AY 21/22

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EN3001 - solid waste & Hazardous Waste Management

1a) Paper / cardboard (38%), Plastics (4%), textiles (4%)

Reasons for low recycling rates:

Textiles - Currently no large-scale textile recycling facility in SG to process the large amount of textile waste produced.

Paper - paper is easily contaminated, even in the blue recycling bins, and cannot be recycled when contaminated.
(From 4 Dec 2021 onwards, new paper (only) recycling bins have been rolled out. Cash can be earned)

Plastics - Lack of proper sorting due to lack of knowledge of the general public on the types of plastics that can/cannot be recycled.

1b)
1. Incineration
2. Resource Recovery
3. Composting

Incineration: Combustion of solid waste to produce CO_2 and incineration ash.

Application in SG:

- Reduce volume of solid waste
- Recovery of waste energy (WTE)
- Main method of solid waste management currently.

Resource Recovery: separating materials from waste that can be used to make new products.

Application in SG:

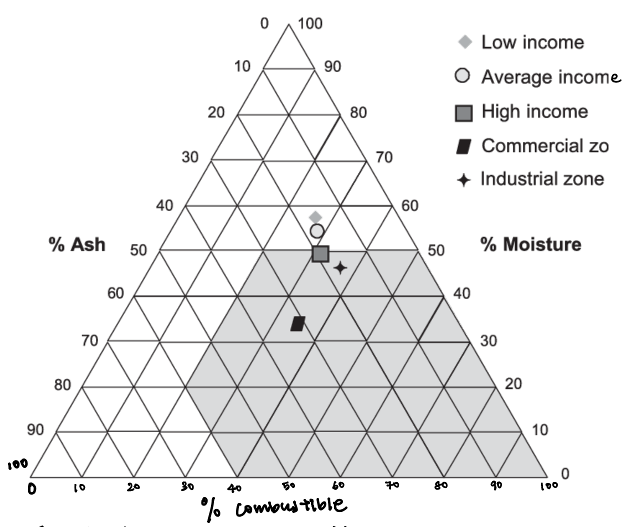
- Recycling of recyclable materials
- Using of Magnetic Separator to extract metals from solid waste

Composting: Making use of biodegradation by microbes to digest and reduce volume of organic waste.

Application in SG:

- There is no large-scale composting facility in SG, so it is not widely applied.

c)



The shaded area in the Tanner Diagram represents compositions of wastes that are good for incineration. For wastes outside of the shaded area, may need to look into other types of treatments.

Major Features :

1d) 1. Bottom liner

2. Dumping and compaction

3. Daily cover

4. Leachate and gas

5. Treatment of leachate and gas

6. Monitoring system

Importance of Semakau Landfill :

- Currently SG's only operating landfill
- Receives most of the incineration ash.
- Based on current dumping rates, estimated to fill up by 2035, rather than 2050 which was the initial time line.

e) Generation :

Countries with lower income level generates lower amounts of solid waste than countries with high income level, and produce higher percentage of organic wastes. Countries with higher income level have higher percentages of plastic & paper wastes.

Management :

Countries with higher income level make use of more sanitary waste collection and disposal methods as compared to countries with lower income level.

