APPENDIX

A LABORATORY

A1 Detailed methodologies

Total Solids Dried at 103-105°C

(Standard Methods, p.2-72)

- Heat clean porcelain crucibles (ca.35ml content, 6cm diam.) to 103-105°C for 1h. Weigh immediately before use.
- Transfer a measured volume of well-mixed sample to preweighed dish and weigh the filled crucible. Dry sample for at least 24h in an oven at 103-105°C. Cool dish to room temperature in desiccator and weigh.

Calculation: mg total solids/L: ((A-B)*1000)/sample volume [ml]
A=weight of dried residue + dish [mg], B=weight of dish [mg]

Volatile Solids Ignited at 550°C

(Standard Methods, p.2-77)

- Ignite clean crucible at 550 +/- 50°C for 1h in a muffle furnace.
- Ignite residue produced by TS-method to constant weight in a muffle furnace at a temperature of 550°C. Have furnace up to temperature before inserting sample. Weigh after crucible has cooled down to room temperature in desiccator.

Calculation: mg Volatile Solids/L= ((A-B)*1000)/sample volume [ml]
A=weight of residue + dish before ignition [mg], B=weight of residue + dish after ignition [mg]

Chemical Oxygen Demand (COD)

Closed Reflux Method (Standard Methods, p.5-15)
Diluton of sample: 1:100 (influent), 1:50 (effluent)

- Preferably use borosilicate culture tubes 16- * 100ml with srew caps
- Reagents: Standard potassium dichromate digestion solution, 0.0167M: Add to about 500ml distilled water 4.913g $K_2Cr_2O_7$, primary standard grade, previously dried at 103°C for 2h, 167 conc H_2SO_4 and 33.3g $HgSO_4$. Dissolve, cool to room temperature and dilute to 1000ml.
- Sulfuric acid reagent: Add Ag_2SO_4, reagent or technical grade, crystals or powder, to conc H_2SO_4, at the rate of 5.5g Ag_2SO_4/kg H_2SO_4. Let stand 1 to 2d to dissolve Ag_2SO_4.
- Add 1.5ml potassium dichromate digestion solution into a 10ml tube.
- Add 3.5ml sulphuric acid reagent into the tube
- Add 2.5ml of sample into the tube; also add 2.5ml of deionized water to two tubes which can be used as blank.
- Close tube tightly and shake well
- Place tubes in preheated block digester reflux for 2h at 150°C.
- Cool down to room temperature
- Transfer the digested sample to 10ml tubes.
- Analyse photometrically, using the blank to zero the Spectrophotometer (Program 440).

Total Phosphorus

Acid Persulfate Digestion Method (Hach, p.871)

- Homogenize the sample for 30seconds in a blender
- Use a graduated cylinder to measure 25ml of diluted sample (1:200). Pour the sample into a 125ml Erlenmeyer flask.
- Add the contents of one Potassium Persulfate Powder Pillow. Swirl to mix.
- Use a 1ml-calibrated dropper to add 2.0ml of 5.25N Sulfuric Acid Solution to the flask.
- Place the flask on a hot plate. Boil gently for 30min. Do not boil dry. Concentrate the sample to less than 20ml for best recovery. After concentration, maintain the volume near 20ml by adding small amounts of deionized water. Do not exceed 20ml.
- Cool the sample to room temperature.
- Use a 1ml calibrated dropper to add 2.0ml of 5.0N Sodium Hydroxide Solution to the flask. Swirl to mix.

- Pour the sample into a 25-ml graduated cylinder. Adjust the volume to 25ml with deionized water rinsings from the flask.
- Proceed with a reactive phosphorus test of the expected total phosphorus concentration range. Extend the color development time to 10min for the Ascorbic Acid method.

