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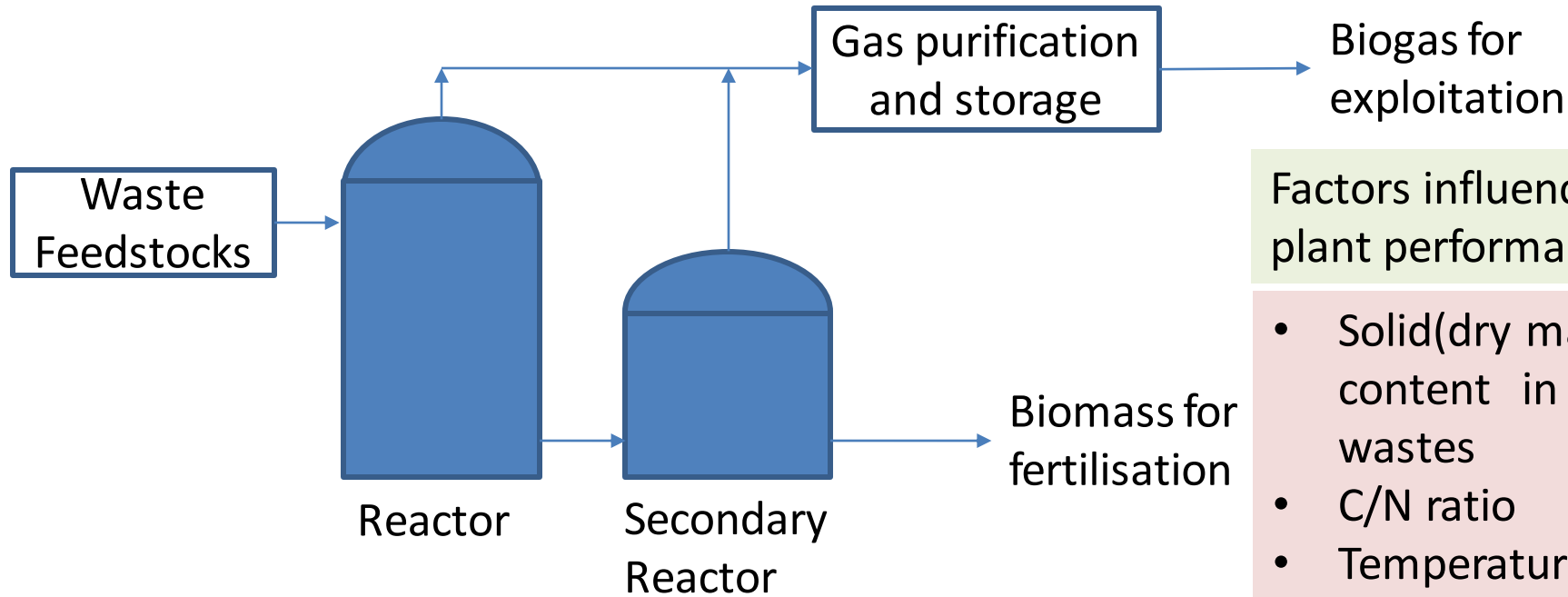
NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

DESIGN OF ANAEROBIC DIGESTER

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Factors influencing plant performance

- Solid(dry matter) content in feed wastes
- C/N ratio
- Temperature
- pH
- Retention time

Simple schematic diagram of a biogas plant

Specific biogas production potential & methane content for several wastes

Wastes	Average Dry Matter(DM) content (wt %)	Biogas Potential l/ kg substrate	Methane Content %
Wheat straws	86.5	367	78.5
Barley straws	84	380	77
Lucene	22.5	445	77.7
Grass	16	557	84
Corn silage	34	108	52
Corn stalks	86	309	-
Dried leaves	12.5	260	58

