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Capacity Building for Ecological Sanitation in India

ASIA PRO ECO II

EUROPEAID
CO-OPERATION OFFICE

Small-Scale Biogas Sanitation Systems

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Definition, Composition and Properties of Biogas

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of microorganisms, which degrade organic material and return the decomposition products to the environment. In this process biogas is generated, a source of renewable energy [1].

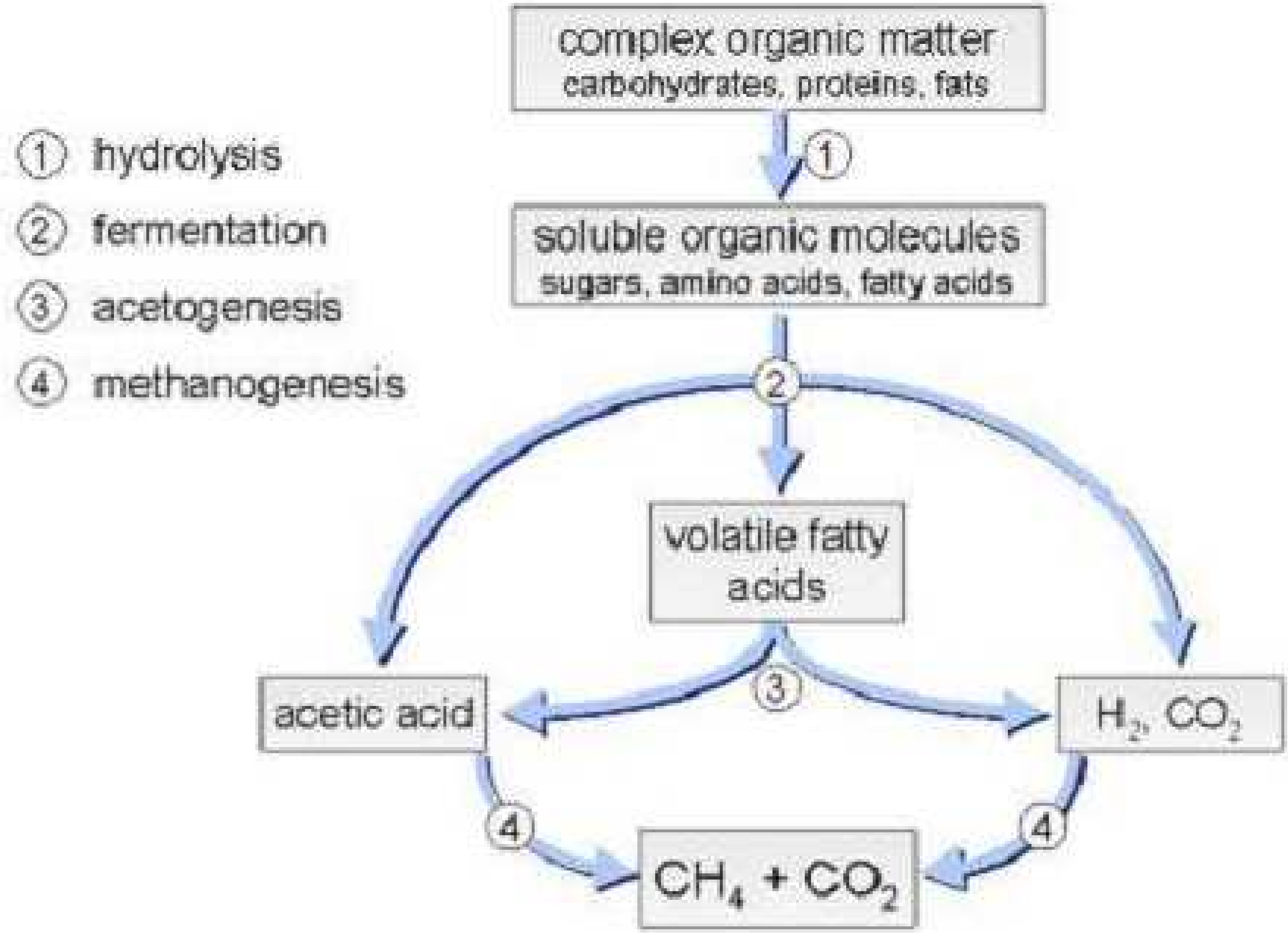
Biogas is a mixture of gases that is composed chiefly of:

- **methane** (CH_4): 40 - 70 vol.%
- **carbon dioxide** (CO_2): 30 - 60 vol.%
- **other gases**: 1 - 5 vol.%

including:

- hydrogen (H_2): 0 - 1 vol.%
- hydrogen sulfide (H_2S): 0 - 3 vol.%

How is it Produced (Three Steps of Biogas Production)



source: [2]

How is it Produced (Three Steps of Biogas Production)

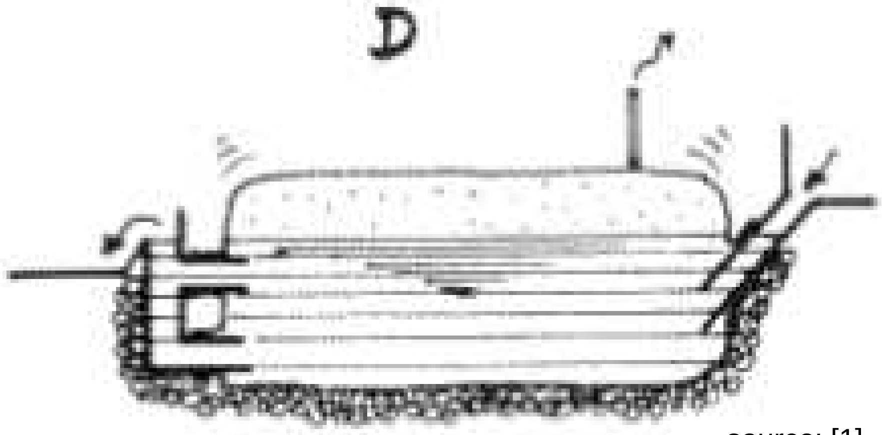
Hydrolysis and fermentation:
organic matter is enzymolyzed externally by extracellular enzymes (cellulase, amylase, protease and lipase) of microorganisms; bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts.

Acidification:
Acid-producing bacteria convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2);
these bacteria are facultatively anaerobic and can grow under acid conditions; to produce acetic acid, they need oxygen (solved in the solution or bound) and carbon, hereby creating an anaerobic condition; they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane;

Methane formation:
methane-producing bacteria utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide; they are obligatory anaerobic and very sensitive to environmental changes.

source: [1]

