Biogas Settlers

Dorothee Spuhler, seecon gmbh

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Depending on the initial situations and respective local circumstances, there is no guarantee that single measures described in the toolbox will make the local water and sanitation system more sustainable. The main aim of the SSWM Toolbox is to be a reference tool to provide ideas for improving the local water and sanitation situation in a sustainable manner. Results depend largely on the respective situation and the implementation and combination of the measures described. An in-depth analysis of respective advantages and disadvantages and the suitability of the measure is necessary in every single case. We do not assume any responsibility for and make no warranty with respect to the results that may be obtained from the use of the information provided.

Contents

1. Concept

Background

Biogas settlers are used **for the pre-settling of biodegradable wastewater.**

They are similar to septic tanks with the difference that **biogas** is collected.

They are most suited for the treatment of **blackwater, brownwater, excreta, faecal sludge, faeces, biodegradable wastewater from the industry** (e.g. slaughterhouses, diary industry etc.). Greywater can also be added. The addition of solids with high organic content (e.g. **green wastes**) enhances biogas production.

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1. Concept

Background

Biogas settlers have been introduced by various organisations as cost-effective pre-treatment or treatment step for domestic wastewater or blackwater in countries where climatic conditions are favorable for anaerobic digestion and biogas production (e.g. Jaimaca, South Africa, China and India). (WAFLER 2008)

They are the most often used:

- as **pre-treatment** in decentralized wastewater treatment plants **(DEWATS)**
- for **on-sanitation** with secondary treatment of effluents in compost/drying beds (solids) and drainages/subsurface irrigation (liquid). (GTZ 2009)

1. Concept

What are Biogas Settlers? (1/2)

Biogas settlers are **rectangular or circular airtight** tank into which wastewater flows.

Solids settle to the bottom and undergo anaerobic digestion, the supernatant continues through the reactor to the outlet. A **baffle** increases solid retention (i.e. high-rate process).

Settable solids and thus a large fraction of the pollution of the wastewaters is removed.

Anaerobic microorganism transforms the organic fraction of the remaining slurry into biogas (**Anaerobic digestion**).

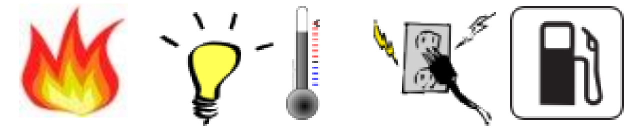
Biogas can be recovered as green energy for heating , lightening , etc.

The effluent in which contains still some nutrients and organic matterfrom the reactor can be used for **fertigation**  **or aquaculture**  . Depending on the inflow pollution, further treatment steps may be necessary.

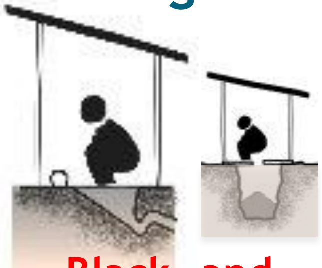
The digested is also rich in nutrients and can be used as a **soil amendment**, optionally after post-composting or drying bed (humification).

1. Concept

What are Biogas Settlers? (2/2)



Coocking, Lightning, Heating, electricity, Fuel, etc.