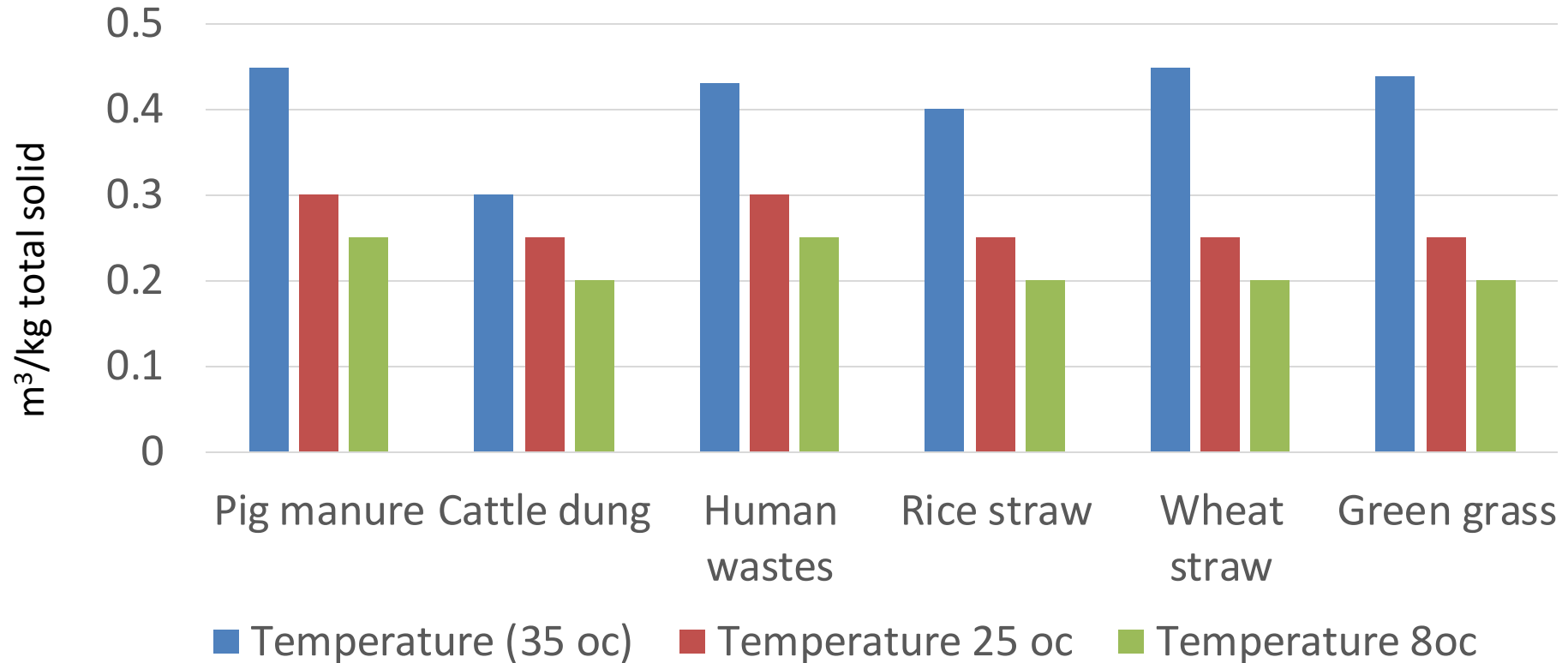
Specific biogas production potential & methane content for several wastes

Wastes	Average Dry Matter(DM) content wt %	Biogas Potential l/ kg Substrate	Methane Content %
Beet leaves	13.5	501	84.8
Poultry wastes	27.5	520	68
Cattle manure	14	260-280	50-60
Horse dung	27.5	200-300	66
Sheep dung	25	320	65
Pig manure	13.5	480	60

☐ Most desirable solid content is 08 %



Variation of biogas production rate with temperature



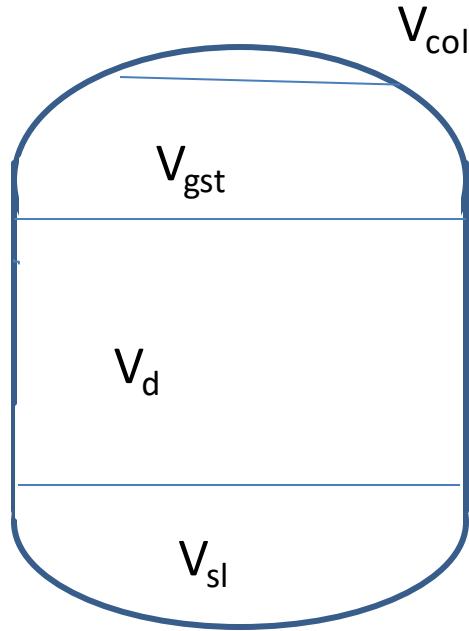
C/N ratio of some wastes

Material	C/N ratio (%/%)
Dry rice straw	67:1 (42/0.53)
Dry wheat straw	87:1 (46/0.53)
Corn stalks	53:1 (40/0.75)
Fallen leaves	41:1 (41/1)
Wild grass	27:1 (14/0.54)
Fresh cattle dung	25:1 (7.3/0.29)
Fresh pig manure	13:1 (7.8/0.60)
Fresh human wastes	29:1 (2.5/0.85)

Suitable conditions for digestion

- Solid(dry matter) content in feed wastes : 08 %
- C/N ratio : 20:1 to 30:1
- Temperature : 25-35 °C
- pH : 6.8 to 7.2
- Retention time : 60-90 days
- For mesophilic digestion it is > 20 days.