2. a) Protein: $30(0.5)(0.3)$

$= 4.5\ kg$

Carbohydrate: $30(0.8)(0.7) + 30(0.5)(0.4) + 10(0.9)(0.3)$

$= 25.5\ kg$

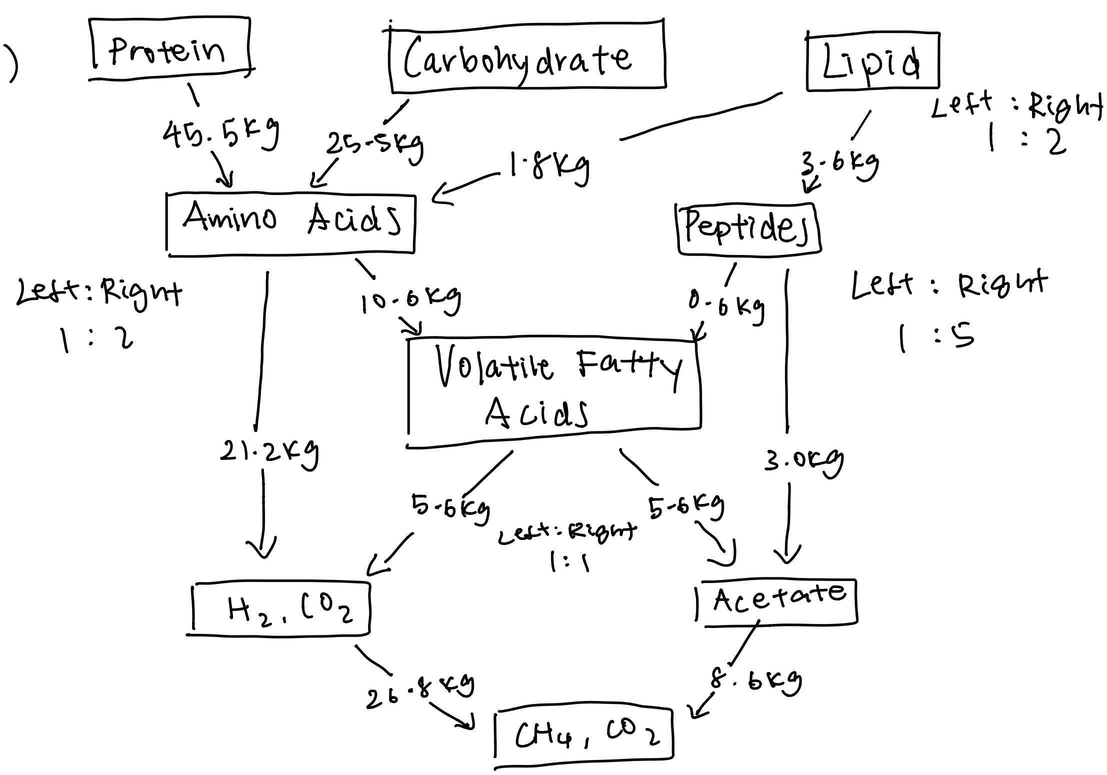
Lipid: $30(0.5)(0.3) + 10(0.9)(0.1)$

$= 5.4\ kg$

b) Anaerobic Digestion:

1. Hydrolysis – Breakdown of particulate matters and larger molecules
2. Acidogenesis – Formation of volatile fatty acids (VFA) by fermentative bacteria
3. Acetogenesis – Formation of acetate, H_2 and CO_2 by acetogens
4. Methanogenesis – Formation of CH_4 and CO_2

c, d)



e) a. $C = 12$ $H = 1$ $O = 16$ $N = 14$

Water stoichiometric :