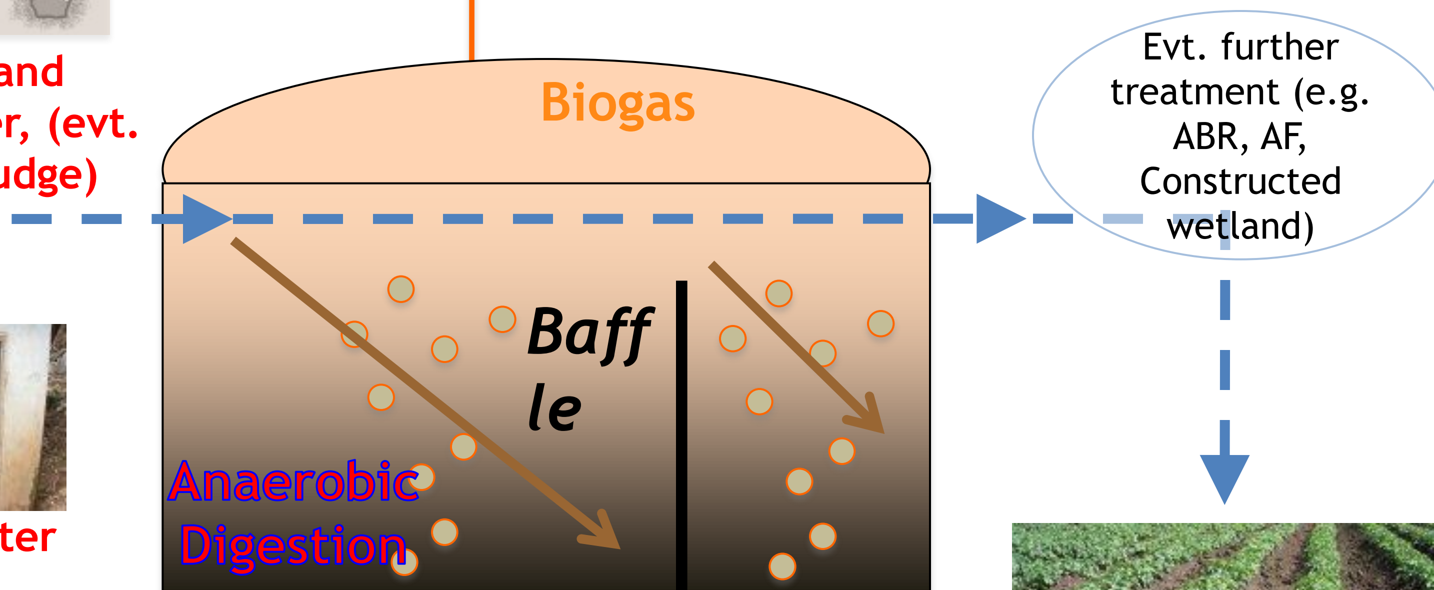


Black- and Brownwater, (evt. faecal sludge)

Green waste (enhances biogas production)

Greywater

Biodegradable WW from industry (slaugtherhouse)



