NPTEL

WASTE TO ENERGY CONVERSION

WEEK 2

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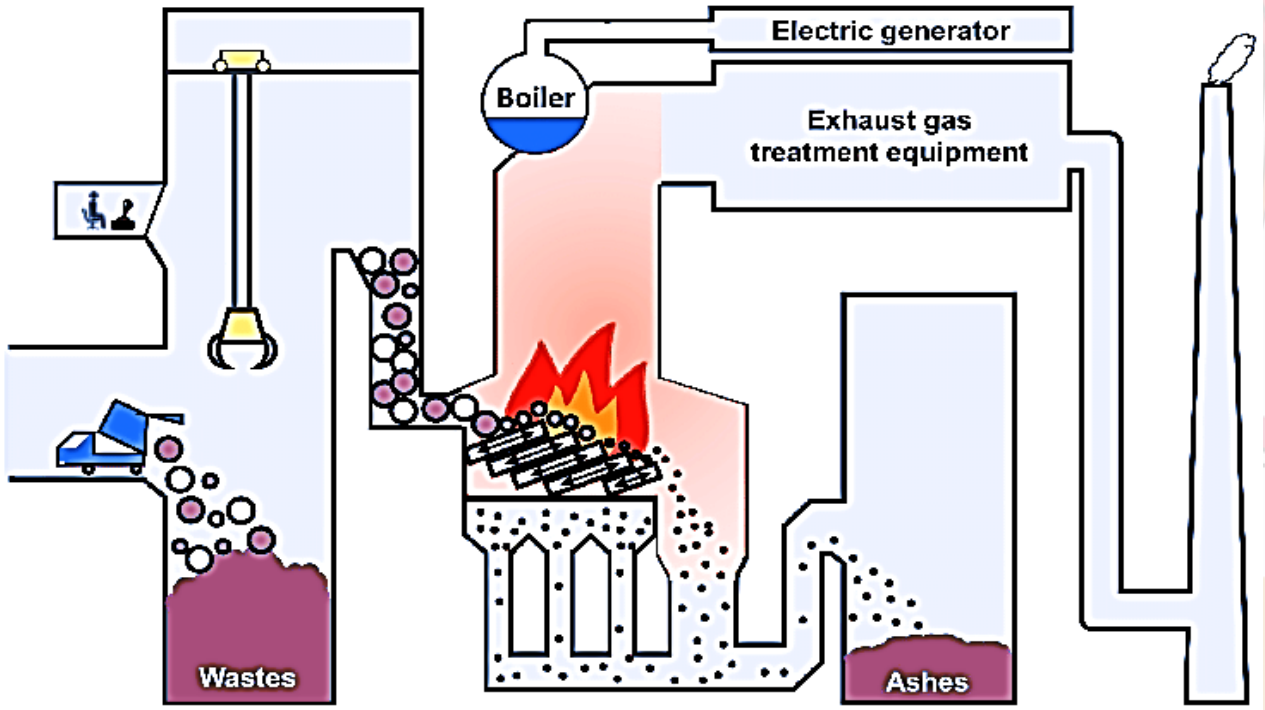
- Circular economy
- Different approaches to convert waste to energy
  - Thermal
  - Chemical
  - Physical
  - Biological
- Characterization of wastes
  - Physical – Size, Sp. Weight, Conductivity, Moisture
  - Chemical
    - Proximate – Moisture, Volatiles, Fixed carbon, Ash
    - Elemental / Ultimate – C, H, N, S, O
    - Energy content
    - Biochemical – Lignin, Cellulose, Lipids, Proteins
- Incineration
- Gasification

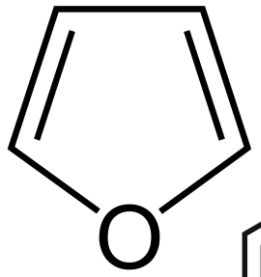
INCINERATION

- Thermochemical process –High T rapid oxidation / combustion – Calcination
- Convert MSW and industrial wastes
- Heat recovered to produce steam – Electricity generation

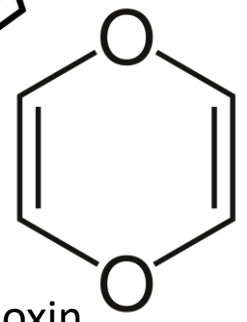


Schematic of an incineration plant
(Ref - DOI:10.1109/COASE.2019.8842972)