For Protein : $\left(\frac{4a - b - 2c + 3d}{4}\right)$

$C_4H_7O_4N$ $= \left[\frac{4(4) - 7 - 2(4) - 1}{4}\right]$

$= 0$

For Carbohydrate : $\left(\frac{4a - b - 2c + 3d}{4}\right)$

$C_6H_{12}O_6$ $= \left[\frac{4(6) - 12 - 2(6)}{4}\right]$

$= 0$

For Lipid : $\left(\frac{4a - b - 2c + 3d}{4}\right)$

$C_6H_8O_6$ $= \left[\frac{4(6) - 8 - 2(6)}{4}\right]$

$= 1$

Mass of Lipid : 5.4kg

no. of mol $= \frac{5.4 \times 10^3}{6(12) + 8 + 6(16)}$

$= 30.682$ mol

$\therefore$ Mass of H_2O needed $= 30.682 \times (2+16)$

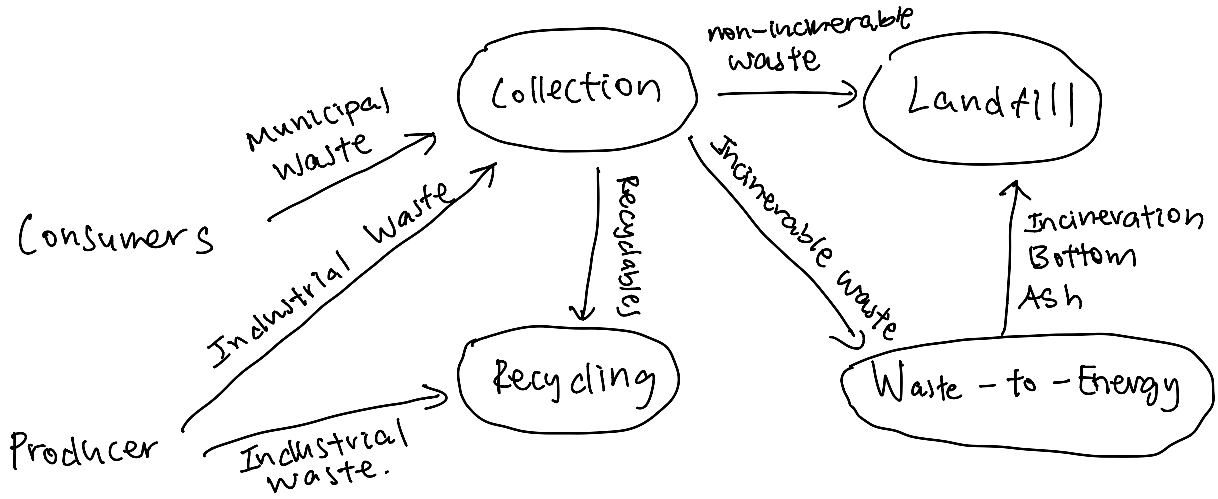
$= 552.27$g

Mass of water initially $= 30(0.2) + 10(0.1) + 30(0.5) + 10(0.1) + 20(0.05)$

$= 24$kg

$\therefore$ There is enough water initially.

3 a)



b) 6 million tonnes $= 6\times10^6 \times10^3$ kg | Recycling Rate = 60% | non incinerable waste : 3%

Amount of waste sent to incinerator per day

$= 6\times10^6 \times10^3 \text{ kg} \times (100-63)\% \div 365$

$= 6.0822\times10^6$ kg/d

no. of mol $= \dfrac{6.0822\times10^6\times10^3 \text{ g}}{10(12)+16+5(16)}$

$= 2.8158\times10^7$ mol

complete Combustion Equation:

$C_{10}H_{16}O_5 + \frac{23}{2}O_2 \longrightarrow 10CO_2 + 8H_2O$

∴ no. of mol of O_2 needed $= 2.8158\times10^7 \times \frac{23}{2}$

$= 3.2382\times10^8$ mol

Volume of air needed $= 3.2382\times10^8 \times \frac{100}{21} \times 22.4$ L

$= 3.4541\times10^{10}$ L

$= 3.45\times10^7\ m^3$

Volume of O_2 needed = $3.45 \times 10^7 \times 21\%$
$= 7.25 \times 10^6\ m^3$

c) Volume of fed air = Volume of stack gas

Heat value = 20000 kg / kJ

Heat Loss due to radiation = 5%

Left behind 10% ash.

specific heat Ash = 0.8 kJ/kg/°C   stack gas = 1.0 kJ/kg/°C

Heat Value = 6.0822×10^6 kg/d × 20000 kJ/kg
$= 1.2164 \times 10^{11}$ kJ/d

Heat remaining after loss due to radiation =
1.2164×10^{11} kJ/d × 95% = 1.1556×10^{11} kJ/d

Amount of ash = 6.0822×10^6 kg/d × 10%
$= 6.0822 \times 10^5$ kg/d.

Mass of stack gas = $3.4541 \times 10^7\ m^3/d \times 1.5\ kg/m^3$
$= 5.1812 \times 10^6$ kg/d

Temperature of ash and stack gas

$$= \frac{1.1556 \times 10^{11}\ kJ/d}{0.8\ kJ/kg/°C \times 6.0822 \times 10^5\ kg/d + 5.1812 \times 10^6\ kg/d \times 1.0\ kJ/kg/°C}$$

$= 20389\ °C$

Heat in stack gases = 1.0 kJ/kg/°C × 20389 °C × 5.1812×10^6 kg/d
$= 1.06 \times 10^{11}$ kJ

3d) For temperature to be 900°C, Let V = Volume of air needed (m^3)

$$1.1556\times10^{4} = 0.8(6.0822\times10^{5})(900) + (1.0)(1.5\times V)(900)$$

$\therefore V = 8.53\times10^{7}\ m^3/d$

Excess-air combustion is better as it keeps the temperature of the combustion chamber at 900 – 1000°C range, improving the longevity of the incineration chamber.

Excess-air combustion also controls/prevents the production of dioxins and furans while ensuring complete combustion.