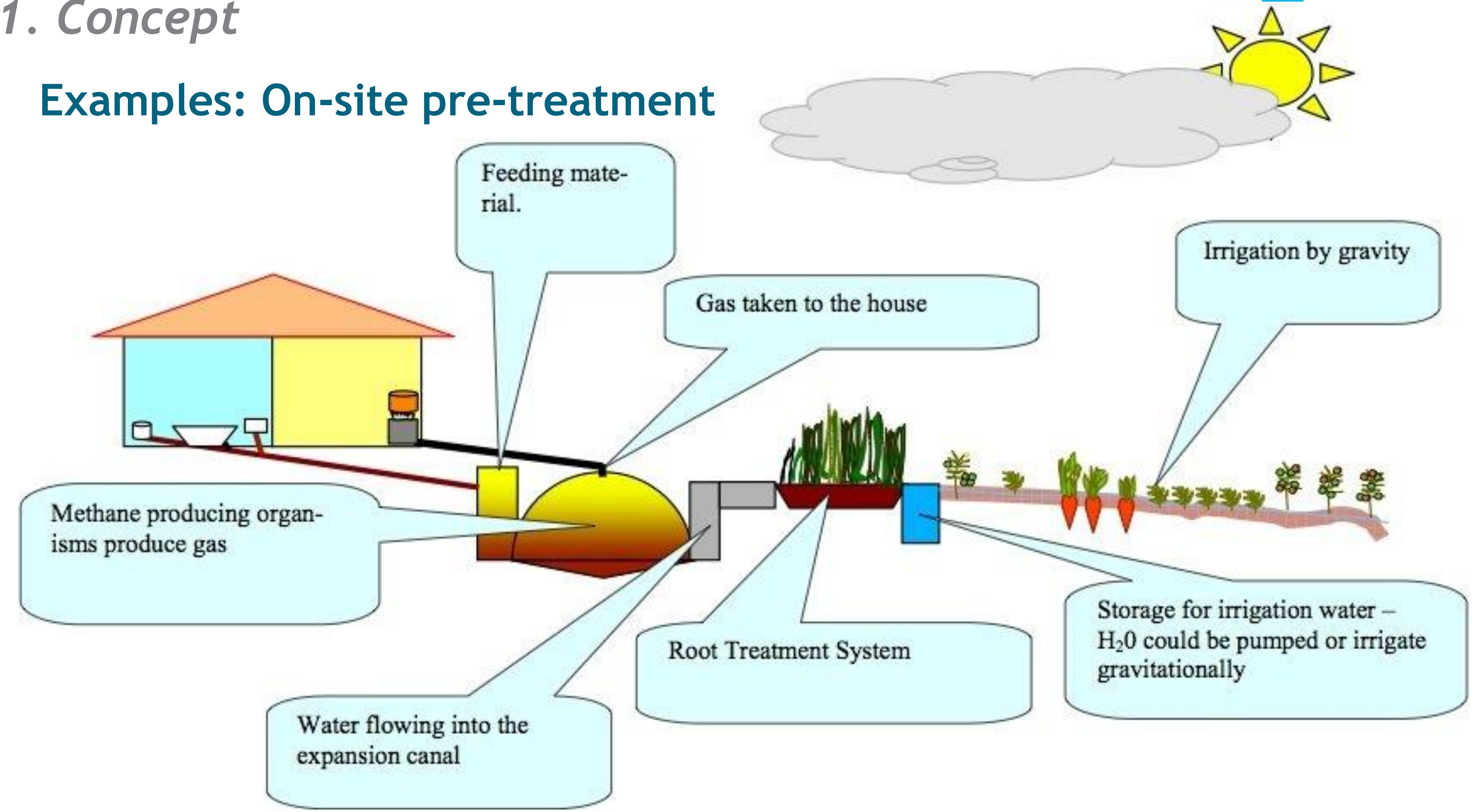
Fertiliser

Fertigation

Source: D. SPUHLER (2010); adapted from BORDA (2008); http://www.rosier-be.com/files/pommes-de-terre-01.jpg; //www.fao.org/docrep/S1250E/S1250EEN.GIF; www.clickr.com; http://www.mytinyplot.co.uk/advice/the-art-of-composting/ [Accessed: 04.06.2010]

1. Concept

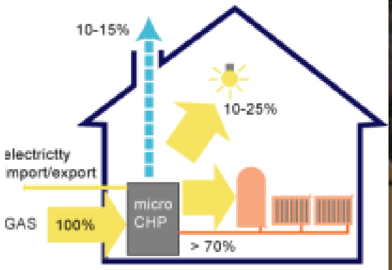
Examples: On-site pre-treatment



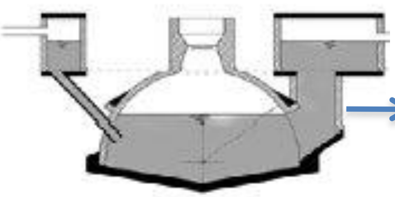
Sketch of biogas reactor replacing a septic tank as part of a DEWATS system. Wastewater, kitchen and garden waste enter the digester and are broken down to biogas and fertile water. The advantage of such systems is that they need to be less often emptied than septic tank and that both, water and the biogas can be reused. Source: LEBOFA (n.y.)