Reactive Phosphorus (Orthosphosphate)

PhosVer3 Method (Hach, p.857)

- Add 25ml of diluted (1:100) and filtered (Schleicher&Schuell, 595½ Folded Filters Ø185mm) sample into a 25ml vial and use it as blank to zero the Spectrophotometer (Program 490).
- Using a funnel, add the contents of one PhosVer3 Phosphate Powder Pillow to the sample in the vial.
- Cap the vial tightly and shake for 10-15 seconds. The powder will not dissolve completely.
- Touch the timer icon. A two-minute reaction period will begin. Read samples between two and eight minutes after adding the PhosVer3 reagent.
- Wipe the outside of the vial with a damp towel, followed by a dry one, to remove fingerprints or other marks.
- When the timer beeps, place the vial into the cell holder. Results will appear in mg/L PO_4^{3-}.

Ammonium

Direct Nesslerization Method (Standard Methods, p.4-117)

- Add 10ml of diluted (1:25) and membrane-filtered sample into a 10ml vial and use it as blank to zero the Spectrophotometer (Program 380)
- Add 7drops of Nessler-reagent to the vial.
- Leave a reaction time of 1min
- Place the vial into the cell holder. Result will appear in mg/L NH3-N

Nessler reagent:
Dissolve 100g HgI and 70g KI in a small quantity of water and add this mixture slowly, with stirring, to a cool solution of 160g NaOH dissolved in 500ml water. Dilute to 1l.

Total Kjeldahl Nitrogen (TKN)
Analytically, organic nitrogen and ammonia can be determined together and are referred to as "kjeldahl nitrogen", a term that reflects the technique used in their determination.

Macro-Kjeldahl Method (Standard Methods)

- Homogenize the sample for 30seconds in a blender
- Digestion: Carefully add 10mL digestion reagent to kjeldahl flask containing 25ml of sample. Add 5 glass beads (3-4mm size) to prevent bumping during digestion
- Set each heating unit on the macro-kjeldahl digestion apparatus to its medium setting and heat flasks under a hood to remove fumes of SO_3. Continue to boil briskly until solution becomes pale green and copious fumes are observed. Turn each heating unit up to its maximum setting and digest for an additional 30min. Then stop and let it cool.
- Add 10ml hydroxide-thiosulfate reagent and turn on stream.
- Distillation: Control rate of steam generation to boil contents in distillation unit so that neither escape of steam from tip of condenser nor bubbling of contents in receiving flask occur. Distill and collect 200ml distillate below surface of 50ml boric acid solution contained in a 250ml Erlenmeyer conical flask.
- Titriation. Add 3 drops of mixed indicator to the distillate (green color) and titrate against 0.02N H2SO4 solution to pink color end point.
- Carry a reagent blank through all steps of procedure and apply necessary correction to results.
  - Calculation **TKN (mg/l) = (A – B) * 280/ml sample**

  Where A = ml of titrant used in the sample
  B = ml of titrant used in the blank
  (and for 0.02N of H2SO4, 1ml = 280 µg N)

- Digestion reagent:
Dissolve 134g K_2SO_4 in 650ml water and 200ml concentrated H_2SO_4. Add, with stirring, 25ml mercuric sulphate solution. Dilute the combined solution to 1l with water. Keep at temperature close to 20°C to prevent crystallization.
- Mercuric sulphate solution:
Dissolve 8g red mercuric oxide, HgO, in 100ml H_2SO_4 (6N)
Sodium hydroxide-sodium thiosulfate reagent:
Dissolve 500g NaOH and 25g $Na_2S_20_3 * 5H_2O$ in water and dilute to 1l.

Procedure of A/TIC measurement according to Nordmann (Genesys Manual)

- A substrate sample is taken out of the well stirred digester.
- The sample is let through a kitchen sieve to separate the liquid phase from the solid particles, which are not used.
- 50ml of the sample are mixed with 50ml of distilled water.
- The pH of the mixed sample is measured with a pH-Meter (previously calibrated) and recorded.
- 0.1N sulphuric acid is slowly added until pH 5.0 is reached. The added volume of the titrant is recorded (= TIC).
- More acid is slowly added until pH 4.4 is reached. The added volume is again recorded (= VFA or A).
- A constant mixing of sample and added titrant is required right from the start.