4. 1000 kg/hr – Ni, Pb, Cu.
1.8 2.1 1.1

For Ni : 1.8 mg/L × 2 L = 3.6 mg → 10% by weight

100% weight = 36 mg

Mass of Ash = 100 g × 55%

= 55 g

$$\% \text{ by weight} = \frac{36\ mg}{55 g} = \frac{36\times10^{-3}}{55}\times100\% = 0.065\%$$

For Pb, 2.1 mg/L × 2 L = 4.2 mg → 8% by weight

$$100\% \text{ weight} = 4.2\ mg\times\frac{100}{8}$$

= 52.5 mg

$$\% \text{ by Weight} = \frac{52.5\times10^{-3}}{55}\times100\% = 0.095\%$$

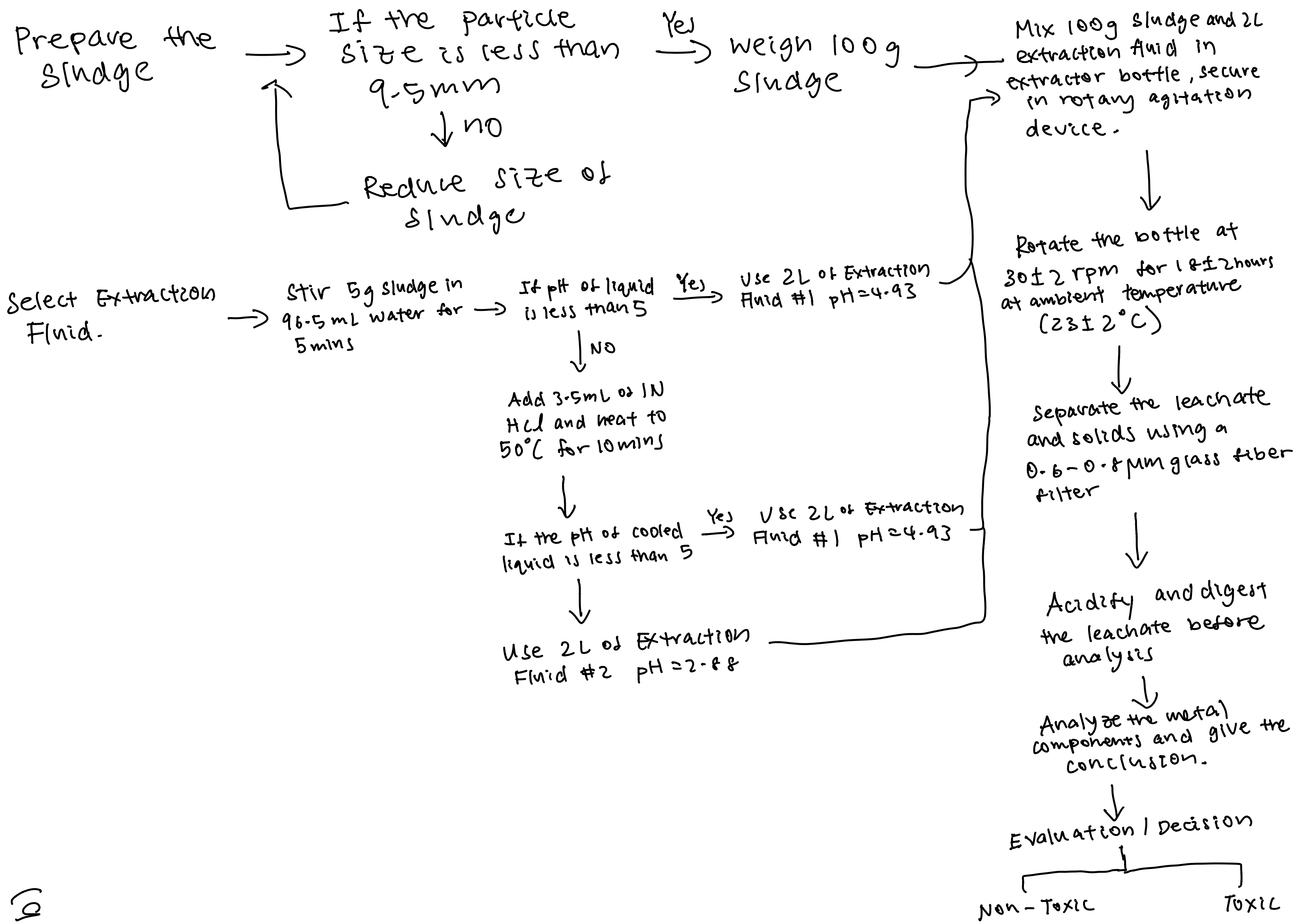
For Cu, $1.1\ mg/L \times 2L = 2.2\ mg/L \rightarrow 5\%$ by weight