1. Concept

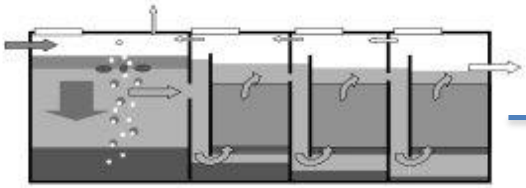
Examples: DEWATS



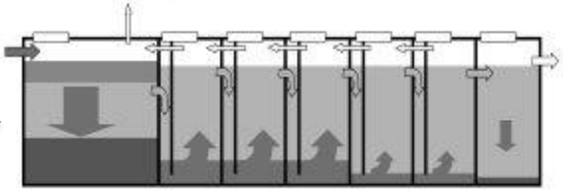
Collection and reuse of biogas



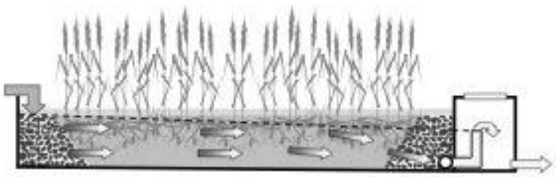
Bigoas settler



Anaerobic baffled reactor (ABR)



Anaerobic filter (AF)



Planted gravel filter

Reuse of fertilising sludge and water for irrigation

Source: D. SPUHLER (2010), adapted from: http://www.terranet.or.id/mitra/dewats/photo/masukan1256.jpg; http://www.borda-sea.org/modules/cjaycontent/index.php?id=6; http://whrefresh.com/wp-content/uploads/2010/01/potato_field.jpg; BUNNY & BESSELINK (n.y.) and http://www.greenspec.co.uk/images/energy/CHP/chp2.gif [Accessed: 30.05.2010]

1. Concept

Reuse of biogas

Biogas lamp in Chang Mai

M. WAFLER

M. WAFLER

http://eng.esperrance.org/index.php/post/2009/11/28/Sulabh-Sanitation-Movement [Accessed: 08.06.2010]

Fuelwood or biogas stove

http://eng.esperrance.org/index.php/post/2009/11/28/Sulabh-Sanitation-Movement [Accessed: 08.06.2010]

Street lightening

http://eng.esperrance.org/index.php/post/2009/11/28/Sulabh-Sanitation-Movement [Accessed: 08.06.2010]

Soure: HEEB (2009)

Heating

http://eng.esperrance.org/index.php/post/2009/11/28/Sulabh-Sanitation-Movement [Accessed: 08.06.2010]