Calculation scheme according to Nordmann (Genesys manual)

$$\frac{VFA = ((SV * B * 1.66 / 2.5) - 0.15) * 500}{TIC = SV * A * 250 / 2.5}$$

VFA = Volatile fatty acid [mg/l]
SV = Sample Volume [ml]
B = Consumption of sulphuric acid (H_2SO_4, 0.1N) to titrate sample from pH 5.0 to pH 4.4 [ml]

TIC = Total anorganic carbon [mg/l]
A = Consumption of sulphuric acid (H_2SO_4, 0.1N) to titrate sample from initial pH to pH 5.0 [ml]

The factor 1.66 is due to the originally used substrate quanitity (20ml) and the molecular mass of the sulphuric acid (0.05 molar, 0.1N). Factor 0.15 corrects the CO_2 which is still in the sample. 500 and 250 are multiplication factors of the empirical formula. The division through 2.5 is added because 50ml are used as a sample volume and not 20ml as originally done.

A2 TITRATION METHODOLOGY ACCORDING TO KAPP FOR MONITORING OF ANAEROBIC DIGESTION: VFA, alkalinity and A/TIC-ratio

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1. Introduction

An increase in volatile fatty acids (VFA) concentration (or the proportional decrease in carbonate alkalinity concentration) is the first practical measurable indication that an anaerobic treatment system is in a state of stress. If the system is not rectified at this early stage, failure is likely. Current methods for VFA measurement include distillation, colorimetry, gas chromatography and various titration techniques. In terms of simplicity, speed and cost-effectiveness it is generally accepted that titration methods are superior for the purpose of on-site routine monitoring and control, particularly in developing countries (Lahav & Morgan, 2004).

2. Anaerobic digestion process

Anaerobic digestion essentially occurs in two steps. In the first, organic matter is converted by hydrolytic and acidogenic bacteria to intermediates such as VFA (mainly acetic acid), CO_2 and H_2. In the second step, these intermediates are converted to methane by methanogenic bacteria. A major danger for overall anaerobic conversions is presented when the microorganism population is not balanced. Disturbances like abrupt temperature change, accumulation of toxic substances, excess of organic biodegradable feed etc. can result in a digester overload. These disturbances mainly affect methanogenic bacteria, whereas acidogenic bacteria are much more tolerant, also in terms of the acceptable pH-range. They continue to produce acids, which in turn inhibit the methane formers, which have a much slower growth rate. This imbalance, if not corrected in time, can finally result in a digester failure (Mata-Alvarez, 2003). It is worth noting that the pH-value of the digester indicates instability of the anaerobic process with quite a delay, since the pH only changes when the substrate-specific buffer capacity has been consumed (Eder & Schulz, 2006). Adequate control of alkalinity and VFA concentration are therefore more suitable to monitor the stability of the anaerobic digestion process.

3. Titration procedure for measurements of VFA and alkalinity according to Kapp

The method according to Kapp (1984), based on a principle suggested by McGhee (1968), was originally developed for the control of mesophilic sludge digesters. The basic idea is that the acid required to titrate a sample from pH 5.0 to pH 4.0 can be considered proportional to the content of VFA present in the sample. This applies because between pH 5 and 4 there is usually no weak acid/base subsystem present that strongly effects acid consumption apart from the acetate acid/base subsystem. Moreover, the pK_a (dissociation constant) values of acetic acid, propionic acid, butyric acid and valeric acid are all close to 4.75. Thus they show very similar buffering characteristics and can be lumped together as one parameter.

The only additional buffer considered in the VFA-procedure of Kapp is the carbonate subsystem of HCO_3^-/CO_2 which has a pK_a of approximately 6.3. Other buffer systems are assumed to be negligible (Buchauer, 1998).

The recorded results of the Kapp titration procedure are evaluated by an iteration scheme which is based on a combined empirical theoretical approach.