Balloon Digesters



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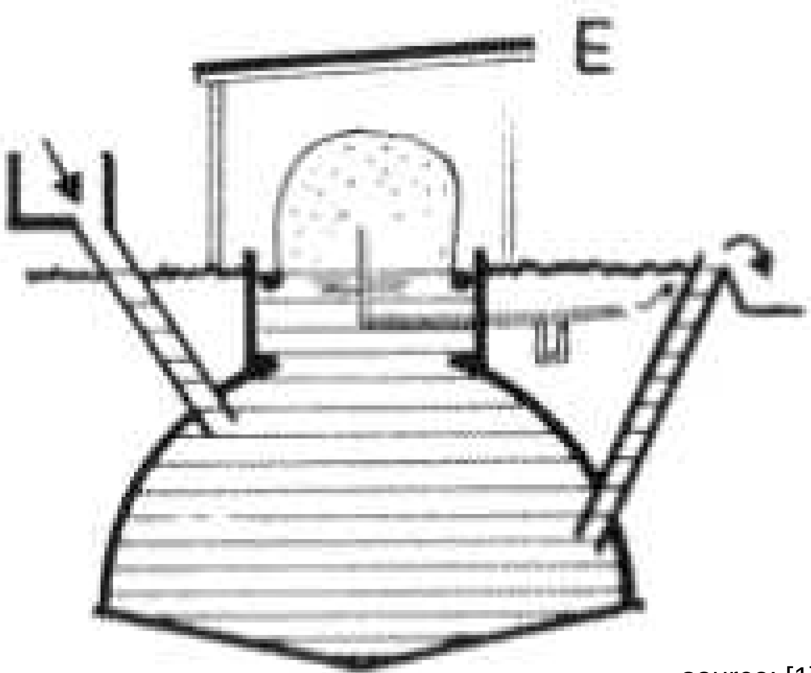


source: [1]

- consists of a digester bag (e.g. PVC) in the upper part of which the gas is stored;
- inlet and outlet are attached directly to the plastic skin of the balloon;
- gas pressure is achieved through the elasticity of the balloon and by added weights placed on the balloon;
- A variation of the balloon plant is the channel-type digester, which is usually covered with plastic sheeting and a sunshade;
- recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high

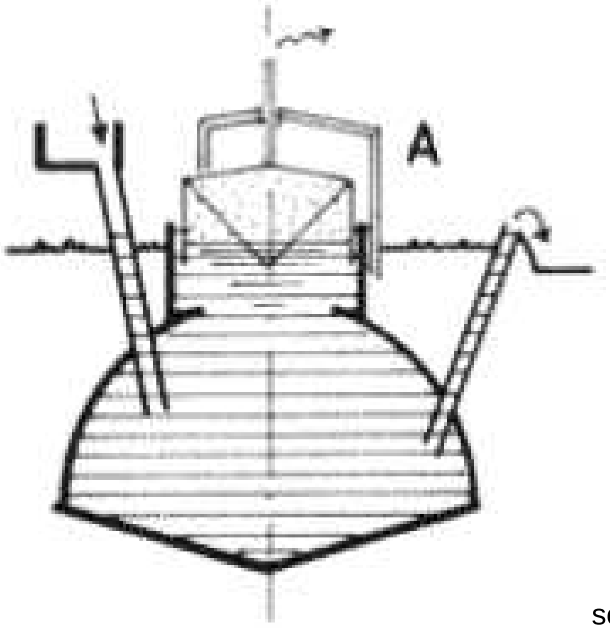
Advantages & Limitations of Balloon Digesters

ADVANTAGES

- low cost;
- ease of transportation;
- low construction sophistication;
- high digester temperatures;
- uncomplicated cleaning, emptying and maintenance;

LIMITATIONS

- relatively short life (about five years);
- susceptibility to damage;
- little creation of local employment;
- limited self-help potential;
- little knowledge for repairing by local craftsmen source: [3]



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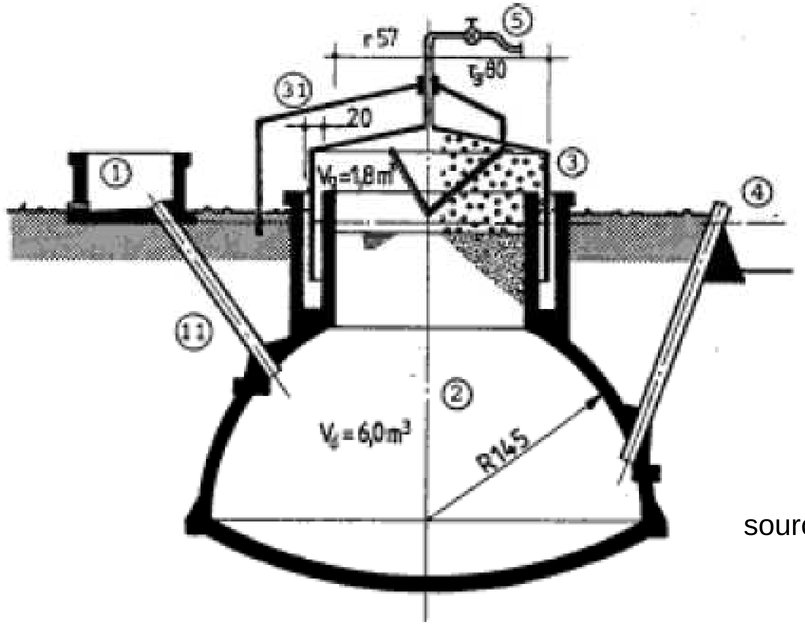


source: [1]

- consist of an underground digester and a moving gasholder;
- the gasholder floats either directly on the fermentation slurry (top) or in a water jacket of its own (bottom);
- the gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored;
- water-jacket digesters are universally applicable and especially easy to maintain, the drum won't stick, even if the substrate has a high solids content;
- PVC drums are unsuitable because they are not resistant to UV radiation;

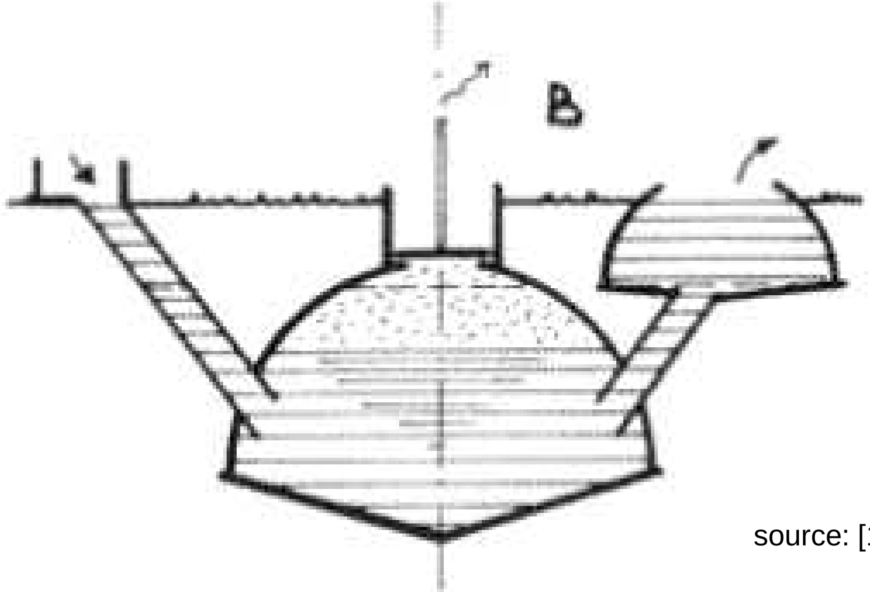
Advantages & Limitations of Floating-drum Digester

ADVANTAGES

- simple, easily understood operation;
- they volume of stored gas is directly visible
- the gas pressure is constant (determined by the weight of the gas holder);
- construction is relatively easy;
- construction mistakes do not lead to major problems in operation and gas yield;