- Resultant ash – Construction industry – as filler in cement
- Commercially established – 12 commercial plants established in India, more planned
- Small capacity mobile incinerators
- Disadvantages –
  - Large volumes of CO, CO_2, SO_x and NO_x
  - Furan and dioxin emissions



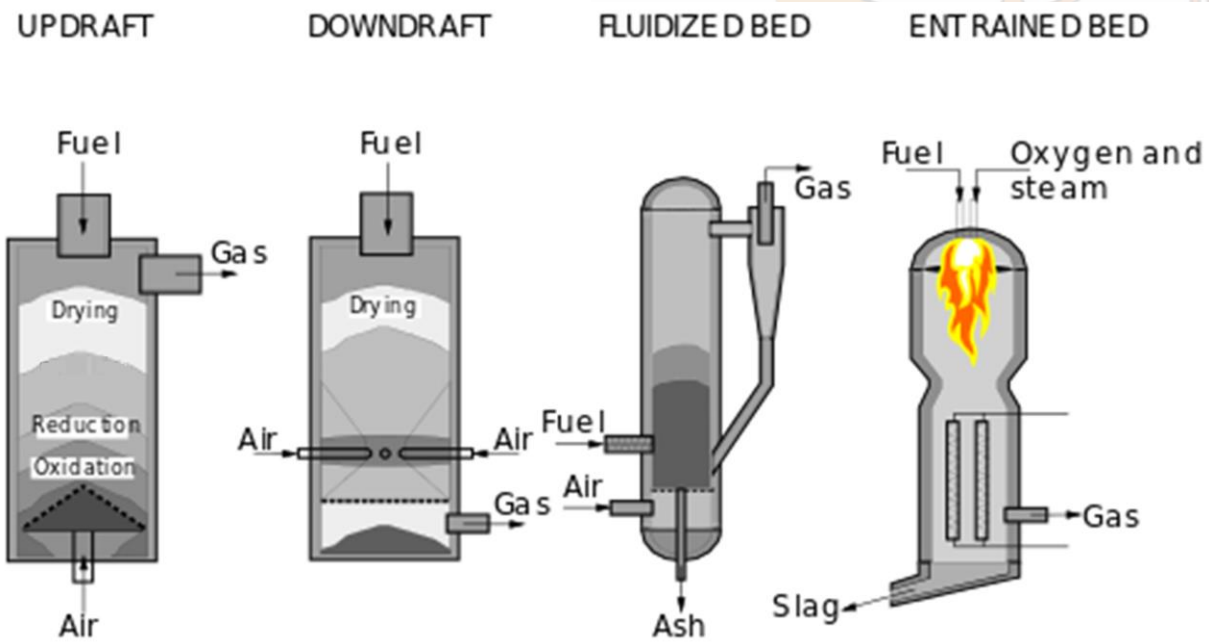
Furan



Dioxin

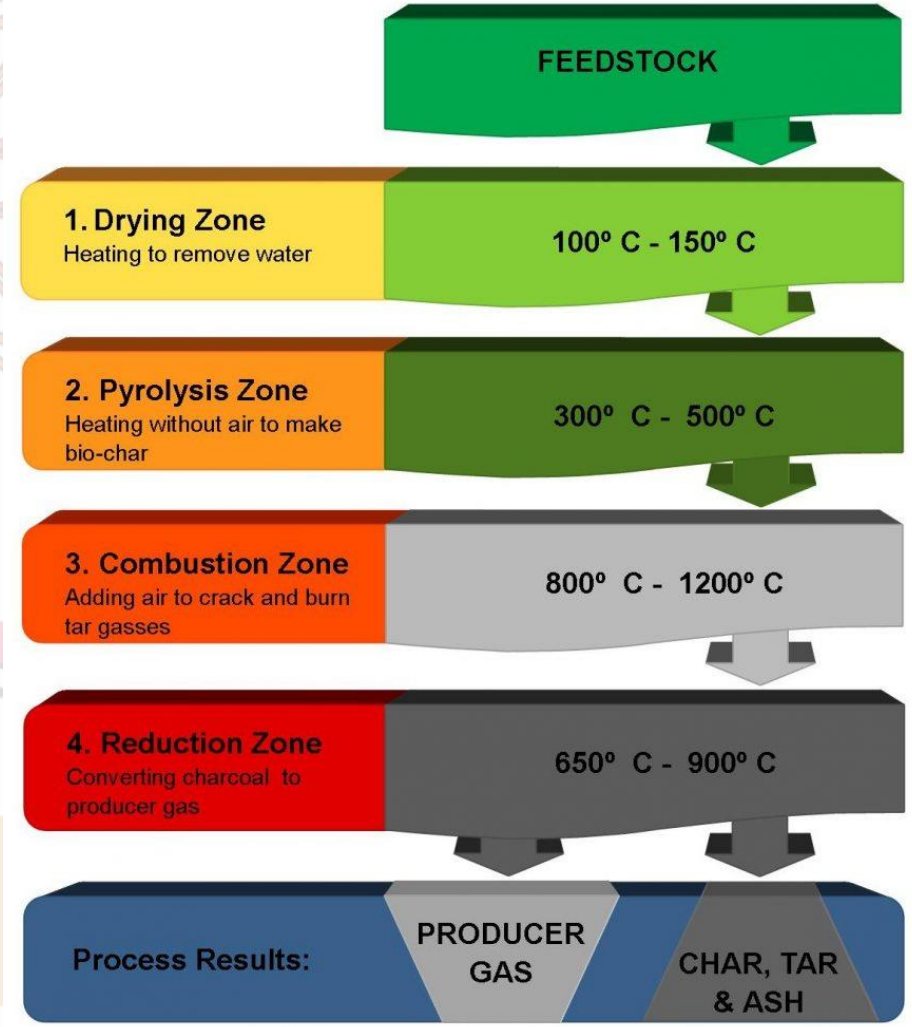
GASIFICATION

- Incomplete combustion
- Main products – H_2, CO, HC
- Updraft – Counter current
- Downdraft – Co-current
  - Tars cracked down in oxidation zone
  - Producer gas has lower tar content



https://en.wikipedia.org/wiki/Gasification#/media/File:Gasifier_types.svg

- Fluidized bed, Entrained flow, Plasma gasifier



https://www.wastetoenergysystems.com/types-of-gasification-which-is-the-best-process/

1) While measuring BOD_5 value of an industrial waste water, the waste water is diluted 35 times with dilution water before it is used. The DO of one real and blank sample are determined immediately, which are found as 6.5 ppm and 9 ppm respectively. Other two BOD bottles filled with real and blank sample are incubated for 5 days at 20°C. After 5 days the DO value of the real and blank samples are found as 2 ppm and 8.5 ppm respectively. Calculate the BOD_5 of the original waste water sample.

- 400 mg/L
- 350 mg/L
- 675 mg/L
- 140 mg/L

Accepted Answers:
140 mg/L

We know $BOD = D^* \times [(DO_{t=0} - DO_{t=5})^{sample} - (DO_{t=0} - DO_{t=5})^{blank}]$

D^* = Dilution factor = 35