Analysis description of 4-point-titration according to Kapp (Buchauer, 1998)

- Before analysis, the sample needs to be filtered through a 0.45µm membrane filter.
- Filtered sample (20-50ml) is put into a titration vessel, the size of which is determined by the basic requirement to guarantee that the tip of the pH electrode is always below the liquid surface.
- Initial pH is recorded
- The sample is titrated slowly with 0.1N sulphuric acid until pH 5.0 is reached. The added volume A1 [ml] of the titrant is recorded.
- More acid is slowly added until pH 4.3 is reached. The volume A2 [ml] of the added titrant is again recorded.
- The latter step is repeated until pH 4.0 is reached, and the volume A3 [ml] of added titrant recorded once more.
- A constant mixing of sample and added titrant is required right from the start to minimise exchange with the atmosphere during titration.

Calculation scheme according to Kapp

$$Alk = A * N * 1000 / SV \quad (1)$$

Alk = Alkalinity [mmol/l], also referred to as TIC (Total Inorganic Carbon)
A = Consumption of sulphuric acid (H_2SO_4, 0.1N) to titrate sample from initial pH to pH 4.3 [ml]. A = A1 + A2 [ml]
N = Normality [mmol/l]
SV = Initial sample volume [ml]

$$VFA = 131'340 * N * B / SV - 3.08 * Alk - 10.9 \quad (2)$$

VFA = Volatile fatty acids [mg/l acetic acid equivalents], in A/TIC also referred to as A (see 4.A/TIC)
N = Normality [mmol/l]
B = Consumption of sulphuric acid (H_2SO_4, 0.1N) to titrate sample from pH 5.0 to pH 4.0 [ml], due to HCO_3/CO_2 buffer. B = A2 + A3 [ml]
SV = Initial sample volume [ml]
Alk = Alkalinity [mmol/l]

4. A/TIC-ratio

The A/TIC-method (German: FOS/TAC) was developed at the Federal Research Institute for Agriculture (FAL) in Braunschweig, Germany. Used as an indicator of the process stability inside the digester, it expresses the ratio between Volatile Fatty Acids and buffer capacity (alkalinity), or in other words the amount of Acids (A) compared to Total Inorganic Carbon (TIC).

$$\frac{A\ [mg/l]}{TIC\ [mg/l]} = \frac{VFA\ [mg/l]}{Alkalinity\ [mg/l]} \quad (3)$$

Alkalinity [mmol/l] needs to be converted to TIC [mg/l $CaCO_3$] by multiplying it with half the molecular weight of $CaCO_3$ (100.084/2=50.042), as each molecule of $CaCO_3$ can take up $2H^+$ ($CaCO_3 + H_2O \rightarrow Ca^{2+} + HCO_3^- + OH^-$).

It is worth noting that the original FOS/TAC-method according to FAL was based on a 3-point-titration method using approximate empirical figures (Nordmann, 1977).

Calculation example for VFA, alkalinity and A/TIC according to Kapp:

Initial sample volume [ml]	Normality of titrant H2SO4 [mmol/l]	Initial pH	A1= H2SO4 [ml] to titrate sample from Initial pH to pH5	A2 = H2SO4 [ml] to titrate sample from pH 5 to pH4.3	**A = A1+A2** H2SO4 [ml] to titrate sample from Initial pH to pH4.3	A3 = H2SO4 [ml] to titrate sample from pH4.3 to pH4.0	**B = A2 + A3** H2SO4 [ml] to titrate sample from pH5 to to 4.0
20	**0.1**	6.72	3.64	0.25	**3.89**	0.08	**0.33**

Alkalinity [mmol/l]

= 3.89ml * 0.1mmol/l * 1000 / 20ml = 19.45 mmol/l (1)

VFA [mg/l] (considered to be acetic acid)

= 131'340 * 0.1mmol/l * 0.33ml / 20ml – 3.08 * 19.45mmol/l – 10.9 = 145.9 mg/l (2)