LIMITATIONS

- high material costs of the steel drum;
- susceptibility of steel parts to corrosion (because of this, floating drum plants have a shorter life span than fixed-dome plants);
- regular maintenance costs for the painting of the drum;
- if fibrous substrates are used, the gasholder shows a tendency to get "stuck" in the resultant floating scum



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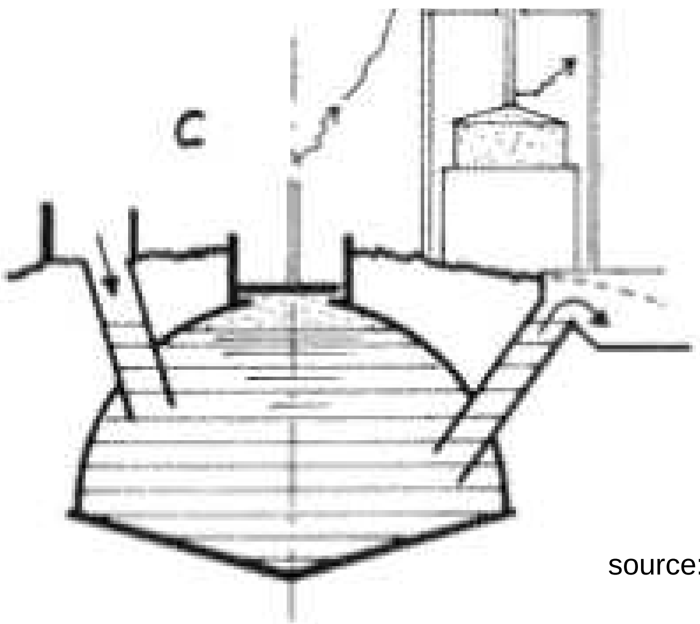


source: [1]

- consist of a digester with a fixed, non-movable gas holder, which sits on top of the digester;
- when gas production starts, the slurry is displaced into the compensation tank;
- gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank;

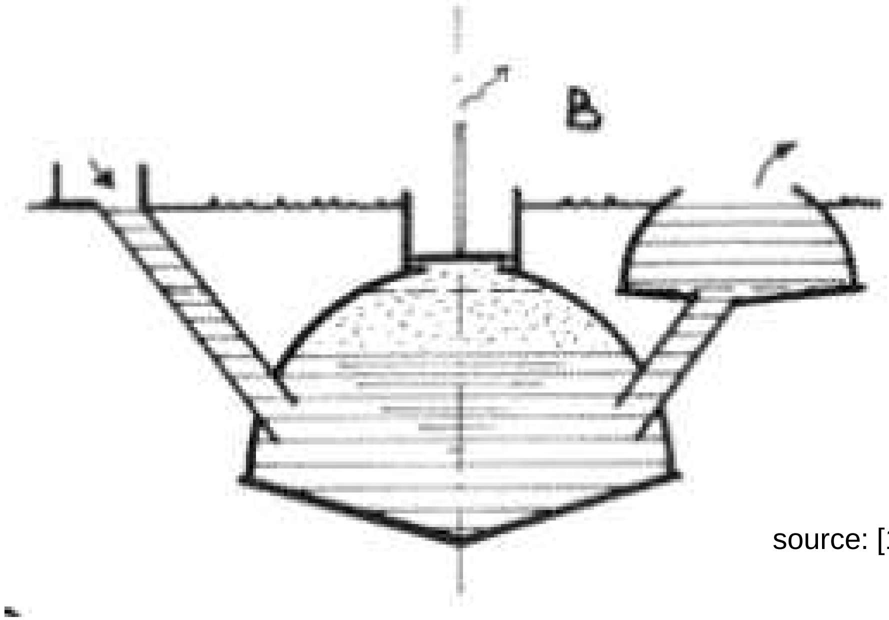
Advantages & Limitations of Fixed-dome Digester

ADVANTAGES

- relatively low construction costs;
- absence of moving parts and rusting steel parts;
- long life span if well constructed;
- underground construction saves space and protects the digester from temperature changes;
- construction provides opportunities for skilled local employment;

LIMITATIONS

- frequent problems with the gas-tightness of the brickwork gas holder (a small crack in the upper brickwork can cause heavy losses of biogas);
- gas pressure fluctuates substantially depending on the volume of the stored gas;
- even though the underground construction buffers temperature extremes, digester temperatures are generally low;



source: [1]

- similar in construction to fixed-dome biogas plants (i.e. digester with a fixed, non-movable gas holder);
- also refered to as “Biodigester Septic Tanks” or “UASB Septic Tanks”;
- facilitate solid-liquid separation;
- provide a high sludge retention time, that facilitates almost complete degradation of organics;
- enable production and collection of biogas for direct use;

Advantages & Limitations of Biogas Settler

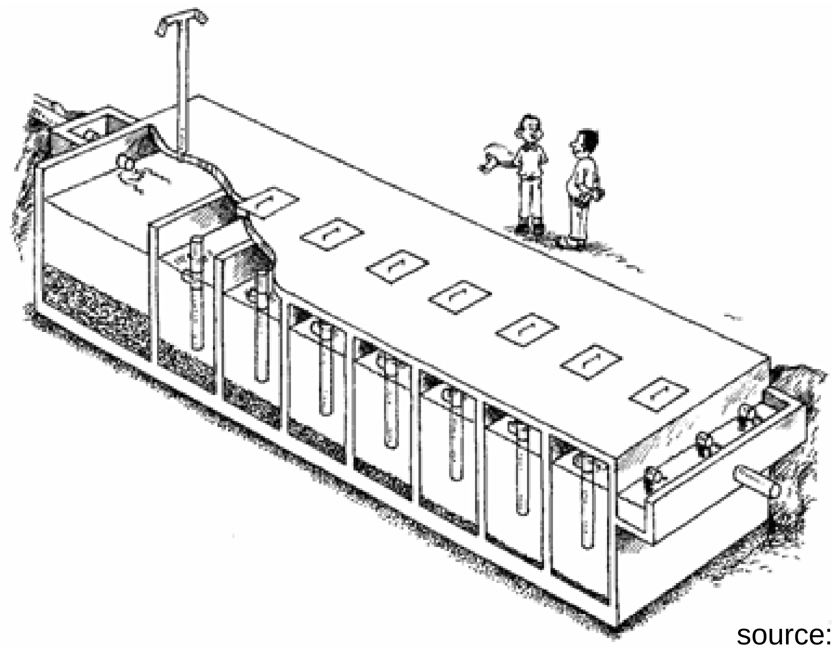
ADVANTAGES

- refer to advantages of fixed-dome digester;
- no handling of raw (unprocessed) wastewater;
- biogas may be used as a substitute to LPG in cooking;

LIMITATIONS

- refer to limitations of fixed-dome digester;

Anaerobic Baffled Reactor (ABR)



source: [4]

- mechanical and anaerobic cleansing processes are applied in sequence;
- reactor consists of different chambers (connected in series);
- mode of flow: up-stream;
- wastewater is intensively mixed up with the sludge;
- integrated sedimentation chamber for pre-treatment;

