

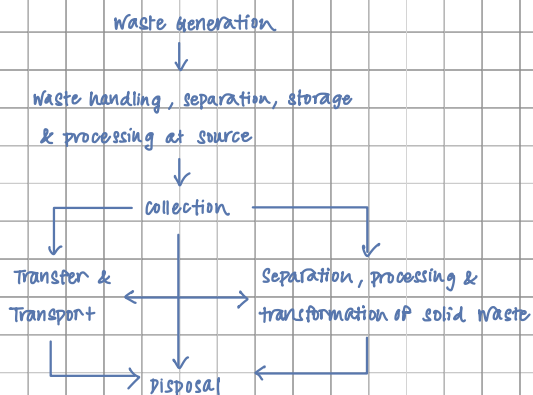
1 a) Integrated Solid waste management system



b) Steps in waste hierarchy

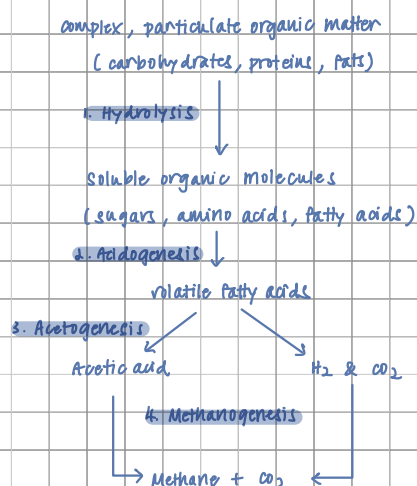
1. Reduce (most favoured)
2. Reuse
3. Recycle
4. Recover
5. Dispose (least favoured)

c) Solid waste Management system



- d) 1. Plastics (14%): contamination of recyclables, lack of source segregation
2. Glass (14%): no glass recycling plants in sg
3. Textile (14%): difficult to recycle due to composite nature of textile materials

e) Anaerobic Digestion



f) Forms: Solid, Liquid, Gas, Sludge

Hazardous waste can be ignitable, corrosive, reactive or toxic. In sufficient quantities and concentrations, these wastes can pose a threat to human life, health or environment when improperly stored, transported, treated or disposed.

2a) Total Solids = Σ (Paper, Plastic, Food, Wood, inert dry weights)

$$= 24 + 9 + 15 + 4.5 + 23.75$$

$$= 76.25 \text{ kg}$$

Volatile Solids = Σ (Paper, Plastic, Food, Wood)

$$= 24 + 9 + 15 + 4.5$$

$$= 52.5 \text{ kg}$$

BVS = Σ (Paper, Food, Wood)

$$= 24 + 15 + 4.5$$

$$= 43.5 \text{ kg}$$

b)	kg	C	H	O	N
24	Paper	11.28	1.44	11.28	0
15	Food	7.2	0.75	5.55	1.5
4.5	Wood	2.30	0.27	1.89	0.045
	Total	20.78	2.46	18.72	1.545

Molar ratio

$$C : H : O : N$$

$$\frac{20.78}{12} : \frac{2.46}{1} : \frac{18.72}{16} : \frac{1.545}{14}$$

$$1.7317 : 2.46 : 1.17 : 0.1104$$

$$15.69 : 21.29 : 10.602 : 1.000$$

$$\approx 31 : 45 : 21 : 2$$

$$\rightarrow C_{31}H_{45}O_{21}N_2$$

c) Amt of BVS = $\frac{43.5 \times 10^3 \text{ g}}{31(12) + 45(1) + 21(16) + 2(14)}$

$$= 55.7 \text{ mol} \quad 13.25$$

Water req. = $55.7 \times \frac{4(31) - 45 - 2(21) + 3(2)}{4}$

$$= 598.75 \text{ mol}$$

$$= 10.78 \text{ kg}$$

Water in solid waste = $20\%(30) + 10\%(10) + 50\%(30) + 10\%(5) + 5\%(25)$

$$= 23.75 \text{ kg}$$

Enough water

d)	CH_4	CO_2	NH_3
Mol	15.125×55.7	15.875×55.7	2×55.7
	= 842.46	= 884.24	= 111.4
Vol.	18871.2	19807.0	2495.4

Vol. of biogas = $CH_4 + CO_2 + NH_3$

$$= 18871.2 + 19807.0 + 2495.4$$

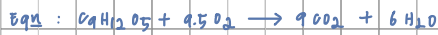
$$= 41173.6 \text{ L}$$

3a) From Terner Diagram,

Ash (%)	= 10	} 100kg
Moisture (%)	= 10	
Combustibles (%)	= 80	

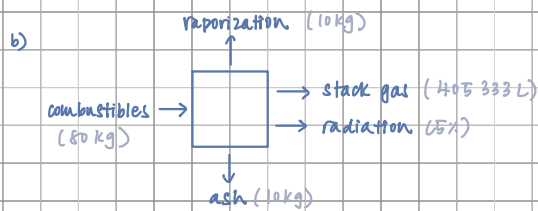
$$\text{Mass of combustibles} = 80\% \times 100 = 80 \text{ kg}$$

$$\text{Amt of combustibles} = \frac{80 \times 10^3 \text{ g}}{9(12) + 12(1) + 5(16)} = 400 \text{ mol}$$



$$\text{O}_2 \text{ req} = 9.5 \times 400 \times 22.4 = 85120 \text{ L}$$

$$\text{Air req} = \frac{100}{21} \times 85120 = 405333 \text{ L}$$



$$\text{Heat from combustibles} = 80 \text{ kg} \times 20000 \text{ kJ/kg} = 1600000 \text{ kJ}$$

