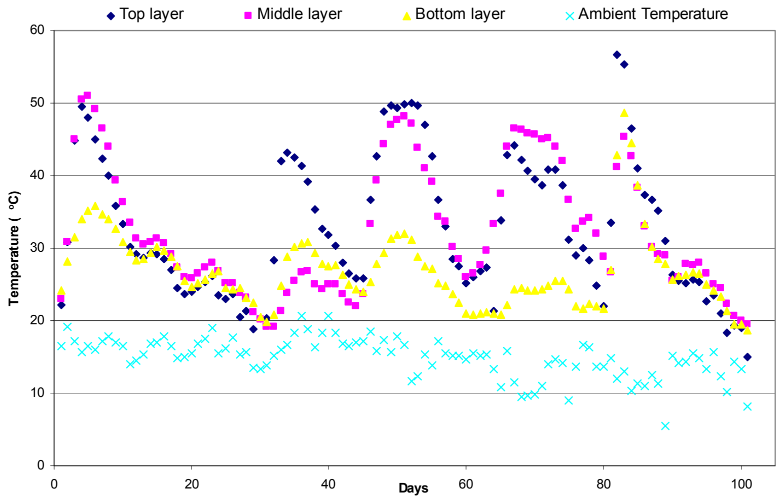


Figure 5.5 Continuous temperature monitoring of the top, middle and bottom layer of home compost bins for Treatment 4 (a) July-November 2005 and (b) January-March 2006

(a)



(b)

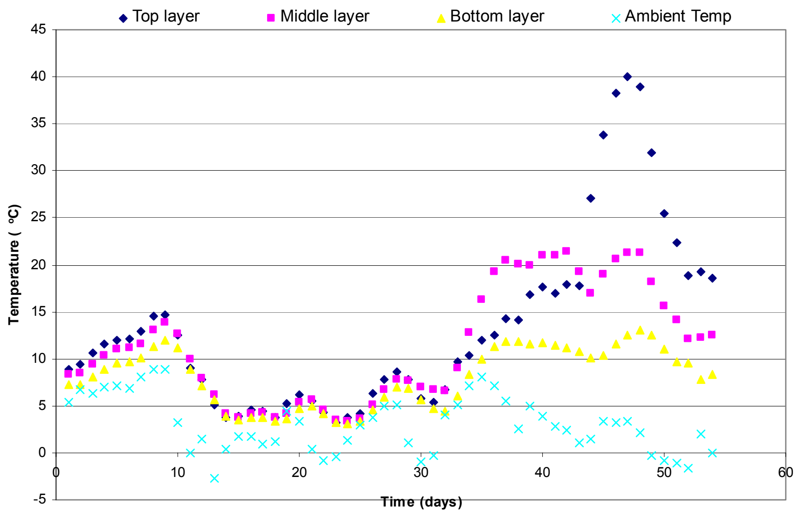
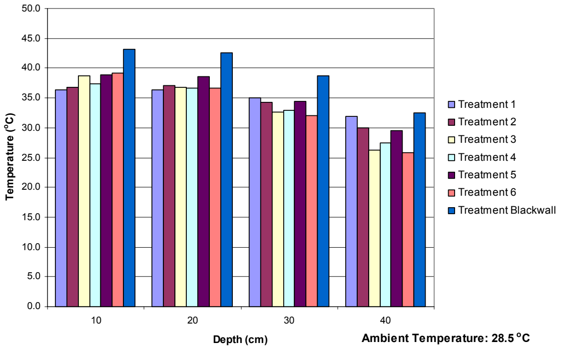
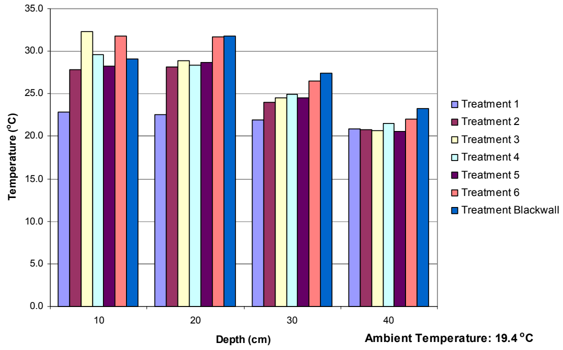


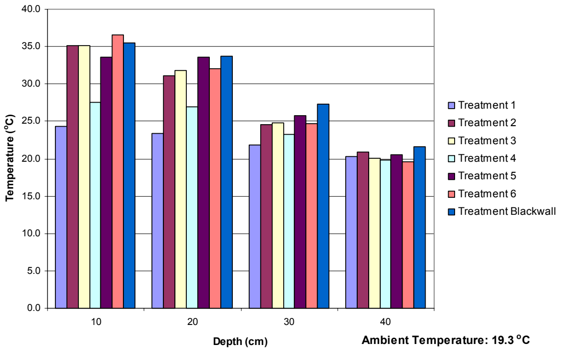
Figure 5.6 Continuous temperature monitoring of the top, middle and bottom layer of home compost bins for Treatment 6 (a) July-November 2005 and (b) January-March 2006



