Module Title  Mechanical, Biological and Thermal Treatment of Wastes
Level  Five
Time Allowed  Two hours

Instructions to students:
• Enter your student number not your name on all answer books.
• Answer all questions from Section A and two questions from Section B.
• Section A carries 40% of the overall marks.
• Section B carries 60% of the overall marks.
• You do not need to use separate booklets for the questions in Section A, but use a separate booklet for each of the answers to questions from Section B. Label each booklet with the number/s of the question you are answering.
• Neither books nor notes may be taken into the examination.
• The use of electronic calculators is permitted.
• Students are permitted to remove this examination paper at the end of the examination.

| No. of Pages | 7 |
| No. of Questions | 13 |
Section A

Answer all questions.

Question 1

One of the parameters which needs to be closely controlled in a compost system is temperature. If the compost temperature goes above 70°C, the beneficial microbial populations can be killed. Explain and briefly illustrate how temperature can be controlled by turning the pile with reference to the diagram below.

![Temperature Graph](image)

(6 marks)

Question 2

The majority of composting sites across the UK are engaged in the Publicly Available Specification (PAS) 100/Compost Quality Protocol (CQP). What are the main benefits derived from this certification?

(4 marks)

Question 3

Explain why lignin is the slowest degrading organic material in a compost system.

(3 marks)
Question 4

With reference to the anaerobic digestion process:

a. What are the three distinct temperature ranges employed in commercial anaerobic digesters? (3 marks)

b. Illustrate using balanced chemical equations the formation of methane under anaerobic conditions from:
   
   i. Methanol.
   ii. Carbon dioxide. (4 marks)

c. Outline the problems caused by the presence of trace quantities (200-4000 ppm) of hydrogen sulphide (H₂S) in biogas and suggest a simple method for removing this gas. (3 marks)

d. Define the following terms:
   
   i. Retention Time.
   ii. Organic Loading Rate. (4 marks)

(Total: 14 marks)

Question 5

Differentiate between exothermic and endothermic reactions. (2 marks)

Question 6

What purpose do “stacks” serve in an EfW plant? (2 marks)

Question 7

Identify the two main products that result from the thermal oxidation of wastes. (2 marks)

Question 8

Identify three air pollution control processes that are used to control dioxin/furan emission levels. (3 marks)
Question 9

Put the following in order according to Calorific Value (highest first):

a. Polystyrene.
b. PVC.
c. PET.
d. Polyethylene.

(4 marks)

(Section A Total: 40 marks)
**Section B**

Answer two questions. Use a separate answer book for each question in this section.

**Question 10**

a. With reference to incinerator design discuss the role of time, temperature, turbulence and oxygen.

(12 marks)

b. The majority of incinerators in Europe have a moving grate as part of the combustion chamber feed chain. Summarise, using diagrams where appropriate, THREE different grate designs.

(18 marks)

(Total: 30 marks)

**Question 11**

Assess the conditions and variables that influence the anaerobic digestion of solid wastes.

(30 marks)

**Question 12**

Discuss the various methods of pre-treatment available for MSW with regard to the biological and thermal treatment of wastes.

(30 marks)

**Question 13**

Mr Wood, Managing Director of the 'Compost For You' company has just won a local authority compost contract for 30,000 tonnes of organic waste per annum.

Two in-vessel systems are being evaluated: a batch tunnel system and continuous tower system: details of these can be found in Table 1 below.

<table>
<thead>
<tr>
<th></th>
<th>Batch tunnel</th>
<th>Continuous composting tower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>4m</td>
<td>4m</td>
</tr>
<tr>
<td>Height/Depth</td>
<td>5m</td>
<td>8m</td>
</tr>
<tr>
<td>Length</td>
<td>30m</td>
<td>4m</td>
</tr>
</tbody>
</table>

**Table 1**: Composting facility type and dimensions.
**Peak Monthly Inputs % of total annual capacity in tonnes per year**

<table>
<thead>
<tr>
<th><em>Bulk Density</em></th>
<th>12%</th>
<th>14%</th>
<th>16%</th>
<th>18%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40</td>
<td>13.3</td>
<td>11.4</td>
<td>10.0</td>
<td>8.9</td>
<td>8.0</td>
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<tr>
<td>0.45</td>
<td>15.0</td>
<td>12.9</td>
<td>11.3</td>
<td>10.0</td>
<td>9.0</td>
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<td>0.50</td>
<td>16.7</td>
<td>14.3</td>
<td>12.5</td>
<td>11.1</td>
<td>10.0</td>
</tr>
<tr>
<td>0.55</td>
<td>18.3</td>
<td>15.7</td>
<td>13.8</td>
<td>12.2</td>
<td>11.0</td>
</tr>
<tr>
<td>0.60</td>
<td>20.0</td>
<td>17.1</td>
<td>15.0</td>
<td>13.3</td>
<td>12.0</td>
</tr>
<tr>
<td>0.65</td>
<td>21.7</td>
<td>18.6</td>
<td>16.3</td>
<td>14.4</td>
<td>13.0</td>
</tr>
</tbody>
</table>

**Table 2**: Capacity for 1m$^3$ of in-vessel processing volume with a one week residence time.

*bulk density in tonnes per cubic metre. **% of total annual capacity in tonnes per year.

(Adapted from Clean Merseyside Centre 2005)

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Batch</th>
<th>*Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>2.00</td>
<td>2.05</td>
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<tr>
<td>1.0</td>
<td>1.00</td>
<td>1.05</td>
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<tr>
<td>1.5</td>
<td>0.67</td>
<td>0.72</td>
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<tr>
<td>2.0</td>
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<tr>
<td>2.5</td>
<td>0.40</td>
<td>0.46</td>
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<td>0.39</td>
</tr>
<tr>
<td>3.5</td>
<td>0.29</td>
<td>0.35</td>
</tr>
</tbody>
</table>

**Table 3**: Conversion factors for different in-vessel residence times.

*Increased capacity is given due to allowances made for 10% volume loss per week during processing through the in-vessel system.

(Adapted from Clean Merseyside Centre 2005)
Answer the following questions using the data provided in Table 1 on page 5 and Tables 2 and 3 above.

a. Calculate the number of tunnels/towers required for each system using the information supplied.

**Batch composting tunnel:** assume the organic material is filled to a depth of 4 metres, with a bulk density of 0.45 tonnes per cubic metre with a peak monthly input of 14% (of the yearly throughput), and one week residence time.

**Continuous composting tower:** assume the organic material is filled to a depth of 6 metres, with a higher bulk density of 0.60 tonnes per cubic metre (due to the taller pile height) and monthly peak inputs of 16% (of the yearly throughput) and a one week residence time.

(12 marks)

b. In a continuous flow in-vessel system, reductions in volume over time increase the available volume and total processing capacity. Assuming the residence time is two weeks, calculate the number of towers required using the data provided.

(6 marks)

c. Enclosed or in-vessel composting technologies come in a range of designs, based around their ability to control oxygen and temperature levels to optimise biological stabilisation and achieve sanitisation. For each of the following IVC technologies briefly describe each system.

- Vertical Towers.
- Rotating drums.
- Enclosed halls.

(12 marks)

(Total: 30 marks)