1. Concept

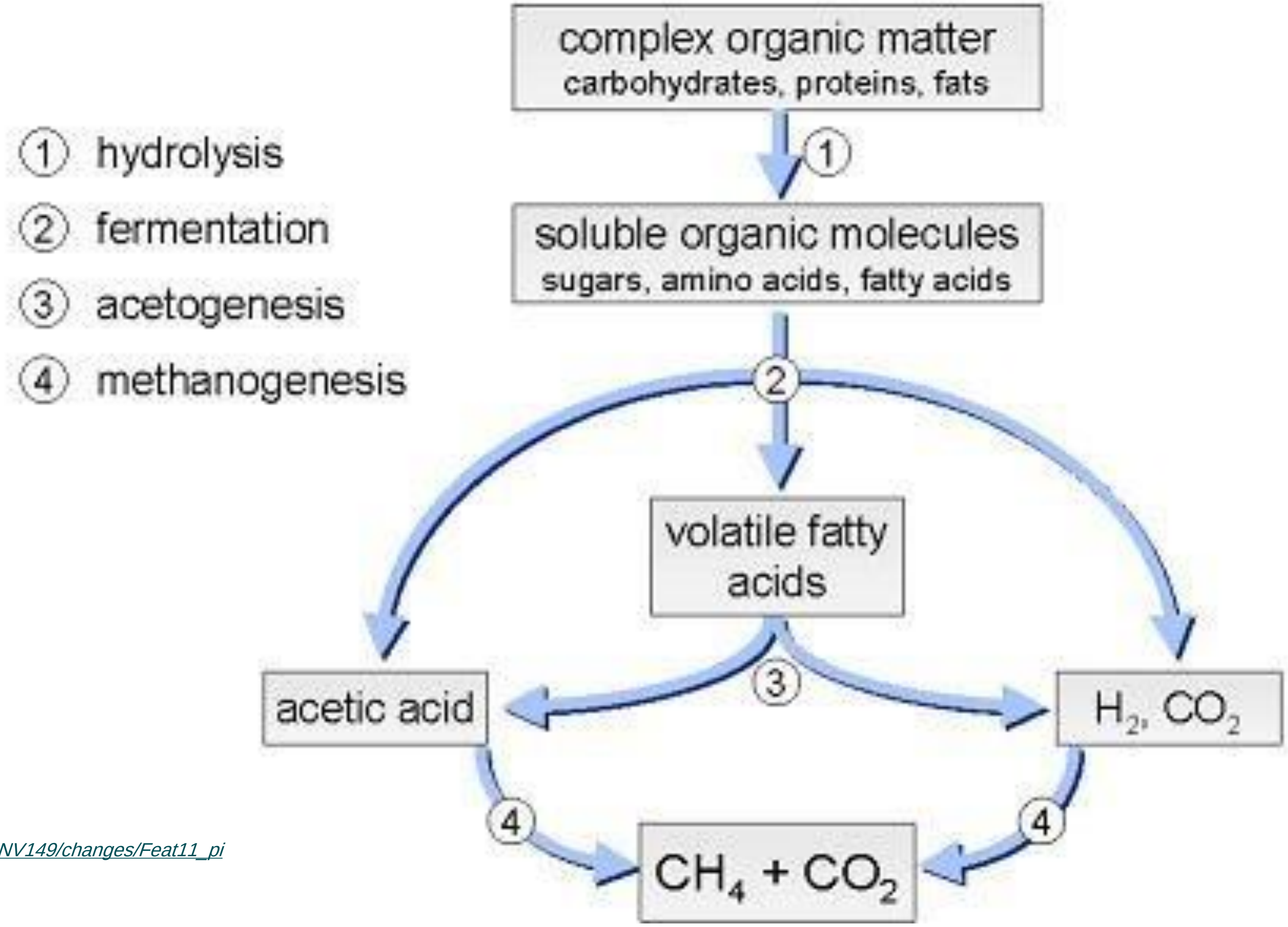
What is Anaerobic Digeastion ? (1/2)

Degradation of organic material by bacteria. In the absence of air (*anaerobic)*. Four stages:

- *Hydrolisis*
  - Cleavage of a chemical compound through the reaction with water.
  - Insoluble complex molecules are bracken down to short sugars, fatty acids and amino acids.
- *Fermentation (Acidogenesis)*
  - Products from hydrolysis are transformed into organic acids, alcohols, carbon dioxide (CO_2), hydrogen (H) and ammonia (NH_3).
- *Acetogenesis*
  - Organic acids and alcohols are converted into hydrogen (H_2), carbon dioxide (CO_2) and acetic acid (CH_3COOH). Therefore, oxygen is consumed and anaerobic conditions are created
- *Methanogenesis*
  - Methanogenic bacteria (methanogenesis), transform the acetic acid, carbon dioxide and hydrogen into biogas.

1. Concept

What is Anaerobic Digestion ? (2/2)



Source: http://water.me.vccs.edu/courses/ENV149/changes/Feat11_picII-1.jpg [Accessed: 02.06.2010]

1. Concept

What is Biogas ?

Biogas is a mixture of **methane** and **carbon dioxide** with similar properties to the ones of natural gas.