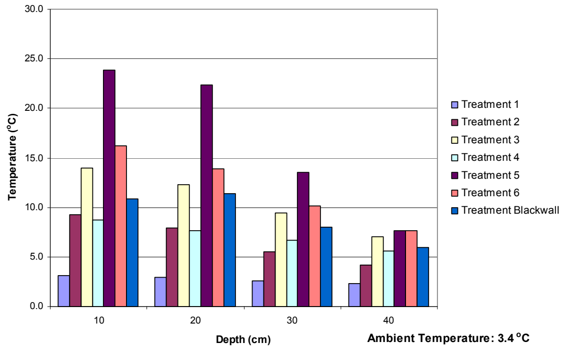
Temperature profile on 12 July 2005



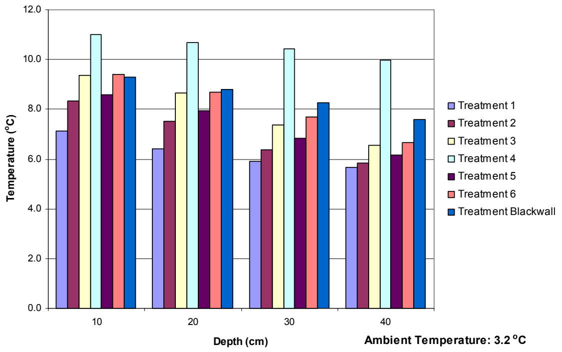
Temperature profile on 21 September 2005



Temperature profile on 11 October 2005



Temperature profile on 12 December 2005



Temperature profile on 13 February 2005

Figure 5.7 Mean temperature of waste materials in home compost bins receiving different waste input regimes in relation to depth (see Table 2.3 for description of Treatments)

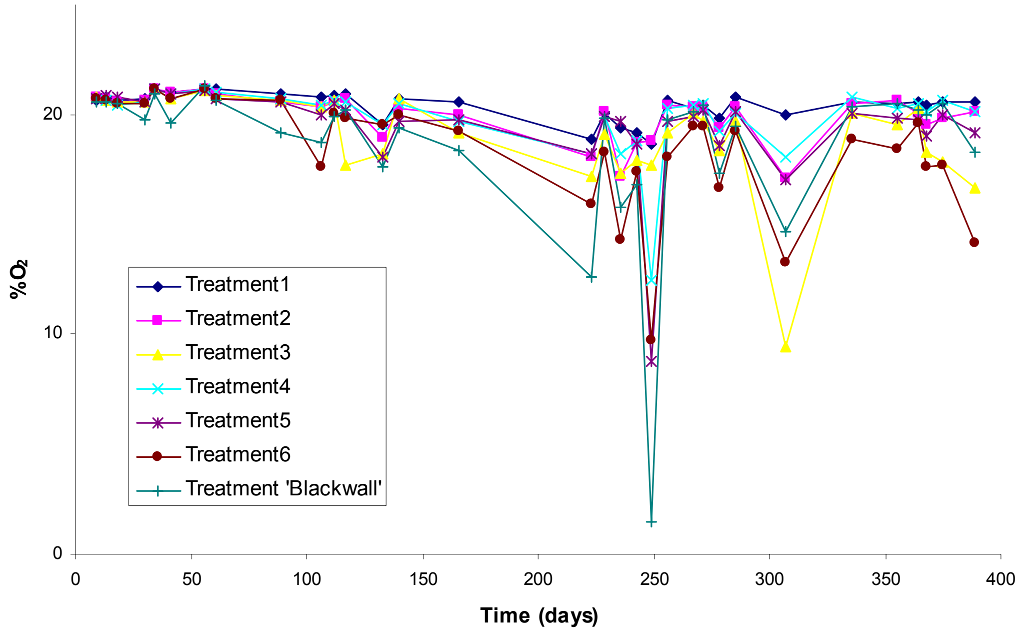


Figure 5.8 O_2 concentrations in the interstitial gas of decomposing materials in In home compost bins (see Table 2.3 for description of Treatments)

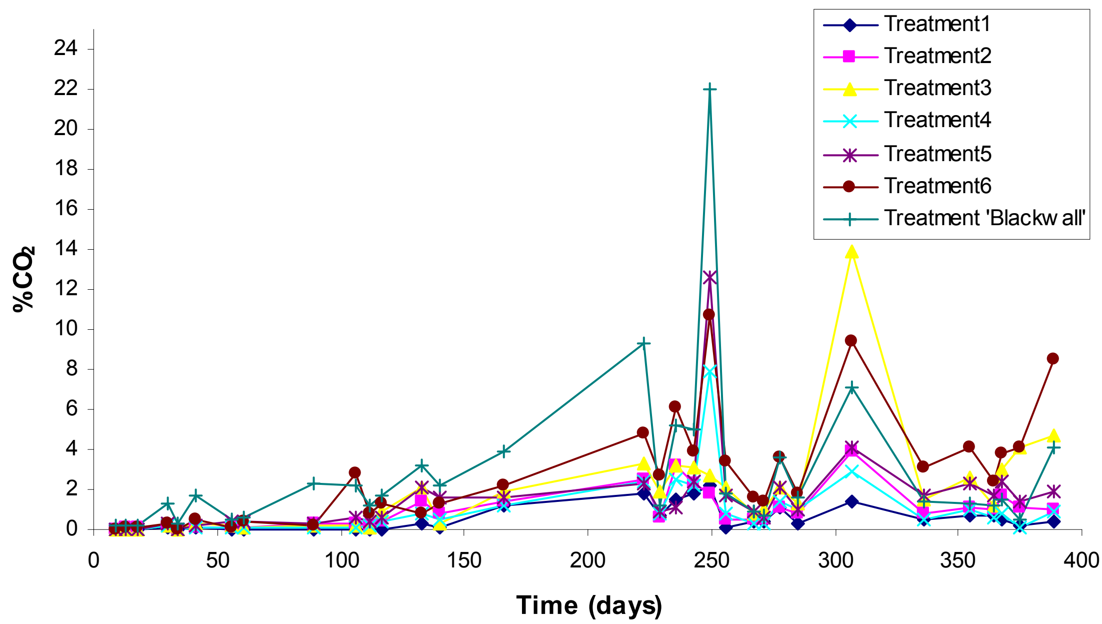


Figure 5.9 CO_2 concentrations in the interstitial gas of decomposing materials in home compost bins (see Table 2.3 for description of Treatments)