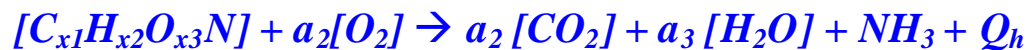


**Compost Engineering  
and  
an ACE Oriented Systems Analysis**

**K.C. Ting and Wei Fang**

- I. Composting Process-microorganisms consuming (oxidizing) substrates ( volatile solids) to support their activities (reproduction):



Input: Municipal Solid Wastes, Food Wastes, Sewage Sludge ,  
Agricultural Crops, Food Wastes, Industrial Wastes, Logging and  
Wood-Manufacturing Residues, Miscellaneous Organic Wastes,  
etc.

Output: Earth Odor, Dark Color, Fluffy Structure, Low Specific Gravity,  
Cool, C/N = 10 to 12, May Contain 25% of Dead and Living  
Microorganisms (Question of Stability ?)

- II. Factors Affecting the Process (Rate Limitations)

Available Substrate (Biodegradable Volatile Solids)

solubilization of solid substrate

mass transport of solubilized substrate to the cell

C/N Ratio (30 to 50 ideal)

C for growth and N for protein synthesis

O<sub>2</sub> Supply

Mass transport of oxygen to the cell

Moisture Content (下限：20% , 適中： 50 to 70%)

aqueous environment

soluble compounds

on available FAS

on the mass transport of oxygen

Temperature (下限：40 ; 適中：45 – 70, 75 ; 上限：80 °C)

mesophilic

thermophilic

Free Air Space (FAS)

Oxygen transport and supply

pH (hydrogen ion H<sup>+</sup> and hydroxide ion OH<sup>-</sup>)

enzymatic activity

### III. Composting Systems

1. Enclosure-
  - Non-reactor (Open)
  - Reactor (Enclosed or Within- Vessel)
2. Bed Condition –
  - Static Solids Bed
  - Agitated Solids Bed
  - Moving Agitated Bed
  - Moving Packed Bed
  - Tumbling Solids Bed
3. Aeration –
  - Natural
  - Forced
4. Material Flow –
  - Stationary
  - Vertical Flow
  - Horizontal and Inclined Flow
5. Compartmentization
  - Single Compartment
  - Multiple Compartment

### IV. Scientific Research vs. Engineering Challenge

Bench Top Experiment vs. Large Scale Operations  
Laboratory Findings vs. Engineering Design  
Narrowly Focused Knowledge Base vs. Systems Integration  
Incorporation of Quantitative Data and Qualitative Knowledge  
Methods for Dealing with Non-Uniformity and Uncertainty  
The Issue of Engineering Economics

### V. Eweson Composter

1. Classification
  - Multiple Compartment (normally three)
  - Inclined Flow
  - Forced Aeration
  - Tumbling Solids Bed

Reactor

2. Schematic Diagram
  
3. Numerical Modeling and ACE Oriented Analysis
  - i. A Modular Compartment
    - Automation: Monitoring, Control, Material Handling
    - Culture: Kinetics of Microbial Activity (BVS Conversion Rate)
    - Environment: Mass (Air, Water, Solid) Balance
    - Energy Balance
    - Chemical Balance (Stoichiometric Balance)
  - ii. The Whole Composter – The Issue Of Connectivity
  - iii. The Entire Composting Facility – Plant Layout and Materials Flow

VI. References

1. Haug, R.T. 1980. Compost engineering principles and practice . Technomic Publishing Company, Inc., Lancaster, PA.655p.
2. Poincelot, R.P. 1975. The biochemistry and methodology of composting. Bulletin 754, The Connecticut Agricultural Experiment Station, New Haven, Connecticut.
3. Singley, M.E., A.J. Higgins and M. Frumkin-Rosengaus. 1982. Sludge composting and utilization: a design and operating manual. Bioresource Engineering Department , Rutgers University , New Brunswick, NJ.
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## MODEL gico