$$\text{Vaporization heat} = 10 \text{ kg} \times 2500 \text{ kJ/kg} = 25000 \text{ kJ}$$

$$\text{Radiation loss} = 5\% \times 1600000 = 80000 \text{ kJ}$$

$$\text{Ash heat loss} = 10 \text{ kg} \times 0.8 \text{ kJ/kg/}^\circ\text{C} \times T = 8T \text{ kJ}$$

$$\text{Stack gas heat loss} = (405.333 \text{ m}^3 \times 1.5 \text{ kg/m}^3) \times 1.0 \text{ kJ/kg/}^\circ\text{C} \times T = 608.0T \text{ kJ}$$

$$1600000 = 25000 + 80000 + 8T + 608T$$

$$1495000 = 616T$$

$$T = 2427^\circ\text{C}$$

c) Let $T = 1000^\circ\text{C}$, Let vol. of air = V

$$1600000 = 25000 + 80000 + (10 \times 0.8 \times 1000) + (V \times 1.5 \times 1.0 \times 1000)$$

$$1497000 = 1500V$$

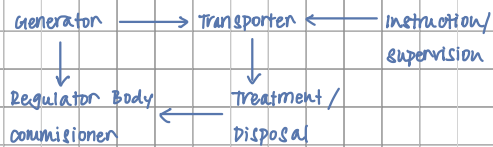
$$V = 998 \text{ m}^3$$

$$V(\%) = \frac{998}{405.333} \times 100\%$$

$$= 244.6\%$$

- d)
1. Fixation by addition: metallic ion incorporated into calcium silicate hydrate structure
 2. Fixation by substitution: metallic ion substitutes calcium ion in calcium silicate
 3. Fixation by formation of a new compound(s): insoluble metal silicates formed during hydration of cement
 4. Fixation by a combination of above or by multiple mechanisms: likely due to complex system of cement & ash
- Treatment mechanisms begin upon mixing & continue as the cement cures through a period of months

4a) Toxic Industrial Waste Regulation (TIWR)



Generator:

- Prepare 5 copies of consignment note
- give 3 to consignee before transportation
- give statement with safety requirements & action to be taken by carrier

Transporter:

- Note to be delivered by transporter to recipient, and signed & kept by both
- give 2 to driver for delivery to consignee
- driver keeps a copy of statement in vehicle

- b)
- To control generation, transboundary movement, transport, disposal & recovery of hazardous waste
 - illegal traffic is any transboundary movement of hazardous waste or other wastes:
 - without notification or consent pursuant to provisions of the Convention to a state concerned
 - with consent obtained through falsification, misrepresentation or fraud
 - that does not conform in a material way with the document
 - that results in deliberate disposal of hazardous wastes / other wastes in contravention of Convention & international law
 - Basel Convention considers illegal traffic to be criminal. Each party will introduce national legislation to prevent & punish illegal traffic. Parties shall cooperate to prevent illegal traffic

c) Benefit

$$PV = 700\,000 \times \frac{(1+0.075)^{20} - 1}{0.075(1+0.075)^{20}}$$

$$= \$ 7\,136\,143.95$$

$$\begin{aligned} \text{Cost} \\ PV &= 7\,500\,000 + 650\,000 + 1000\,000 \times \frac{(1+0.075)^{20} - 1}{0.075(1+0.075)^{20}} \\ &= 7\,500\,000 + 650\,000 + 10\,194\,491.36 \\ &= \$ 18\,344\,491.36 \end{aligned}$$

$$\begin{aligned} \text{Benefit/cost ratio} &= 7\,136\,143.95 / 18\,344\,491.36 \\ &= 0.39 < 1.5 \end{aligned}$$

should not be built //

5a) compound	Mass (kg)	Max Emission (kg/d)
Toluene	$867 \text{ kg/m}^3 \times 30 \text{ m}^3 = 26010$	$\frac{26010}{55065} \times 125 \times 0.01\% \times 24 = 0.142 //$
Benzene	$852 \times 20 = 17040$	$\frac{17040}{55065} \times 125 \times 0.01\% \times 24 = 0.093 //$
1,1-dichloroethane	$984 \times 10 = 9870$	$\frac{9870}{55065} \times 125 \times 0.01\% \times 24 = 0.054 //$
Clay	$1650 \times 1.3 = 2145$	-
Total	55065	

b) composition:

	leadrate
cement = 29.5%	Pb = 2.10 mg/L (40%)
water = 0.5%	Hg = 1.21 mg/L (65%)
Ash = 70%	Ni = 1.51 mg/L (47%)

100g sample in 2000 mL leadrate

Mass of heavy metal in 100g sample

$$\text{Pb} = 2.10 \text{ mg/L} \times 2 \text{ L} \times \frac{100}{40} = 10.5 \text{ mg}$$

$$\text{Hg} = 1.21 \times 2 \times \frac{100}{65} = 3.72 \text{ mg}$$

$$\text{Ni} = 1.51 \times 2 \times \frac{100}{47} = 6.43 \text{ mg}$$

% by weight in ash (70g ash in 100g sample)

$$\text{Pb} = \frac{10.5 \times 10^{-3} \text{ g}}{70 \text{ g}} \times 100\% = 0.015\%$$

$$\text{Hg} = \frac{3.72 \times 10^{-3}}{70} \times 100\% = 0.0053\%$$

$$\text{Ni} = \frac{6.43 \times 10^{-3}}{70} \times 100\% = 0.0092\% //$$