Advantages & Limitations of Anaerobic Baffled Reactors

ADVANTAGES

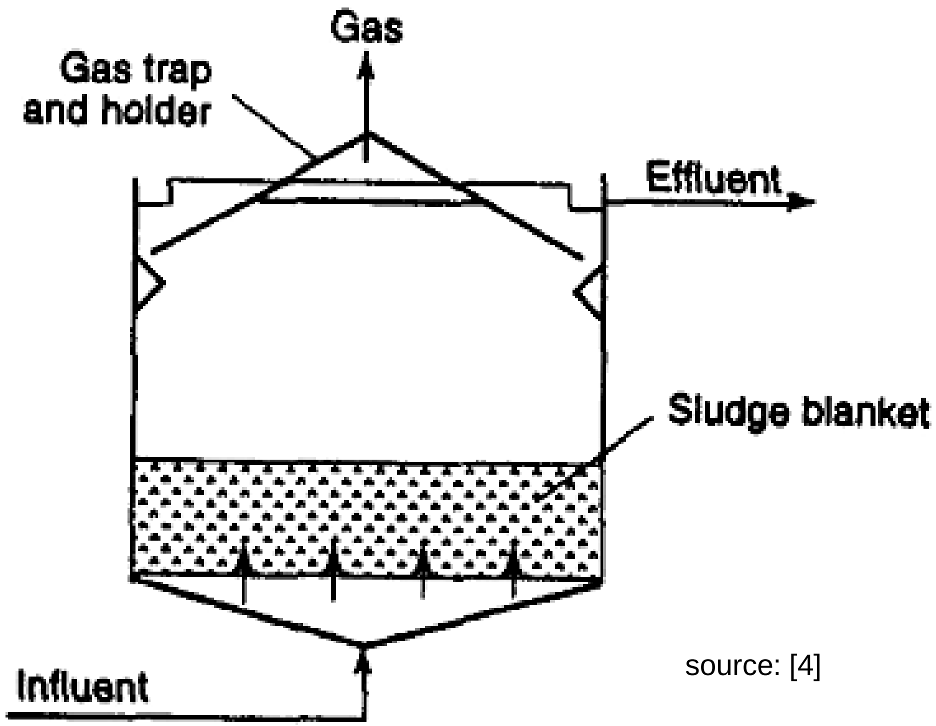
- suitable for small & large settlements;
- little space required due to underground construction;
- low investment costs;
- very low operation and maintenance costs;
- standardised designs and standard operation procedures available;
- simple operation and maintenance;
- high treatment efficiency;

LIMITATIONS

- experts required for design and supervision;
- master mason required for high-quality plastering work;
- infectious organisms are not sufficiently removed;
- well-organized CBO or service provider needed for operation and maintenance;
- manual de-sludging of the tank is highly hazardous and an inhumane task;
- mechanical de-sludging (vacuum trucks) requires sophisticated instruments;

source: [4]

Upflow Anaerobic Sludge Blanket (UASB) Reactor



source: [4]

- deep tank in which wastewater pours near the bottom and is equally distributed;
- lower part maintains a sludge blanket through which the wastewater is forced;
- upper part provides for separation of water, sludge and biogas in gas-liquid-solids separator (GLSS);
- excess sludge has to be removed;

Advantages & Limitations of UASB Reactors 

ADVANTAGES

- relatively low investment and maintenance costs;
- little space required due to underground construction;
- high potential treatment efficiency;

LIMITATIONS

- low community contribution for construction work;
- technical energy and feeder pump required;
- stable fluidised bed difficult to maintain;
- not resistant against shock-loads;
- operation difficult for fluctuating inflows;
- de-sludging procedures require professional service provider;

source: [4]

Anaerobic Lagoon

(photo: H.P. Mang)

- extremely simple in construction, operation and maintenance;
- pond is made of 2,5 – 5 m deep earthen basin;
- detention time of influent is about 20 – 30 days;
- common design: pond systems in series of two or three modules for a full scale treatment;

Advantages & Limitations of Anaerobic Lagoons

ADVANTAGES

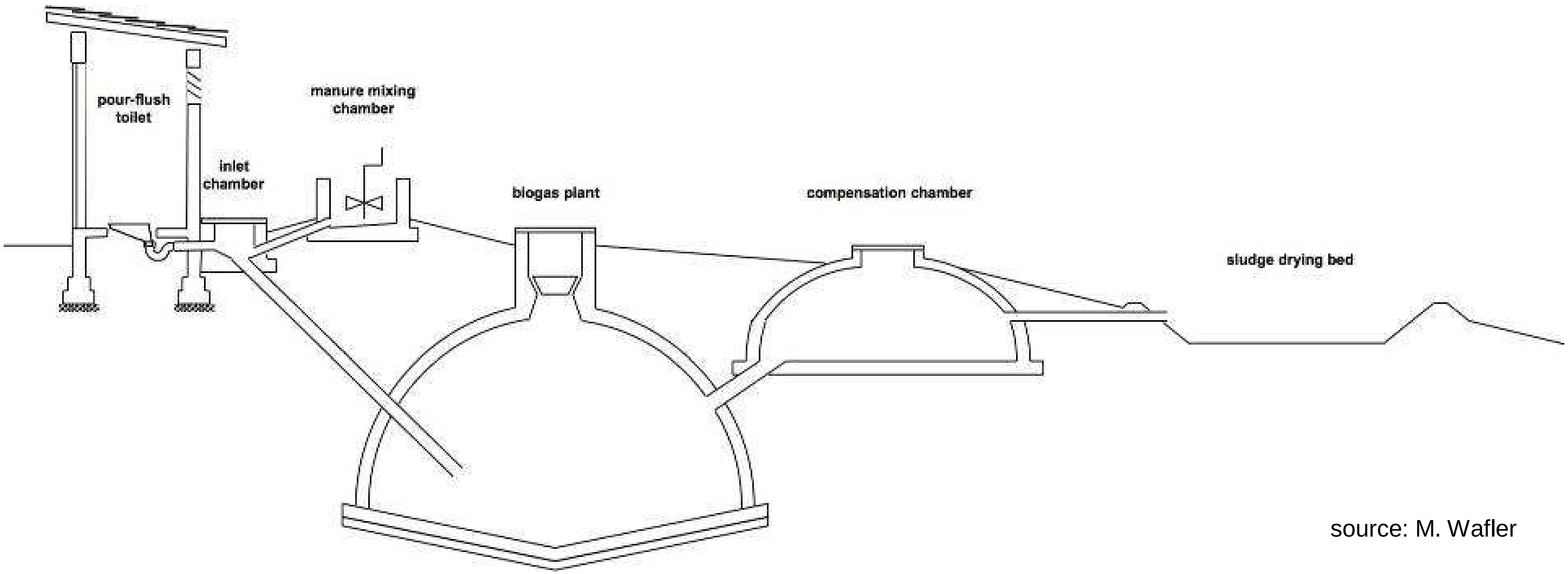
- low-cost system suitable for rural and semi-urban communities;
- high community participation in construction and O & M possible;
- simple operation & maintenance;
- resistant against shock load and variable inflow volume, if lagoon size is big enough;

LIMITATIONS

- only applicable where land is available and cheap;
- permanent overload leads to breakdown of biological cleansing processes;
- misuse of system leads to public health hazard;
- sullage is in the open and thus poses a potential health threat;
- low treatment efficiency, effluent is still infectious;
- not suitable where there is a high groundwater table due to infiltration of sullage
- public health hazard if system if overloaded;

source: [4]

Toilet-linked Biogas Plants (TBP): Conceptual Sketch



source: M. Wafler

TBP: Background Information

Night-soil based or toilet-linked biogas plants are widely used in Asia for the co-digestion of human excreta along with animal manure (e.g. cattle or buffalo dung, etc.) or the hygienically safe on-site treatment of toilet water and recovery of valuable energy in the form of biogas to be used as a substitute to LPG (Liquefied Petroleum Gas) in cooking and lighting.