For sample, $DO_{t=0} = 6.5$, $DO_{t=5} = 2$

For blank, $DO_{t=0} = 9$, $DO_{t=5} = 8.5$

Substitute, $BOD = 35 \times [(6.5-2)-(9-8.5)] = 35 \times 4 =$ **140 mg/L**

2) 3 g of a dried agricultural waste is leached with benzene and ethanol mixture (2:1 v/v) at ~ 60 ^{0}C for 3 h. After leaching, the residue is dried in a hot air oven at 105 ^{o}C to a constant weight of 1.6 g. This dried material is put in a flask containing 150 ml of (N/2) NaOH solution. The mixture is boiled for 3.5 h with recycled distilled water. After this the residue is washed with distilled water till all the sodium ions are removed and dried to a constant weight of 1.3 g. Determine the extractives and hemicelluloses content of this waste on dry basis.

- 46.67% and 10%
- 10.67% and 25.67%
- 17.67% and 15.67%
- 5% and 15%

Accepted Answers:
46.67% and 10%

Initial weight M_0= 3g

Weight after extractives leaching, M_1 = 1.6g

Weight after hemicellulose separation, M_2 = 1.3g

Weight of extractives = M_0-M_1 = 3 – 1.6 = 1.4g

Weight of hemicellulose = M_1 – M_2 = 1.6-1.3 = 0.3g

Extractive content = $(M_0 – M_1)x100/M_0$ = (3 – 1.6)*100/3 = 46.67%

Hemicellulose content = $(M_1 – M_2)x100/M0$ = (1.6 – 1.3)x100/3 = 10%

3) Which of the following is not a step involved in gasification?

- Devolatilization
- Oxidation
- Incineration
- Ash cooling

Accepted Answers:
Incineration

4) Which process converts carbonaceous feed stocks including biomass and wastes into combustible gases like rich in CO and H_2?