Cross section of digester



Where

V_{col} is gas collection volume

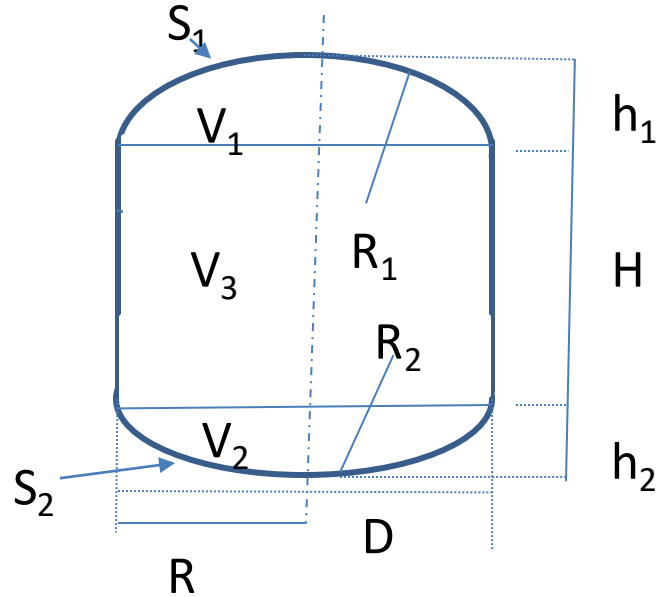
V_{gst} is gas storage volume

V_d is active digestion volume

V_{sl} is sludge layer volume

$$\text{Total volume (V)} = V_{col} + V_{gst} + V_d + V_{sl}$$

Reactor dimension

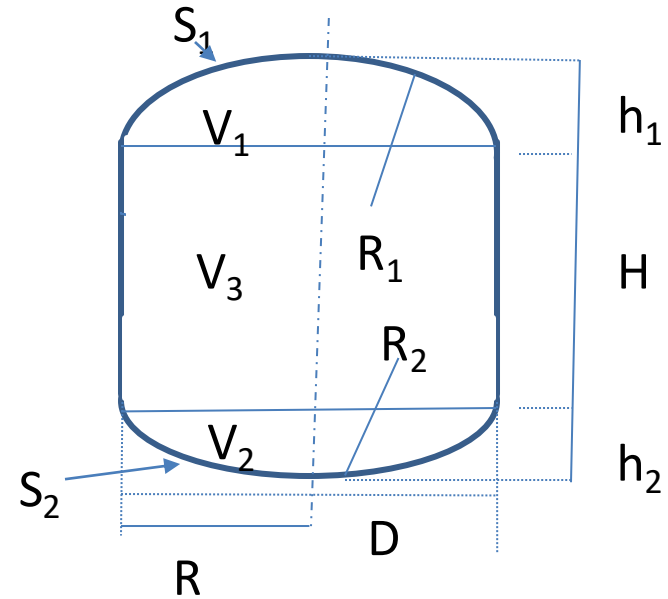
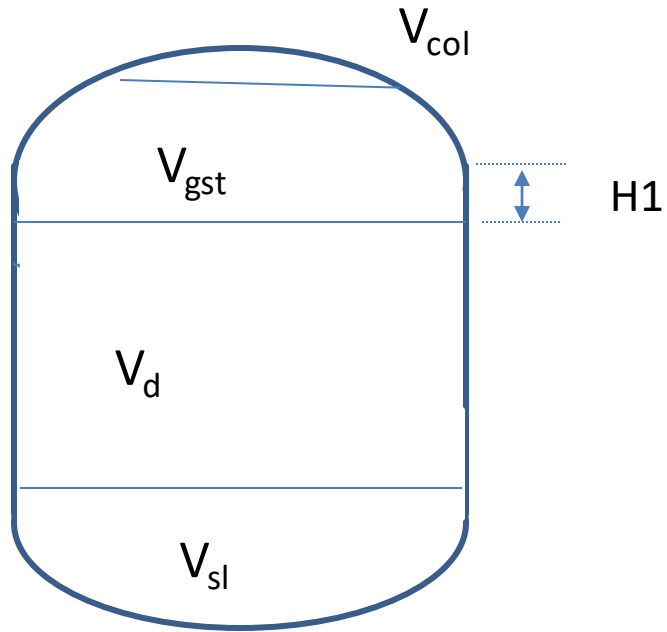