ADVANTAGES

- no handling of raw (unprocessed) toilet water;
- increased biogas production if additional feed material (e.g. animal manure, etc.) is available for co-digestion;
- biogas may be used as a substitute to LPG in cooking;
- application of digested slurry as soil amendment to agricultural plots possible;

LIMITATIONS

- limited biogas production if only toilet water is treated;

TBP: Properties of Different Feed Materials

animal species/ feed material	daily manure yield			fresh-manure solids		liveweight	C/N	gas yield	
	manure		urine	DM	ODM			range	average
	[kg/d]	[$\%_{lw}$]	[$\%_{lw}$]	[%]	[%]	[kg]	[-]	[l/kg ODM]	
cattle manure	8	5	4 - 5	16	13	135 - 800	10 - 25	150 - 350	250
buffalo manure	12	5	4 - 5	14	12	340 - 420	20		
pig manure	2	2	3	16	12	30 - 75	9 - 13	340 - 550	450
sheep/goat droppings	1	3	1 - 2	30	20	30 - 100	30	100 - 310	200
chicken manure	0.08	4.5	-	25	17	1.5 - 2	5 - 8	310 - 620	460
human excreta	0.5	1	2	20	15	50 - 80	8		
corn straw	-	-	-	80	73	-	30 - 65	350 - 480	410
water hyacinths	-	-	-	7	5	-	20 - 30	300 - 350	325
vegetable residues	-	-	-	12	10	-	35	300 - 400	350
fresh grass	-	-	-	24	21	-	12	280 - 550	410

source: ÖKOTOP in [5], [6]

TBP: Biogas Demand vs. Anticipated Biogas Yield

Anticipated biogas production must be greater than the energy (i.e. biogas) demand. In case of a negative balance, the planner must check both sides - production and demand - against the following criteria [5] :

energy demand:

- shorter use of gas-fueled appliances, e.g. burning time of lamps;
- omitting certain appliances, e.g. radiant heater, second lamp;
- reduction to a partial-supply level that would probably make operation of the biogas plant more worthwhile.

energy supply - biogas production:

- the extent to which the useful biomass volume can be increased (better collecting methods, use of dung from other livestock inventories, including more agricultural waste, night soil, etc.);
- the extent to which prolonged retention times, i.e. a larger digester volume, would increase the gas yield;
- the extent to which the digesting temperature could be increased by modifying the structure;

TBP: Biogas Appliances and Their Biogas Consumption

(photo: K.P. Pravinjith)

(photo: M. Wafler)

appliance:	**biogas consumption □l/hour□**
household burner	200 - 450
industrial burner	1,000 – 3,000
refrigarator (100 l capacity; depending on outside temperature)	720 – 1,800
gas lamp (equivalent to 60 W bulb)	120 - 150
biogas/diesel engine (per bhp)	420

source: [6]

TBP: Calculation of Biogas Demand

Calculate the biogas demand for a rural household with 8 persons and estimate the biogas yield from the anaerobically treatment of buffalo manure and toilet water in a small-scale biogas plant.

assumptions for sample design problem:

- 2-flame biogas cooker used for cooking 2 hot meals (breakfast and dinner) and making tea (in the afternoon);
- operating hours of the biogas cooker are from 5 a.m. to 7 a.m. and 7 p.m. to 10 p.m. for cooking and from 4 p.m. to 5 p.m. for making tea;
- both flames are used for cooking, while one flame is used for making tea;
- gas consumption of one flame is about 175 litres of biogas per hour;
- the gas shall also be used for lighting a single biogas lamp. The lamp shall be lit from 5 a.m. to 7 a.m. and from 7 p.m. to 10 p.m. Gas consumption of the biogas lamp is ca. 120 litres per hour;
- the family owns 9 heads of buffalos (kept in overnight stabling). Mean manure and biogas yield per buffalo per day is 9 kg and 270 liters, respectively;
- specific toilet water production per person per day is ca. 5 liters; expected biogas production is 40 liters per person per day;

TBP: Calculation of Biogas Demand

The biogas cooker will be used for ca. 5 hours per day (from 5 a.m. to 7 a.m. and 7 p.m. to 10 p.m.) using both flames and about 1 hour per day (4 p.m. to 5 p.m.) using only one flame; gas consumption is ca. 175 litres per flame per hour. Hence biogas demand (D_{C+T}) for cooking and making tea is:

$$D_{C+T} = 175 \cdot 2 \cdot (2 + 3) + 175 \approx 2{,}000\ l / d$$

A biogas lamp will be lit for 5 hours per day (from 5 a.m. to 7 a.m. and 7 p.m. to 10 p.m.); gas consumption is ca. 120 litres per hour. Biogas demand for lighting (D_L) is therefore:

$$D_L = 120 \cdot 5 = 600\ l / d$$

Total biogas demand (D_T) for cooker, making tea and lighting is:

$$D_T = 2{,}000 + 600 = 2{,}600\ l / d$$

TBP: Estimation of Biogas Yield

Anticipated biogas yield (Y_B) from the digestion of buffalo manure is about 270 liters per head per day (@ ca. 9 kg of dung per head and 60 days HRT). Hence, estimated biogas yield from all 9 buffaloes is:

$$Y_B = 270 \text{ g}9 \approx 2,400 \; l / d$$

Specific biogas production from the co-digestion of toilet water is about 40 liters per person per day. Estimated biogas yield (Y_S) from all 8 family members is:

$$Y_S = 40 \text{ g}8 \approx 300 \; l / d$$

Total biogas production (Y_T) from the anaerobic treatment of buffalo manure and toilet water is:

$$Y_T = 2,400 + 300 = 2,700 \; l / d$$

Anticipated biogas production (Y_T) matches gas demand (D_T), hence it is not necessary to either decrease energy demand or increase biogas yield.

TBP: Scaling of Gasholder

The required gasholder capacity, i.e. the gasholder volume (V_G), is an important planning parameter and depends on the relative rates of biogas generation and gas consumption. The gasholder must be made large enough to :

- cover the peak consumption rate (V_{G1}) and
- hold the gas produced during the longest zero-consumption period (V_{G2}),
- furthermore, the gasholder must be able to compensate for daily fluctuations in gas production. These fluctuations range from 75 % to 125 % of calculated gas production.

