

Done by : Ten Wei Ze

EN3001

23-24_S1

Q1(a)

1. Construction waste. Can be recycled by being crushed and used as aggregate for future construction
2. Medical waste. Mostly cannot be recycled due to its hazardous or infectious nature.
3. Industrial waste. Can be recycled, waste from one industry can be used as materials in another industry.

Q1(b)

Anaerobic digestion. Singapore lacks the land space required to carry-out large-scale anaerobic digestion, thus this method is still not common yet in Singapore

Q1(c)

It is more economical to concentrate the waste being transferred into a smaller number of vehicles, especially if the treatment/disposal site is far away. Reducing the number of transfer vehicles through the use of waste transfer stations also help reduce traffic congestion, and pollution caused by the vehicles.

Q1(d)

1. Construction of bottom liner
2. Dumping and compaction of waste
3. Use of daily cover at the end of each day
4. Collection system for landfill gas and leachate
5. Use of final cover after dumping of final batch of waste
6. Set-up of monitoring system to monitor landfill after its closure

1(e)

Aerobic composting	Anaerobic composting
Net energy consumer	Net energy producer
Primary goal : volume reduction Secondary goal : compost production	Primary goal : energy production Secondary goal : volume reduction
Requires oxygen	Does not require oxygen (requires water instead)

Q2(a)

1. Incinerable waste
2. Food waste
3. Household Recyclables (sorted at IWMF)
4. Electricity to NEWater facility + food waste for anaerobic digestion at WRP
5. Electricity back to grid
6. Flue gas
7. Incinerator bottom ash
8. Used water
9. Sludge
10. Cleaned NEWater returned to homes and industries

Q2(b)

Component	Wet mass (ton)	Dry mass (ton)	Energy (GJ)
Paper	1,050,000	840,000	14,280,000
Plastic	950,000	855,000	28,215,000
Food	760,000	380,000	1,900,000
Wood	840,000	672,000	10,080,000
Inert municipal waste	100,000	95,000	95,000
Construction debris	1,600,000	1,520,000	1,520,000
Industrial residues	1,700,000	1,615,000	8,075,000

Total heat = 64,165,000 GJ

Q2(c)

Paper, food, and wood are biodegradable

Component	Carbon %mass	Carbon mass (ton)	C converted to methane (ton)
Paper	$\frac{12 \times 6}{12 \times 6 + 10 + 16 \times 5} = 44.4\%$	372,960	186,480
Food	$\frac{12 \times 10}{12 \times 10 + 20 + 16 \times 10} = 40\%$	152,000	76,000
Wood	$\frac{12 \times 6}{12 \times 6 + 10 + 16 \times 5} = 44.4\%$	298,368	149,184

Total C converted to methane = 411,664 tons

$$\text{Mass of methane} = \frac{12+4}{12} = 548,885 \text{ ton} = 548,885,000 \text{ kg}$$

Energy from anaerobic digestion = 548,885,000 × 55,500

$$= 3.046 \times 10^{13} \text{ kJ}$$

$$= 30,460,000 \text{ GJ}$$

Energy from combustion of = 14,280,000 + 1,900,000 + 10,080,000

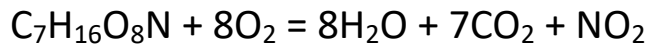
$$= 26,260,000 \text{ GJ}$$

Anaerobic combustion generates more heat. Anaerobic digestion converts waste to energy more efficiency, as it is able to capture more of the chemical energy present in waste, compared to incineration, where some of the energy left behind in the ash is uncaptured.

Q3(a)

Combustible : 70%

Mass of combustible : 700 kg



$$\text{Mol of } O_2 = \frac{700 \times 10^3}{12 \times 7 + 16 + 16 \times 8 + 14} \times 8 = 23140 \text{ mol}$$

$$\text{Vol } O_2 = 23140 \times 24 = 555360 \text{ L} = 555.36 \text{ m}^3$$

$$\text{Vol air} = 555.36 / 0.21 = 2645 \text{ m}^3$$

$$\text{Vol excess air} = 2645 \times 2 = 5290 \text{ m}^3$$

Q3(b)

$$\text{Total energy} = 25000 \times 700 = 17,500,000 \text{ kJ}$$

$$\text{Energy after radiation loss} = 17,500,000 \times 0.9 = 15,750,000 \text{ kJ}$$

$$\text{Ash \%} = 20\%$$

$$\text{Mass ash} = 0.2 \times 1000 = 200 \text{ kg}$$

$$\text{Energy lost to ash} = 0.8 \times 200 \times 800 = 128,000 \text{ kJ}$$

$$\text{Energy in air} = 15,750,000 - 128,000 = 15,622,000 \text{ kJ}$$

If steam temperature = 900 °,

$$\text{Mass air} = \frac{15,622,000}{900 \times 1} = 17358 \text{ kg}$$

$$\text{Extra air} = \frac{17358}{10000} - 100\% = 73.58\%$$

Excess air :

- Ensures complete combustion
- Increases flue gas
- Lowers temperature
- Dioxin/Furans control