A/TIC

$$\frac{VFA\ [mg/l] = \mathbf{A\ [mg/l]} = 145.9\ mg/l}{Alkalinity\ [mmol/l] \rightarrow \mathbf{TIC\ [mg/l]} = 19.45mmol/l * (100.084/2) = 973.3\ mg/l} = 0.15 \quad (3)$$

The results of the A/TIC-ratio are normally below 1.0. Each digester has its own A/TIC-ratio optimum which needs to be determined by conducting measurements on a regular basis. Significant changes of the A/TIC-ratio indicate disturbances of the process stability at an early stage in order to introduce counter-measurements (decrease or increase of feedstock quantity, addition of buffer capacity) at the appropriate time.

5. Researches on anaerobic digestion using the titration method of Kapp

Within different research projects of Eawag/Sandec (Swiss Federal Institute for Aquatic Sciences and Technology / Department of Water and Sanitation in Developing Countries), the titration method according to Kapp was applied on substrate samples of biogas digesters in India (Heeb, 2009), Lesotho (Müller, 2009) and Tanzania (Lohri, 2009). The

samples were filtered using a kitchen sieve and textile mash to analyze VFA, alkalinity and A/TIC-ratio. Lohri includes furthermore a description and results of another simple yet less accurate and therefore less recommendable 3-point-titration method (according to Nordmann, 1977) and some experiments concerning the influence of different pre-treatment methods (sieve, centrifuge, membrane filter) of the digester samples on the VFA and alkalinity results by Kapp.