TBP: Scaling of Gasholder

Calculate the required gasholder capacity for a biogas plant to treat manure from 9 buffaloes and toilet water from a household with 8 persons.

assumption for sample design problem:

- the produced biogas will be used for cooking meals, making tea and lighting a biogas lamp;
- operating hours of the biogas cooker (2-flame cooker) are from 5 a.m. to 7 a.m. and 7 p.m. to 10 p.m. for cooking and from 4 p.m. to 5 p.m. for making tea;
- for cooking both flames will be used, while for making tea only one flame is used;
- gas consumption of one flame is ca. 175 litres per hour;
- lighting a single biogas lamp (from 5 a.m. to 7 a.m. and from 7 p.m. to 10 p.m.) consumes ca. 120 litres of biogas per hour;
- average biogas yield is about 2,700 liters per day;
- to simplify calculation uniform gas production and consumption is assumed;

TBP: Scaling of Gasholder

Daily gas yield is ca. 2,700 liter, therefore mean hourly biogas production (Y_M) is:

$$Y_M = \frac{2,700}{24} \approx 110\ l / h$$

Maximum gas consumption happens if the biogas is used for both, cooking (using both flames) and lighting at the same time. Hence maximum hourly biogas consumtion (D_M) is:

$$D_M = 175\ \text{g}2 + 120 = 470\ l / h$$

As biogas is also produced during consumption, only the difference between the maximum consumption and average production is relevant to the calculation of the necessary gas storage capacity (V_{G1}):

$$D_M - Y_M = 470 - 110 = 360\ l / h$$

TBP: Scaling of Gasholder

The longest period of maximum biogas consumption is 3 hours (from 7 p.m. to 10 p.m.). Hence the necessary gasholder volume (V_{G1}) during consumption is:

$$V_{G1} = 360 \cdot 3 = 1{,}080\ l$$

The longest interval between periods of consumption is from 7 a.m. to 4 p.m. (9 hours). The necessary gasholder volume (V_{G2}) is therefore:

$$V_{G2} = 110 \cdot 9 = 990\ l$$

The larger volume (V_{G1} or V_{G2}) determines the size of the gasholder. V_{G1} is the larger volume and must therefore be used as the basis. Allowing for the safety margin of 25%, the gasholder volume (V_G) is thus:

$$V_G = 1{,}080 \cdot 1.25 = 1{,}350\ l$$

TBP: Scaling of Gasholder

The size of the digester, i.e. the detention volume (V_D), is determined on the basis of

- the chosen detention time and
- the daily substrate input quantity [5].

Detention time (HRT) indicates the period spent by the feed material in the digester and, in turn, is determined by

- the chosen/given digesting temperature [5] or
- chosen by economic criteria and is appreciably shorter than the total time required for complete digestion of the feed material [6].

For a plant of simple design: **HRT ≥ 40 days**;
HRTs of 60-80 days (even 100 days or more) are no rarity when there is a shortage of substrate (extra-long HRTs can increase gas yield by up to 40% [4]).

TBP: Estimation of Feed Material Production and Scaling of Digester

Estimate the daily amount of feed material for a biogas plant to anaerobically treat manure of 9 heads of buffalo and toilet wasterwater produced by a household of 8 persons.

Assumtions for sample design problem:

- mean dung yield per buffalo is 9 kilogram per day (@ 300 – 450 kg live weight per buffalo and overnight stabling);
- buffalo manure is mixed with water in the proportions of 1:1;
- specific toilet wastewater production is 5 liter per person per day;
- desired hydraulic retention time (HRT) is 60 days;

type of substrate	substrate/water
fresh cattle manure	1/0.5 Ğ1/1
semi-dry cattle manure	1/1 Ğ1/2
pig dung	1/1 Ğ1/2
cattle and pig dung fro, a floating removal device	1/0
chicken manure	1/4 Ğ1/6
stable manure	1/2 Ğ1/4

source: ÖKOTOP in [4]

TBP: Estimation of Feed Material Production and Scaling of Digester

The amount of fermentation slurry (Q_B) prepared from 9 heads of buffaloes (@ a specific manure yield of 9 kg per buffalo per day and a substrate mixing ratio of 1:1) is:

$$Q_B = 9 \cdot 9 \cdot 2 \approx 160 \; l/d$$

Daily amount of toilet water (Q_S) produced by 8 persons (@ a specific toiletwater production of 5 liters per person per day) is:

$$Q_S = 8 \cdot 5 = 40 \; l/d$$

Total volume of feed material (Q_T) is thus:

$$Q_T = 160 + 40 = 200 \; l/d$$

Based upon a substrate input of ca. 200 liter per day and a chosen HRT of 60 days, the detention volume (V_D) is:

$$V_D = 200 \cdot 60 = 12{,}000 \; l$$

TBP: Scaling of Floating-drum Type Biogas Plant

For a given volume (V_D), the dimensionsion of a floating-drum type biogas plant (KVIC biogas plant) can be taken from standard designs.

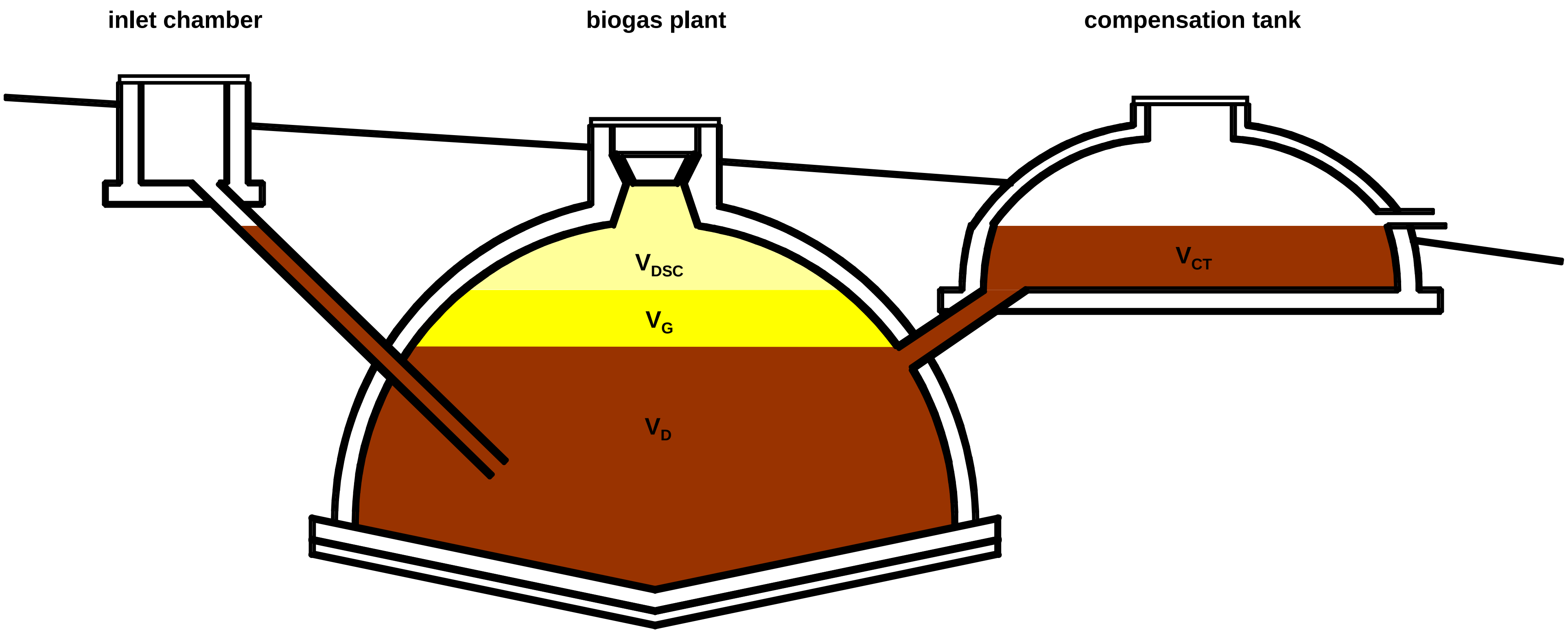
Chose appropriate dimensions of a floating-drum type biogas plant for given volume (V_D = ca. 12,000 liter) and gas storage volume (V_G = ca. 1,350 liter).