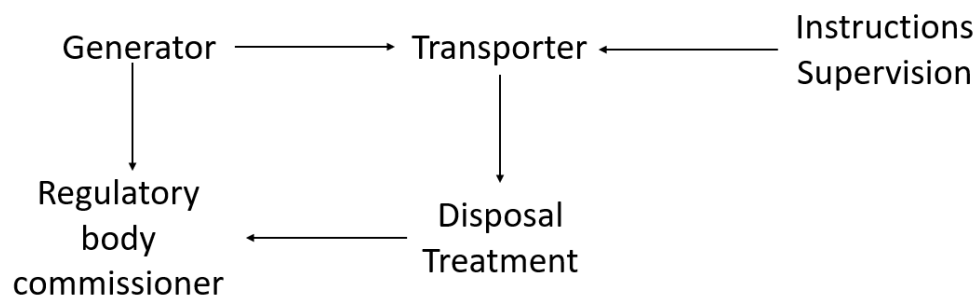
Q4(a)

In the form of solid, liquid, or gas.

The sludge is hazardous waste as it is unwanted material, that when in high enough concentration or amounts, poses a threat to human health and life when improperly collected, transported, treated or disposed of, it has at least one of the following characteristics : Toxic, Reactive, Corrosive or ignitable. Hazardous waste is also still hazardous waste when mixed with non-hazardous waste unless confirmed otherwise by tests like TCLP test.

Q4(b)

Toxic industrial waste regulation



Generator :

1. Prepare 5 copies of consignment note
2. Give 3 copies to consignor before transport of hazardous waste
3. Provide statement regarding safety, requirements, and actions to be taken by transporter

Transporter :

1. Given 2 copies of consignment note
2. Consignment notes delivered to consignee, signed by both transporter and recipient, and each party keeps a copy of the note
3. Must have hazard labels and warning panels
4. Keep a copy of provided statement on vehicle

Q4(c)

Purpose : Global approach to control transboundary movement of Hazardous waste (HW). Act as global legal instrument to control the generation, transboundary movement, transport, treatment, disposal, and recovery of HW. Defines illegal traffic of HW as criminal

Objectives :

1. Minimise generation of HW
2. As much as possible, dispose of HW in country of origin
3. Allow enhanced control on import and export of HW
4. Prohibit transport of HW to countries that lack the legal, administrative, or technical capacity to manage and dispose of HW in an environmentally sound manner
5. Co-operate on exchange of information, technology transfer and harmonisation of guidelines, codes, and standards

Illegal Traffic :

Transboundary movement of HW :

1. Without notification pursuant to the provision of this convention to all states involved
2. Without consent pursuant to the provision of this convention of any state involved
3. With consent obtained through falsification, misinformation, or fraud
4. That do not conform in any material way to the document
5. That results in deliberate dumping of waste in contravention of the convention or general principle of international law

Countries can carry out audits and checks, giving fines to violators of the convention, and jail repeat offenders

Q4(d)

In TCLP test, 100g sludge, 2L leachate used.

$$\text{Mass in sludge} = \frac{1.25 \times 2}{0.1} = 25 \text{ mg}$$

$$\% \text{ in sludge} = \frac{25 \times 10^{-3}}{100} = 0.025 \%$$

$$\% \text{ in toxic ash} = 0.025\% / 0.35 = 0.0714\%$$

$$\% \text{ in toxic oil sludge} = 0.0714\% \times 0.75\% = 0.0536\%$$

Q5(a)

	Density g/L	Vol (L)	Mass (g)
Toluene	867	30000	26010000
Benzene	852	20000	17040000
1-1 Dichloroethane	987	10000	9870000
Soil	15500	2600	4030000
Total mass :			56950000

	% Mass	Mass in 120 kg of hazardous waste (kg)
Toluene	45.7	54.84
Benzene	29.9	35.88
1-1 Dichloroethane	17.3	20.76
Soil	7.1	8.52

Toluene :

$$\frac{54.84 - W_{out}}{54.84} = 0.9999$$

$$\mathbf{Maximum\ } W_{out} = \mathbf{0.005484\ kg/hr = 0.132\ kg/d}$$

Benzene :

$$\frac{35.88 - W_{out}}{35.88} = 0.9999$$

$$\mathbf{Maximum\ } W_{out} = \mathbf{0.003588\ kg/hr = 0.086\ kg/d}$$

1-1 Dichloroethane :

$$\frac{20.76 - W_{out}}{20.76} = 0.9999$$

$$\mathbf{Maximum\ } W_{out} = \mathbf{0.002076\ kg/hr = 0.050\ kg/d}$$

Q5(b)(i)

Fixation by addition, where metal ion is incorporated into the structure

Fixation by substitution, where metal ion is swapped with another ion in the structure

Fixation by formation of new products. Insoluble compounds containing the metal ions may be formed during hydration of the cement.

Fixation by combination of the above mechanisms/multiple mechanisms

Q5(b)(ii)

$$\frac{C_t}{C_0} = e^{-kt}$$

$$0.01 = e^{-(0.35)(t)}$$

$$\ln(0.01) = -0.35t$$

$$\mathbf{t = 13.16 h}$$

This material **cannot** be used as construction material, as the pb fixed inside of it will leach out very fast, causing harm to the environment and people around it.