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A3 Results: Data sheets

Phase	Day	date		Feed	Feed [kg]	Feed ww [kg/d]	pH low	pH middle	pH high	Temp. low [°C]	Temp. middle [°C]	high [°C]	day&night [°C]	Redox [mV]	Gas [l/d]	Gas [nL/d]	CH4 [Vol-%]	CO2 [Vol-%]	O2 [Vol-%]
Phase 1		31.07.08	morn		0		6.85	6.99	7.06	25.5	26.2	26.5							
			aftn		0	0	6.76	6.65	6.68	28.0	27.4	27.4	29	-314			1	3	18.2
		1.08.08	morn		0		6.58	6.53	6.64	24.6	26.3	26.7							
			aftn		0	0	6.48	6.09	6.16	27.7	27.0	27.2	28	-337			4	5	15.8
		2.08.08	morn		0		6.52	6.02	6.22	25.7	25.9	26.1							
			aftn		0	0	6.66	6.82	6.76	26.3	25.9	26.3	29	-328			9	9	11.7
		3.08.08	morn		0		6.44	6.44	6.00	26.3	26.9	27.6							
			aftn		0	0	6.54	6.60	6.13	28.8	28.4	28.4	29	-319			17	14	6.7
		4.08.08	morn		0		5.98	6.05	6.17	26.1	27.1	27.8							
			aftn		0	0	6.00	6.03	6.11	29.3	29.0	29.3	30	-320			25	19	3.5
		5.08.08	morn		0		6.56	6.56	6.07	26.5	27.6	26.8							
			aftn		0	0	6.19	6.05	6.46	28.9	28.4	30.5	30	-307			38	24	0.5
		6.08.08	morn		0		6.43	6.39	6.32	26.3	26.6	26.6							
			aftn		0	0	6.03	6.22	6.16	28.5	28.4	28.4	29	-321			47	26	0.5
		7.08.08	morn		0		6.22	6.38	6.42	26.6	26.8	26.8							
			aftn		0	0	6.19	6.25	5.95	27.0	27.1	27.0	30	-306			52	28	1.3
		8.08.08	morn		0		6.34	6.29	6.39	26.4	26.9	27.1							
			aftn		0	0	6.09	6.16	6.21	30.2	29.6	29.6	31	-303			58	28	0.6
		9.08.08	morn		0		6.39	6.31	6.28	26.7	26.8	27.0							
			aftn		0	0	6.55	6.53	6.26	29.3	29.1	29.9	31	-306			61	31	0.5
		10.08.08	morn		0		6.20	6.28	6.43	27.5	27.8	27.9							
			aftn		0	0	6.45	6.14	6.16	30.6	30.7	30.8	30	-302			62	33	0.6
	1	11.08.08	morn	food	0.15		6.21	6.19	6.21	27.0	28.1	28.5							
			aftn		0.15	0.3	6.15	6.22	6.25	28.1	27.8	27.9	29	-297			64	33	0.6
	2	12.08.08	morn	food	0.3		6.01	6.32	6.27	25.7	27.3	27.3							
			aftn		0.3	0.6	5.85	6.34	6.32	29.0	28.3	28.8	29	-272			64	35	0.5
	3	13.08.08	morn	food	0.45		5.51	6.31	6.26	25.8	27.0	26.6							
			aftn		0.45	0.9	5.34	6.27	6.22	29.5	28.5	28.8	30	-270			65	36	0.4
	4	14.08.08	morn	food	0.6		5.44	6.32	6.26	26.0	27.2	27.3							
			aftn		0.6	1.2	5.10	6.23	6.19	29.8	28.8	29.5	31	-235			64	37	0.6
	5	15.08.08	morn	food	0.75		5.12	6.28	6.26	26.0	27.1	27.0							
			aftn		0.75	1.5	5.36	6.24	6.20	26.8	26.7	27.3	28	-253			65	38	0.7
	6	16.08.08	morn	food	0.9		5.57	6.27	6.25	24.2	26.1	25.7							
			aftn		0.9	1.8	5.54	6.21	6.19	29.9	28.8	29.0	31	-275			64	39	0.5
	7	17.08.08	morn	food	1		5.50	6.20	6.19	26.7	27.4	27.2			200	179			
			aftn		1	2	5.26	6.09	6.07	29.8	29.2	29.5	30	-249			61	43	0.3
	8	18.08.08	morn	food	1		5.64	6.08	6.09	25.6	26.8	26.9			198	178			
			aftn		1	2	5.43	6.17	6.21	28.5	28.4	28.3	29	-234			60	46	0.6
	9	19.08.08	morn	food	1		5.54	6.22	6.24	25.1	26.5	26.3			216	194			
			aftn		1	2	5.61	6.30	6.27	28.6	28.6	28.5	30	-250			58	47	0.5