Biogas is the common name for the mixture of gas es released from anaerobic digestion. Typically biogas is composed of:

Methane (CH_4)	50 to 75 %
Carbon Dioxide (CO_2)	25 to 50 %
Hydrogen (H)	5 to 10 %
Nitrogen (N_2)	1 to 2 %
Hydrogen sulphide (H_2S)	Traces

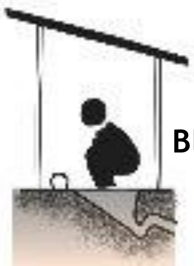
Sources: YADAV & HESSE (1981); FAO (1996); PIPOLI (2005); GTZ (2009

Source: MUENCH (2008)

Methane is the valuable part of the biogas. Biogas that contains about 60 to 70 % of CH_4 has a calorific value of about **6 kWh/m3** what corresponds to about half an L of diesel oil. (ISAT/GTZ 1999, Vol. I)

2. How can Biogas settlers can optimize SSWM

Biogas plants can contribute to sustainable sanitation; reducing CH_4 and CO_2 emissions

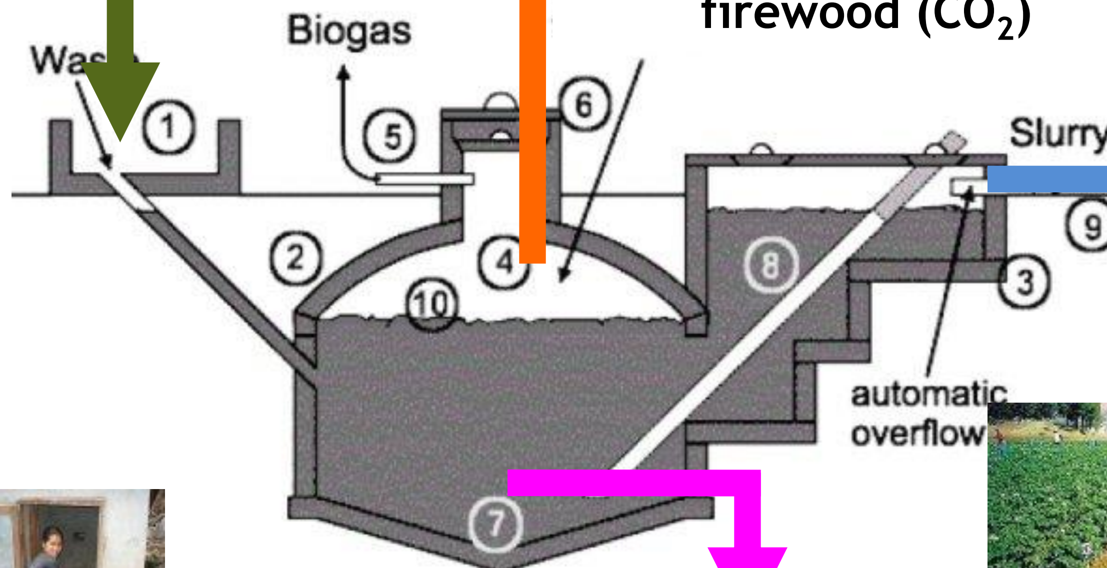


Black- and Brown- water

Green waste (enhances biogas production)

Greywater

Biodegradable WW from industry



Biogas substitutes conventional energy sources, reducing reliance on fossil fuel and firewood (CO_2)

Nutrient-rich effluent can be used for fertigation or aquaculture

Digested sludge can be used as soil amendment

Source: D. SPUHLER (2010), adapted from BPO (2006); BUNNY & BESSELINK (n.y.); *BORDA (2008); BALASUBRAMANIYAM (2008) and http://whrefresh.com/wp-content/uploads/2010/01/potato_field.jpg; http://static.howstuffworks.com/gif/aquaculture-25.jpg; http://www.iaea.org/NewsCenter/Features/IaeaWssd/Wssd_gallery/images/08_fertigation.jpg [Accessed: 08.06.2010]*
s

3. Design Principals

Basic Process Parameters

Biogas settlers are designed to: (WAFLER 2008)

- Facilitate **solid-liquid separation**
- Providing **a high sludge retention time**, that facilitates almost complete degradation of organics
- Enable **production and collection of biogas** for direct use (e.g. lighting, cooking, etc.).