Geometrical dimensions of the cylindrical shaped biogas digester body

- V_1 is volume of top head
- V_2 is Volume of bottom head
- S_1 is surface area of top head
- S_2 is surface area of bottom head
- V_3 is the volume of cylindrical part
- R_1 is the characteristic diameter of top head
- R_2 is the characteristic diameter of bottom head
- H is the height of cylindrical portion
- h_1 is the height of top head
- h_2 is the height of bottom head
- R is radius of the cylindrical part
- D is the diameter of the cylindrical part

All the above parameters can be related to “D” differently on the basis of head types

Comparison between cross section and dimension



Reactor dimension

For volume

$$V_{col} \leq 5 \% \text{ of } V$$

$$V_{sl} \leq 15 \% \text{ of } V$$

$$V_{gst} + V_d = 0.8 * V$$

$$V_{gst} = 0.5 * (V_{gst} + V_d + V_{sl}) * K$$

$$\text{Or } = 0.5 * TS * M$$

Where K is gas production rate per m^3 digester volume per day
and M is gas production rate per kg of TS per day.

For Bangladesh K is $0.4 \text{ m}^3/\text{m}^3/\text{d}$ and M is $0.28 \text{ m}^3/\text{kg}/\text{d}$

For a typical case

Source

http://www.sswm.info/sites/default/files/reference_attachments/BRC%20ny%20Design%20Biogas%20Plant.pdf

For geometrical dimension

$$D = 1.3078 * V^{1/3}$$

$$V_1 = 0.0827 D^3$$

$$V_2 = 0.05011 D^3$$

$$V_3 = 0.3142 D^3$$

$$R_1 = 0.725 D$$

$$R_2 = 1.0625 D$$

$$h_1 = D/5$$

$$h_2 = D/8$$

$$S_1 = 0.911 D^2$$

$$S_2 = 0.8345 D^2$$



Volume calculation of digester chamber-

Determine the volume of the digester chamber and dimension of the chamber for the biogas production from the cow dung of 10 cows having body weight of 200 kg each. Assume the temperature is 30 °C , the solid content of the cow dung is 16 %, HRT is 40 days. One cow produces 10 kg cow dung daily.

Solution:

Total discharge = 10 kg X 10 = 100 Kg/day

TS of fresh discharge = 100 kg X 0.16 = 16 Kg.

In 8% concentration of TS (To make favourable condition)

8 Kg. Solid = 100 Kg. Influent

1 Kg. Solid = 100 / 8 Kg influent

16 Kg Solid = 100 x 16/ 8 = 200 Kg. Influent.

Total influent required = 200 Kg.



Water to be added to make the discharge 8% concentration of TS
= 200 Kg - 100 Kg. = 100 Kg.

Working volume of digester = $V_{gst} + V_d$

$$\begin{aligned} V_{gst} + V_d &= Q \cdot \text{HRT} \\ &= 200 \text{ Kg/day} \times 40 \text{ days} \\ &= 8000 \text{ Kg. (} 1000 \text{ Kg} = 1 \text{ m}^3 \text{)} = 8 \text{ m}^3. \end{aligned}$$

From geometrical assumptions:

$$V_{gst} + V_d = 0.80 V$$

$$\text{Or } V = 8 / 0.8 = 10 \text{ m}^3. \text{ (Putting value } V_{gst} + V_d = 8 \text{ m}^3 \text{)}$$