	digester			floating drum		
aprox. volume [m^3]	**inner dia. [m]**	**outer dia. [m]**	**height [m]**	**volume [m^3]**	**dia. [m]**	**height [m]**
1.8 / 2.2 / 2.5	1.20	1.66	1.64 / 1.95 / 2.27	0.5	1.05	0.60
2.6 / 3.6 / 4.6	1.35	1.81	1.87 / 2.57 / 3.27	1.2	1.25	1.00
4.0 / 5.5 / 7.5	1.60	2.06	2.02 / 2.77 / 3.77	1.7	1.50	1.00
5.7 / 7.8 / 10.8	1.80	2.26	2.27 / 3.07 / 4.27	2.1	1.65	1.00
8.6 / 11.6 / 16.2	2.20	2.66	2.27 / 3.07 / 4.27	3.1	2.00	1.00
10.9 / 15.6 / 21.5	2.40	2.86	2.42 / 3.47 / 4.77	4.9	2.25	1.25
14.3 / 20.6 / 28.3	2.75	3.21	2.42 / 3.47 / 4.77	6.6	2.60	1.25
29.4 / 38.3	3.20	3.90	3.66 / 4.77	8.8	3.00	1.25
37.2 / 53.6	3.60	4.40	3.66 / 5.27	11.3	3.40	1.25
41.5 / 65.4	3.80	4.60	3.66 / 5.77	12.7	3.60	1.25
59.5 / 93.8	4.55	5.45	3.66 / 5.77	19.0	4.40	1.25
76.2 / 120.1	5.15	6.05	3.66 / 5.77	23.0	4.85	1.25
101.7 / 160.4	5.95	6.85	3.66 / 5.77	32.4	5.75	1.25
140.8 / 222.0	7.00	7.90	3.66 / 5.77	45.3	6.80	1.25

TBP: Scaling of Fixed-dome Type Biogas Plant

While calculating the net volume (V_{BP}) of fixed-dome biogas plant, three distinct volumes viz.,

- the dead storage capacity (V_{DSC}),
- the volume for gas storage (V_G) and
- the volume for recommended hydraulic detention time (V_D) have to be considered.



TBP: Scaling of Fixed-dome Type Biogas Plant

Net volume (V_{BP}) of a fixed-dome biogas plant provides for detention volume (ca. 12,000 liter), gas storage volume (ca. 1,350 liter) and the dead storage capacity. For ease of calculation dead storage capacity is not considered, but it is assumed that the conically shaped bottom to the digester compensats for dead storage capacity:

$$V_{BP} = 12,000 + 1,3500 \approx 13,500\ l$$

The volume of a half round biogas plant is determined by the equation for calculation of the volume of a hemisphere (V_{HSP}):

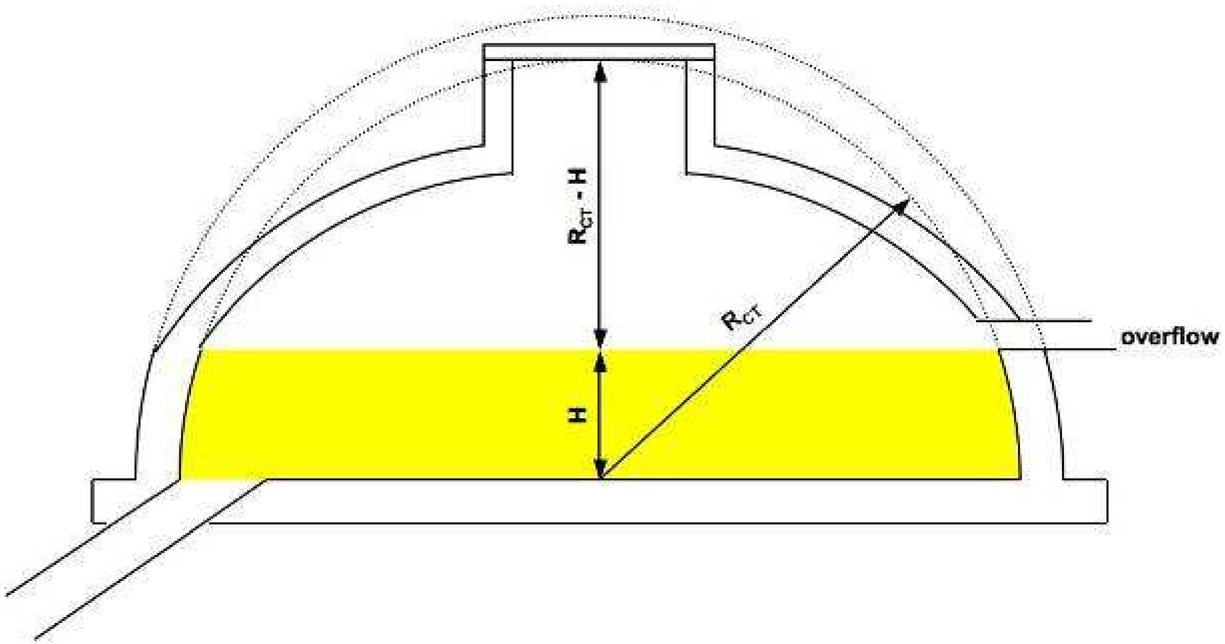
$$V_{HSP} = \frac{2 \cdot R^3 \cdot \pi}{3}$$

The equation of the volume of a hemisphere can be rearranged to calculate the halfmeter/radius (R_{BP}) of the biogas plant. Assume the net volume of the biogas plant (V_{BP}) is 13.5 m^3 (13,500 liter). Hence halfmeter R_{BP} is:

$$R_{BP} = \sqrt[3]{\frac{3 \cdot 13.5}{2 \cdot \pi}} \approx 1.86\ m$$

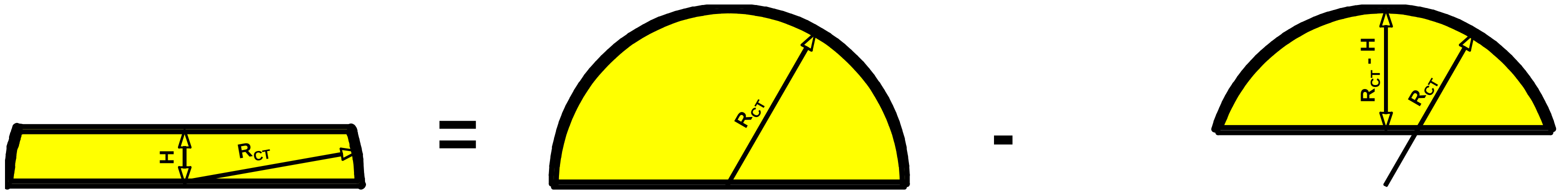
For construction of the dome, the radius RBP has to be increased by the thickness of the plaster (e.g. 0.02 meter). Hence, the actual radius of the brick dome is ca. 1.88 meter.

A common design for the compensation tank is to provide a hemisphere with the overflow at height H above the base (or “zero line”). Usually the radius R_{CT} of the compensation tank is reduced by 1.5 cm per course of bricks above the overflow level.