Optimal conditions required that bacteria feel wealthy:

- Temperature (effectiveness of anaerobic digestion)
- Chemical oxygen demand (COD) and Biological oxygen demand (BOD) determine **potential methane** production potential
- The strict anaerobic conditions during methanogenesis define the proportional content CH_4 to CO_2 in the biogas

3. Design Principals

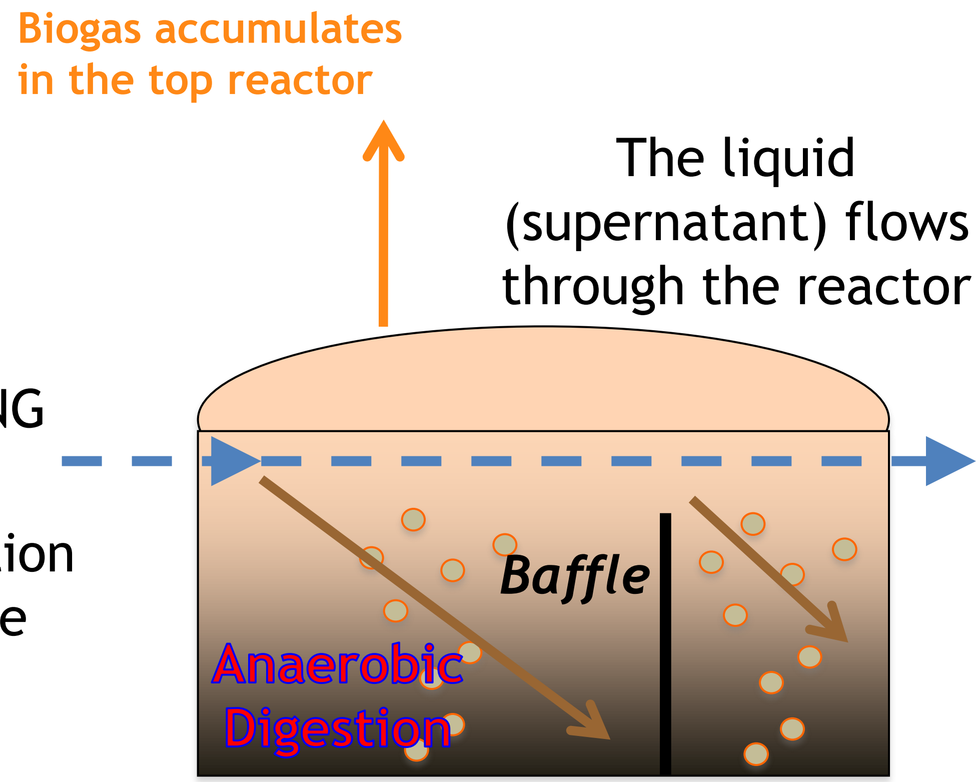
Basic Process Parameters

A baffle enhances solid retention:

- Hydraulic retention time (HRT): SHORT (e.g. some days)
- Sludge retention time (SRT): LONG (e.g. several years)

Depending upon the hydraulic retention time (HRT) a biogas settler may be considered a pre-treatment or treatment unit (WAFLER 2008):

- Pre-treatment in DEWATS: 24 hours
- On-site Biogas Sanitation combined with composting/infiltration: 8 to 10 days and ca. 15 days with and without urine-separation, respectively



The sludge is retained in the settler for anaerobic digestion and emptying once every few years

4. Treatment Efficiency

Retention times (HRT and SRT)

The retention times defines

- State of methanogenesis
- The removal efficiency of organics and pathogens

Digestion type	Temperature (°C)	HRT (days) (WAFLER 2008)	HRT (days) without post-treatment (WAFLER 2008)	SRT (days) (MANG 2005)
Psychrophilic	10 to 20	8 to 15	1	100
Mesophilic	20 to 35	8 to 15	1	50 (>30°C)
Thermophilic	50 to 60	8 to 15	1	10

4. Treatment Efficiency

Pollution removal

Efficiencies vary greatly depending on operation & maintenance, and climatic conditions.