### Governing Equations for a Modular Compartment

$$d(\text{BVS})/dt = -k_d (\text{BVS})$$

where, BVS = Biodegradable Volatile Solid, kg

t = time, day

$k_d$  = rate constant, day<sup>-1</sup>

$$k_d = (F1)(F2)(FO2)(k_{dm})(C1)$$

$$k_{dm} = 0.0126[1.066^{(T-20)} - 1.21^{(T-60)}]$$

where, T = temperature, °C

$$F1 = 1.0 - 17.3 (\text{SM})^{6.94} \quad \text{if } (1.0 - \text{SM}) \geq 0.4$$

$$20.6614(1.0 - \text{SM})^{4.06} \quad \text{if } (1.0 - \text{SM}) < 0.4$$

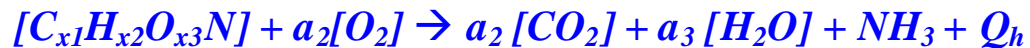
where, SM = Solid Mass content, decimal

F2 = function(Free Air Space); approximately 0.95 for FAS > 0.3

$$FO2 = (\text{VOLPO2}) / [(\text{VOLPO2}) + 1.0]$$

where, VOLPO2 = volumetric percentage of O<sub>2</sub> in free air, %

C1 = first calibration factor for model gico



$$a_1 = [2.0 x_1 + (x_2 - 3.0) / 2.0 - x_3] / 2.0$$

$$a_2 = x_1$$

$$a_3 = (x_2 - 3.0) / 2.0$$

$$Q_h = 395.253 a_2 + 286.391 a_3 + 45.638$$

where, Q<sub>h</sub> = heat generation, kJ/mol of  $C_{x1}H_{x2}O_{x3}N$

$$\text{VSMW} = 12 x_1 + x_2 + 16 x_3 + 14$$

where, VSMW = Volatile Solid Molecular Weight, g/mol

therefore, Q<sub>h</sub> = (1000) [(395.253 a<sub>2</sub> + 286.391 a<sub>3</sub> + 45.638) / VSMW]

in kJ/kg  $C_{x1}H_{x2}O_{x3}N$

### **Mass Consumption**

from	air	O <sub>2</sub>	:	32 a <sub>1</sub> / VSMW	kg/kg
	VS	C	:	12x <sub>1</sub> / VSMW	kg/kg
		H	:	x <sub>2</sub> / VSMW	kg/kg
		O	:	16x <sub>3</sub> / VSMW	kg/kg
		N	:	14 / VSMW	kg/kg
		H <sub>2</sub> O	:	Drying	

### Mass Generation

in	air	CO <sub>2</sub> :	44a <sub>2</sub> / VSMW	kg/kg	
		H <sub>2</sub> O :	18a <sub>3</sub> / VSMW	kg/kg	and from VS drying
	VS	H <sub>2</sub> O :	condensation	kg/kg	
		NH <sub>3</sub> :	17/VSMW	kg/kg	

### Psychrometric Equations

[ASAE Data: ASAE D271.2, 1983-84 Agricultural Engineers Yearbook of Standards, p.314-316.]

dry bulb temperature , relative humidity , humidity ratio,  
specific volume, dew point, enthalpy, wet bulb temperature,  
latent heat of vaporization(condensation)

### Energy Balance

$$\begin{aligned} & \text{MASSAIR} * \text{ENTHALPY}]_{\text{in}} - [\text{MASSAIR} * \text{ENTHALPY}]_{\text{out}} \\ & + [\text{MASSSW} * \text{CPSW} * \text{TSW}]_{\text{in}} - [\text{MASSSW} * \text{CPSW} * \text{TSW}]_{\text{out}} \\ & + Q_h * \text{DBVS} + \text{HFG} * \text{MASSCOND} - \text{AUS} * (\text{TSW} - \text{TAMB}) * (\text{C2}) \\ & - \text{AUE1} * (\text{TSW} - \text{TE1}) * \text{C3} - \text{AUE2} * (\text{TSW} - \text{TE2}) * \text{C4} = 0 \end{aligned}$$

where, MASSAIR = mass flow rate of air, kg/day  
ENTHALPY = enthalpy of air, kJ/kg  
MASSSW = mass flow rate of solid waste including added water, kg/day  
CPSW = specific heat of solid waste, kJ/kg °C  
TSW = temperature of solid waste, °C  
DBVS = consumed portion of biodegradable volatile solid, kg/day  
HFG = latent heat of condensation, kJ/kg  
MASSCOND = mass of condensate, kg/day  
AUS = side heat conductance of drum, kJ/°C day  
TAMB = side ambient temperature, °C  
AUE1 = end 1 heat conductance of drum, kJ/°C day  
TE1 = end 1 ambient temperature, °C  
AUE2 = end 2 heat conductance of drum, kJ/kg day  
TE2 = end 2 ambient temperature, °C  
C2 = second calibration factor for model gico  
C3 = third calibration factor for model gico  
C4 = fourth calibration factor for model gico

### Governing Equations for a Multi-compartment Composter

Integrate the equations for a number of modular compartments.

User Interface and pre- and Post- Data Processing

Menu-driven data entry

Initial conditions, information flow, and process control of simulation

Presentation of results