	10	20.08.08	morn	food	1		5.59	5.86	5.88	26.2	28.4	27.8			276	247			
			aftn		1	2	5.62	5.90	5.92	29.2	28.9	28.7	27	-219			56	49	0.3
	11	21.08.08	morn	food	1		6.11	6.03	6.11	25.6	26.5	26.8			242	219			
			aftn		1	2	5.35	5.66	5.68	29.0	29.1	28.9	27	-211			55	49	0.7
	12	22.08.08	morn	food	1		5.34	5.93	5.96	25.3	27.2	26.6			230	208			
			aftn		1	2	6.14	6.34	6.31	30.8	30.0	29.8	27	-221			56	49	0.5
	13	23.08.08	morn	food	1		5.60	6.07	6.15	25.3	27.3	26.9			235	213			
			aftn		1	2	6.89	6.13	6.12	28.9	28.8	29.0	27	-216			57	47	0.5
	14	24.08.08	morn	food	1		6.18	6.25	6.26	25.5	26.5	26.7			221	200			
			aftn		1	2	5.95	6.32	6.33	28.7	28.4	28.3	27	-226			59	46	0.6
	15	25.08.08	morn	food	1		5.55	6.20	6.22	25.4	26.8	27.0			213	193			
			aftn		1	2	4.75	5.68	5.65	26.5	27.0	27.0	26	-214			61	45	0.6
	16	26.08.08	morn	food	1		5.61	5.88	5.91	25.1	25.3	25.8			238	216			
			aftn		1	2	6.38	6.35	6.32	29.5	28.7	28.3	29	-218			60	44	0.5
	17	27.08.08	morn	food	1		6.03	6.23	6.23	27.3	28.5	27.2			227	204			
			aftn		1	2	5.30	5.95	6.01	29.3	29.3	29.4	30	-215			61	46	0.5
	18	28.08.08	morn	food	1		5.20	5.95	6.05	25.4	26.8	27.3			218	195			
			aftn		1	2	5.34	6.12	6.14	29.8	29.4	29.2	28	-211			60	46	0.6
	19	29.08.08	morn	food	1		5.24	6.09	6.14	25.5	26.8	27.1			272	245			
			aftn		1	2	4.83	6.25	6.22	30.2	30.5	30.8	30	-202			60	45	0.5
	20	30.08.08	morn	food	1		5.21	6.26	6.25	24.9	27.2	27.3			320	287			
			aftn		1	2	5.21	6.26	6.22	30.9	30.6	30.3	30	-208			60	46	0.3
	21	31.08.08	morn	food	1		4.44	6.28	6.27	27.1	29.6	29.6			273	245			
			aftn		1	2	5.42	6.23	6.19	29.8	30.2	30.9	29	-211			60	46	0.4
	22	1.09.08	morn	food	1		5.85	6.26	6.27	25.5	27.3	27.6			286	257			
			aftn		1	2	6.40	6.34	6.31	30.1	29.7	30.3	32	-205			60	46	0.6
	23	2.09.08	morn	food	1		6.44	6.38	6.40	26.2	26.9	27.3			274	244			
			aftn		1	2	6.45	6.40	6.36	29.0	28.9	28.9	30	-206			60	45	0.5
	24	3.09.08	morn	food	1		6.46	6.37	6.41	25.8	26.6	26.8			282	253			
			aftn		1	2	6.27	6.42	6.38	27.7	27.5	27.6	29	-207			61	45	0.5
	25	4.09.08	morn	food	1		6.13	6.22	6.42	25.0	25.8	25.9			279	251			
			aftn		1	2	6.09	6.13	6.35	26.8	27.0	27.2	29	-191			62	44	0.3
	26	5.09.08	morn	food	1		6.06	6.09	6.46	23.9	25.1	25.2			299	269			
			aftn		1	2	6.23	6.11	6.09	29.5	28.7	29.5	32	-208			62	45	0.4
	27	6.09.08	morn	food	1		6.12	6.10	6.08	24.5	25.9	26.6			306	273			
			aftn		1	2	6.04	6.00	6.00	31.9	31.0	30.9	31	-212			62	45	0.4
	28	7.09.08	morn	food	1		6.10	6.07	6.15	26.9	27.1	27.2			296	265			
			aftn		1	2	6.15	6.12	6.23	27.4	29.6	29.8	30	-205			60	45	0.5
	29	8.09.08	morn	food	0.5		6.11	6.14	6.18	23.9	25.9	26.6			263	236			
			aftn		0.5	1	6.29	6.28	6.26	32.4	31.5	32.1	30	-224			59	44	0.5
	30	9.09.08	morn	food	0.5		6.33	6.33	6.37	30.7	29.6	28.8			286	256			
			aftn		0.5	1	6.10	6.26	6.27	29.5	29.9	30.3	31	-197			61	44	0.5