If corrected maintained and operated, digested sludge from biogas settlers are generally pathogen free.

Some guideline values for the removal of pollution: (GTZ 2009)

- Total solids (TS): 65%
- Biological oxygen demand (BOD): 40%
- E. Coli: 1-log

4. Treatment Efficiency

Health aspects

In reality, fresh sludge is always mixed with new sludge and it is very difficult to control retention times. Therefore, caution needs to be taken when emptying and handling sludge manually.

Bacteria	Thermophilic fermentation		Mesophilic fermentation		Psycrophilic fermentation	
	53-55 °C		35-37 °C		8-25 °C	
	Fatality		Fatality		Fatality	
	Days	Rate (%)	Days	Rate (%)	Days	Rate (%)
Salmonella	1-2	100.0	7	100.0	44	100.0
Shigella	1	100.0	5	100.0	30	100.0
Poliviruses			9	100.0		
Schistosoma ova	hours	100.0	7	100.0	7-22	100.0
Hookworm ova	1	100.0	10	100.0	30	90.0
Ascaris ova	2	100.0	36	98.8	100	53.0
Colititre	2	10^{-1} - 10^{-2}	21	10^{-4}	40-60	10^{-5} -10^{-4}

Source: WERNER et al. 1998

4. Treatment Efficiency

Nutrients

Anaerobic digestion only removes organics, and the main mineral material and almost all nutrients remain in the bottom sludge.

- Phosphorus: almost 100 %
- Nitrogen (ammonium): and 50 to 70 % (JOENSSEN et al. 2004)

Further treatments to increase the safety (pathogen removal)

- Composting
- Drying beds / Humification

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5. Operation and Maintenance (O&M)

Start-up

Seeding with living sludge form other anaerobic reactor required. The establishment of the complex biological conditions for anaerobic digestion and biogas production may takes some weeks to months.

Operation

As long as the plant is well maintained and functional by people that understand the system, no professional operator is required.

Accumulated slurry in the bottom of the reactor needs to be de-sludged every 2 to 5 years, depending on the type of reactor. (UNEP 2002, MANG 2005)

Regular maintenance includes

- Checking for foaming or scum formation
- Checking for air/gas- tightness

6. Applicability

Can be installed in any type of climate although the efficiency will be affected in cold climates. At low average temperature biogas production is not interesting form an economical point of view.

Municipal wastewater (domestic and industrial) as long as they are biodegradable.

Demand for biogas and fertilizer should be there.

Biogas settlers are often used either as

- Pre-treatment in DEWATS (followed by and ABR, AF and a constructed wetland)
- Pre-treatment (followed by constructed wetland, drainage or subsurface irrigation) or treatment for on-site sanitation (drying/composting of sludge).

Should not be constructed in areas with high groundwater tables or areas prone to frequent flooding.

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6. Applicability

Design and construction of biogas setters demand exact knowledge of the influent characteristics

- Climatic conditions (daily average temperatures, annual minimal temperatures etc.)
- Daily wastewater production
- Hourly peak flow
- BOD/COD
- Etc.

Therefore carful preliminary investigations and expert planning and design are required.

7. Pros' and Cons'

Advantages:

- Generation of biogas and fertilizer
- Avoids greenhouse gas emissions
- No external energy source required
- Combined treatment of different organic waste and wastewaters
- Low operation and maintenance
- Underground construction possible (low space requirement and high acceptance)
- Low risk of odours
- Long life span if maintained and operated correctly
- De-sludging is required only every few years

Disadvantages:

- Experts are required for the design of the reactor and skilled labour is required for the construction of a gas-tight tank
- Slurry may has to be further treated before reuse (i.e. post-composting)
- Gas production at low temperatures is not interesting from an economic point of view
- TS and BOD content as well as C/N ration need to be appropriated

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