100% weight $= 2.2\ mg \times \frac{100}{5}$

$= 44 mg$

$\%$ by weight $= \frac{44 \times 10^{-3}}{55} \times 100\% = 0.08\%$

4b)


Prepare the sludge
If the particle size is less than 9.5mm
Yes
Weigh 100g sludge
no
Reduce size of sludge
Mix 100g sludge and 2L extraction fluid in extractor bottle, secure in rotary agitation device.
Select Extraction Fluid.
Stir 5g sludge in 96.5 mL water for 5 mins
If pH of liquid is less than 5
Yes
Use 2L of Extraction Fluid #1 pH=4.93
NO
Add 3.5mL of 1N HCl and heat to 50°C for 10mins
If the pH of cooled liquid is less than 5
Yes
Use 2L of Extraction Fluid #1 pH=4.93
Use 2L of Extraction Fluid #2 pH=2.88
Rotate the bottle at 30±2 rpm for 18±2hours at ambient temperature (23±2°C)
Separate the leachate and solids using a 0.6-0.8μm glass fiber filter
Acidify and digest the leachate before analysis
Analyze the metal components and give the conclusion.
Evaluation / Decision
Non-Toxic
Toxic

4b) If the concentrations of the metal components exceed the limits stated by the regulations, the waste is considered hazardous.

4c) Ni : $0.00017 d^{-1}$, Pb: $0.000068 d^{-1}$; Cu $= 0.0012 d^{-1}$

First order Reaction : $C = C_o e^{-kt}$

For Ni, $\frac{100-99.99}{100} = e^{-0.00017(t)}$

$t = 54178$ days

$= 148$ years.

For Pb, $\frac{100-99.99}{100} = e^{-0.000068(t)}$

$t = 135446$ days

$= 371$ years

For Cu, $= \frac{100-99.99}{100} = e^{-0.0012(t)}$

$t = 7675$ days

$= 21$ years

21 years is too short for the toxic ash to be used as a construction material since buildings are built to last longer than that. Hence using Portland Cement in toxic ash treatment might cause Cu contamination in the area. Toxic ash may be applicable as a value-added construction aggregate if the leaching can be better controlled.

d) Waste is considered hazardous waste as it may, in sufficient quantities and concentrations, pose a threat to human life, human health or the environment when improperly stored, transported, treated or disposed.

They are designated as hazardous waste if they are ignitable, corrosive, reactive, toxic.

Hazardous wastes may be in solid, liquid, gas and sludge forms.

5a) $110\ t/d = 110 \times 10^3\ kg/d$.

Mass of Sulphur $= 110 \times 10^3 \times 5\%$

$= 5500\ kg$

no. of mol of $SO_2 = \frac{5500 \times 10^3}{32} = 171875\ mol$

$CaO + SO_2 \rightarrow CaSO_3$

$CaSO_3 + \frac{1}{2}O_2 \rightarrow CaSO_4$

Overall Eqn: $CaO + SO_2 + \frac{1}{2}O_2 \rightarrow CaSO_4$

Mass of $CaSO_4 = 171875 \times (40 + 32 + 4(16))$

$= 23.375 \times 10^6\ g$

$= 23375\ kg$

Mass of soil $= 110 \times 10^3 \times 28.6\%$

$= 31350\ kg$

Total ash collected $= 23375 + 31350$

$= 54725\ kg$

5b) Mass of organic compound = $70.9\% \times 110 \times 10^3$ kg/d
= 77990 kg/d

Max amount of organic compounds. = 77990 × (100 − 99.99)%
= 7.799 kg/d

c) NO_x, TOC, Principle Organic Hazardous components (POHCs)
Dust, HCl, CO, HCl, HF, dioxins.

Emission Monitoring system can be set up, with flue gas treatment unit with cyclones, dry reactors and bag filters.

d). Purpose of Basel convention: To control transboundary movements of hazardous waste. It controls the generation, transboundary movement, transport, disposal and recovery of these wastes.

Objective of Basel convention:

1. ensure generation of hazardous is reduced to a minimum
2. as much as possible, hazardous wastes are to be disposed within country of generation.
3. establish enhanced controls on exports and imports of hazardous waste
4. prohibit shipments of hazardous wastes to countries lacking the legal administrative and technical capacity to manage and dispose of them in an environmentally sound manner
5. co-operate on the exchange of information, technology transfer and the harmonization of standards, codes and uidelines.