- Sedimentation
- Gasification
- Pyrolysis
- Combustion

Accepted Answers:
Gasification

5) From data given, calculate the percent carbon and hydrogen in the dry waste. Composition of the flue gas (dry basis) from an incinerator is as follows: 14% CO_2 (mole/mole), 5% O_2 (mole/mole), and the rest is nitrogen

- C = 94.32 %, H_2 = 5.68 %
- C = 78.92 %, H_2 = 21.08 %
- C = 88.92 %, H_2 = 11.08 %
- C = 44.46 %, H_2 = 55.54 %

Accepted Answers:
$C = 94.32\ \%,\ H_2 = 5.68\ \%$

Basis – 100 mole of flue gas
CO_2 = 14%, O_2 = 5%, N_2 = 100-14-5 = 81%
Moles of CO_2 = 14 moles
Moles of O_2 = 5 moles
Moles of N_2 in flue gas = 81 moles = Moles of N_2 supplied

$C + O_2 \rightarrow CO_2$
$2H_2 + O_2 \rightarrow 2H_2O$

Air supplied = 81/0.79 = 102.53 moles
O_2 in the supplied air = 0.21 * 102.53 = 21.53 moles

O_2 consumed = O_2 supplied – O_2 in the flue gas
=21.53 – 5 = 16.53 moles

14 moles CO_2 ➔ 14 moles O_2 consumed
So 16.53 – 14 = 2.53 moles consumed by H_2
For 1 mole of O_2, 2 moles of H_2 is required
So moles of H_2 in waste = 2 * 2.53 = 5.06

Weight of H in waste = 5.06*2 = 10.12g
Weight of C in waste = 14 * 12 = 168g

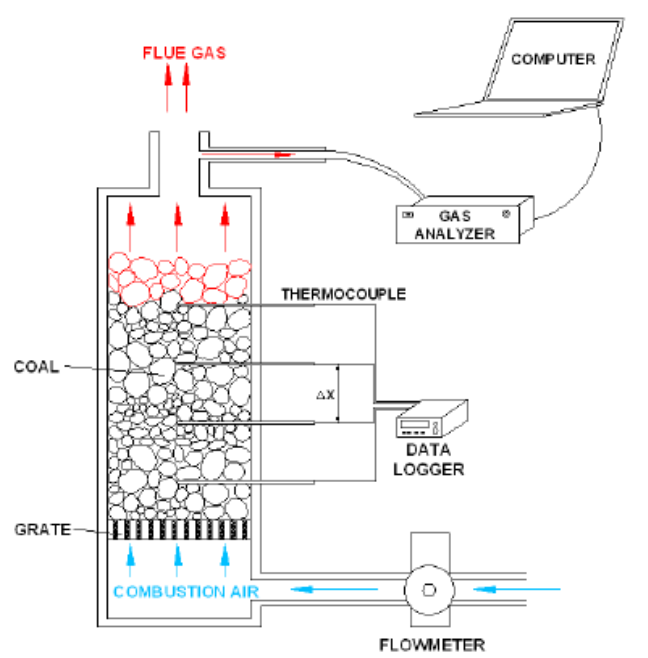
Weight of waste = 10.12 + 168 = 178.12g

%C in dry waste = 100 x 10.12/178.12 = 94.32%
%H in dry waste = 100 x 168/178.12 = 5.68%

6) Which type of combustion system included under feed strokers and grate firings?

- Fluidized bed combustion
- Fixed bed combustion
- Bubbling fluidized bed
- None of these

Accepted Answers:
Fixed bed combustion



7) Which grate resembles stairs with alternating fixed or moving grate sections?

- The roller grate
- The rotary kiln
- The reciprocating grate
- None of the above

Accepted Answers:
The reciprocating grate

8) Fluidized-bed combustion uses which of the bed material?

- Silica sand
- Limestone
- Dolomite
- All of the above

Accepted Answers:
All of the above

https://www.researchgate.net/figure/The-measurement-setup-with-fixed-bed-reactor_fig1_268385627
https://www.topboilerparts.com/reciprocating-grate-stoker/reciprocating-grate-stoker%20heat%20resistant.html

9) Which of the following are the disadvantages of combustion?

- Fuel quality and consistency can vary significantly
- Creates the risk of fire and carbon monoxide poisoning
- Fuel storage requires a lot of space
- All of the above

Accepted Answers:
All of the above

10) What is the range of excess air requirement for effective combustion of wastes and biomass?

- 5 to 50%
- 70 to 100%
- 0 to 2%
- None of the above

Accepted Answers:
5 to 50%