$$\& D = 1.3078 V^{1/3} = 2.8176 \text{ m} \sim 2.82 \text{ m}.$$



Again

$$V_3 = 3.14 * D^2 * H / 4$$

$$\text{Putting } V_3 = 0.3142 D^3 = 7.046 \text{ m}^3$$

$$3.14 * D^2 * H / 4 = 0.3142 D^3$$

$$\text{Or } H = 4 * 0.3142 D / 3.14 = 1.129 \text{ m}$$

$$h_1 = D / 5 = 0.564 \text{ m}$$

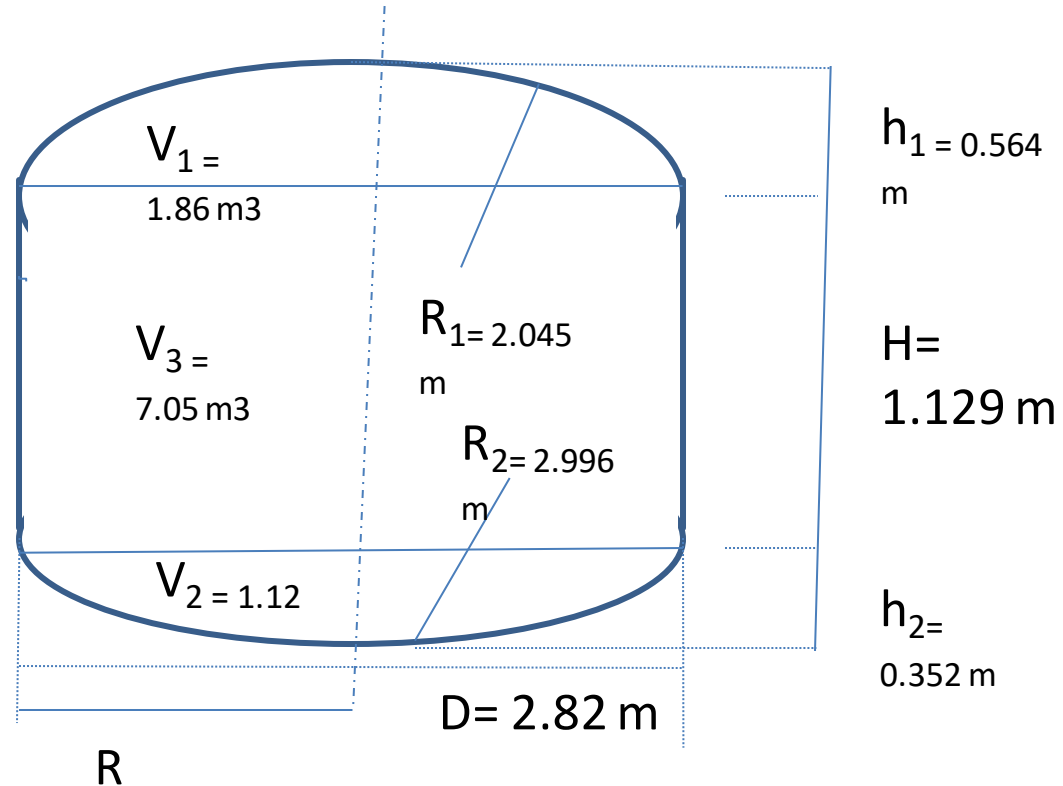
$$h_2 = D / 8 = 0.352 \text{ m}$$

$$R_1 = 0.725 D = 2.045 \text{ m}$$

$$R_2 = 1.0625 D = 2.996 \text{ m}$$

$$V_1 = 0.0827 D^3 = 1.855 \text{ m}^3$$

$$V_2 = 0.05011 D^3 = 1.124 \text{ m}^3$$



$$V_{col} = 0.05 * V = 0.5 \text{ m}^3$$

$$V_{gst} = 0.5 * (V_{gst} + V_d + V_{sl}) * K = 0.5 * (V - V_{col}) * K = 0.5 * (9.5) * 0.4 = 1.9 \text{ m}^3$$

Alternatively,

$$V_{gst} = 50 \% \text{ of daily gas yield} = 0.5 * \text{TS} * \text{gas production rate per kg TS/day}$$

$$= 0.5 * 100 * 0.16 * 0.28 \text{ m}^3/\text{kg TS} = 2.24 \text{ m}^3$$

$$V_{gst} + V_{col} = 0.5 + 2.24 = 2.74 \text{ m}^3$$

Further,

$$V_1 = [(V_{gst} + V_{col}) - (3.14 * D^2 H_1 / 4)] = 2.74 - 6.24 H_1$$

$$\text{Or } H_1 = (2.74 - 1.855) / 6.24 = 0.142 \text{ m}$$

$$\text{Assuming } V_{sl} = 15 \% \text{ of } V = 10 * 0.15 = 1.5 \text{ m}^3$$

$$\begin{aligned} V_d &= (V - V_{gst} - V_{col} - V_{sl}) \\ &= 10 - 2.74 - 1.5 = 5.76 \text{ m}^3 \end{aligned}$$



Thanks...