TBP: Scaling of Fixed-dome Type Biogas Plant

The net volume of the compensation tank (V_{CT}) is calculated by subtracting the volume of the free space above the overflow (R_{CT} – H) from the volume of the hemisphere:



$$V_{CT} = \frac{2}{3} \cdot R_{CT}^3 \cdot \pi - (R_{CT} - H)^2 \cdot \pi \cdot \left(R_{CT} - \frac{R_{CT} - H}{3} \right)$$

The net volume of the compensation tank (V_{CT}) equals the gas storage capacity (V_G).

$$V_{CT} = V_G = \frac{2 \cdot R_{CT}{}^3 \cdot \pi}{3} - \left[(R_{CT} - H)^2 \cdot \pi \cdot \left(R_{CT} - \frac{R_{CT} - H}{3} \right) \right]$$

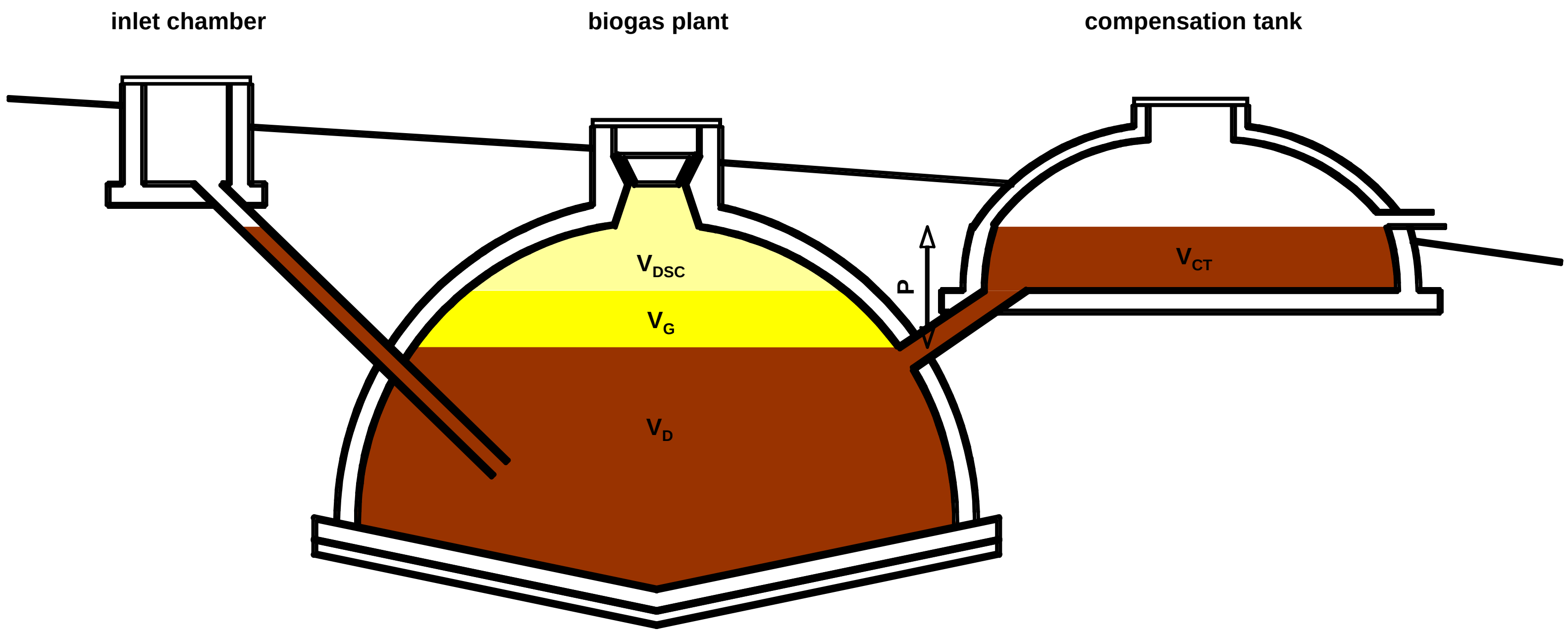
TBP: Scaling of Fixed-dome Type Biogas Plant

By trial and error (for H = 0.45 m and V_G = 1.35 m³), R_{CT} is 1.00 meter.

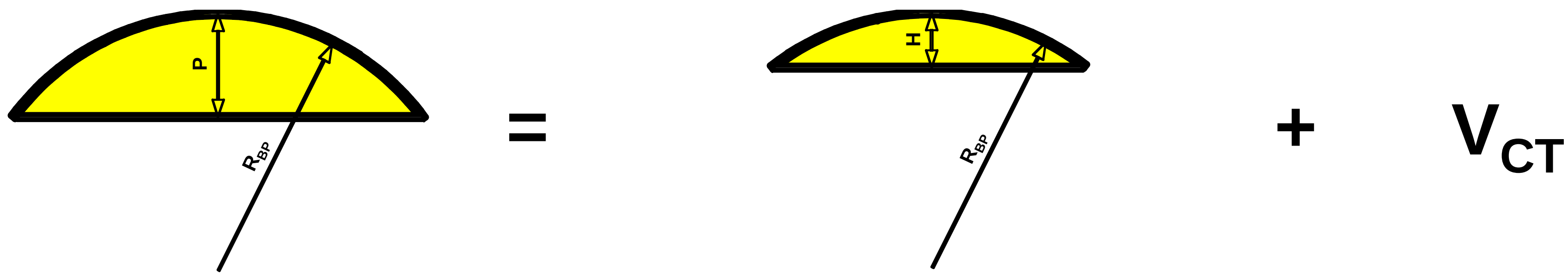
$$1.5 = \frac{2 \cdot (1.10 - 0.02)^3 \cdot \pi}{3} - \left[(1.10 - 0.45)^2 \cdot \pi \cdot \left(1.10 - \frac{1.10 - 0.45}{3} \right) \right]$$

For construction, the radius R_{CT} has to be increased by the thickness of the plaster (e.g. 0.02 meter). Hence, the actual radius is ca. 1.02 meter.

Maximum gas pressure occurs at a level P below the overflow level of the compensation tank, which is also the lowest slurry level.



For calculation of level P the equation of the spherical calotte volume is applied to the total volume of the free space above maximum slurry level and the net volume of the compensation tank (V_{CT}).



$$P^2 \, g \pi \, g \left(R_{BP} - \frac{R_{BP} - P}{3} \right) = H^2 \, g \pi \, g \left(R_{BP} - \frac{R_{BP} - H}{3} \right) + V_{CT}$$

By trial and error (for R_{BP} = 1.86 m; H = 0.45 m and V_{CT} = 1.35 m3), P is 0.69 meter.

$$0.69^2 \, g \pi \, g \left(1.86 - \frac{0.69}{3} \right) \approx 0.45^2 \, g \pi \, g \left(1.86 - \frac{0.45}{3} \right) + 1.35$$

TBP: Construction of Fixed-dome Type Biogas Plant

(photo: K.P. Pravinjith)

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TBP: Construction of Fixed-dome Type Biogas Plant

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If the slurry is not used directly used, it may be collected and treated in sludge drying beds. The simplest way of providing for sludge drying beds is to partially dig up the ground and pile up the excavated soil to earthen bunds. These perimeter bunds will also help in keeping surface run-off water from entering the sludge drying beds

(photo: M. Wafler)

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