steady state condition foodwaste

	Gas total [l]			
	2887	average [kg/d]		
	gas	ww	ts	vs
	288.7	20	4.82	4.51
	average gas [l/kg]			
DSM	288.7	144.4	599.0	640.1
Norm cond.	258.8	129.4	537.0	573.9

Phase 2	31	10.09.08	morn	food	0.5		6.33	6.37	6.35	25.2	27.3	28.1			185	165			
			aftn		0.5	1	6.14	6.31	6.38	29.4	29.9	30.3	29	-200			62	44	0.3
	32	11.09.08	morn	food	0.5		6.20	6.35	6.36	23.8	25.8	26.7			177	159			
			aftn		0.5	1	5.91	6.13	6.21	27.7	29.1	28.7	29	-342			63	43	0.4
	33	12.09.08	morn	food	0.5		5.94	6.13	6.14	25.6	26.8	28.0			179	161			
			aftn		0.5	1	6.21	6.19	6.21	29.7	30.0	30.1	32	-425			64	42	0.3
	34	13.09.08	morn	food	0.5		6.37	6.41	6.38	25.5	26.7	27.4			175	156			
			aftn		0.5	1	6.29	6.40	6.37	30.2	29.9	30.8	31	-312			64	42	0.3
	35	14.09.08	morn	food	0.5		6.35	6.49	6.48	25.4	27.0	27.3			194	173			
			aftn		0.5	1	6.30	6.62	6.60	27.8	28.7	29.0	28	-308			65	42	0.3
	36	15.09.08	morn	food	0.5		6.49	6.54	6.51	24.8	26.2	26.5			157	142			
			aftn		0.5	1	6.47	6.43	6.42	25.7	29.0	29.4	30	-313			66	40	0.4
	37	16.09.08	morn		0		6.74	6.68	6.64	25.2	26.3	26.7			150	134			
			aftn		0	0	6.69	6.56	6.52	29.4	29.5	29.0	30	-324			66	39	0.4
	38	17.09.08	morn		0		6.83	6.64	6.62	26.0	27.5	27.9			108	97			
			aftn		0	0	6.86	6.66	6.63	29.4	29.9	30.2	30	-325			67	38	0.5
	39	18.09.08	morn	mark	0.25		6.93	6.68	6.65	25.5	27.3	28.0			71	64			
			aftn		0.25	0.5	6.88	6.54	6.50	28.8	29.5	30.4	30	-333			68	35	0.6
	40	19.09.08	morn	mark	0.5		6.73	6.58	6.56	25.7	27.5	28.0			90	81			
			aftn		0.5	1	6.72	6.58	6.55	31.6	31.9	32.1	30	-338			66	35	0.8
	41	20.09.08	morn	mark	0.5		6.66	6.57	6.54	27.6	28.8	29.0			104	93			
			aftn		0.5	1	6.96	6.55	6.51	30.5	31.0	31.2	28	-349			66	35	0.3
	42	21.09.08	morn	mark	0.5		6.77	6.59	6.57	26.0	27.9	28.5			120	108			
			aftn		0.5	1	6.71	6.52	6.53	30.8	30.2	30.5	28	-344			66	35	0.3
	43	22.09.08	morn	mark	0.5		6.83	6.61	6.58	26.8	28.4	28.9			130	117			
			aftn		0.5	1	6.68	6.57	6.55	30.5	30.9	31.2	28	-335			66	35	0.4
	44	23.09.08	morn	mark	1		6.75	6.48	6.48	25.7	28.0	28.4			120	108			
			aftn		1	2	6.87	6.47	6.40	31.5	31.8	31.9	31	-359			68	34	0.5
	45	24.09.08	morn	mark	1		6.74	6.57	6.56	25.3	27.9	28.1			120	107			
			aftn		1	2	6.73	6.48	6.46	32.0	32.5	32.9	31	-360			70	34	0.3
	46	25.09.08	morn	mark	1		6.80	6.63	6.59	26.9	28.8	29.3			150	134			
			aftn		1	2	6.83	6.60	6.56	31.7	32.3	33.0	23	-363			70	35	0.3
	47	26.09.08	morn	mark	1		6.47	6.38	6.38	27.1	28.9	29.6			100	92			
			aftn		1	2	6.64	6.54	6.51	32.2	32.0	32.6	32	-364			68	35	0.3
	48	27.09.08	morn	mark	1		6.74	6.61	6.59	27.2	28.9	29.4			110	98			
			aftn		1	2	6.46	6.31	6.26	31.2	31.7	32.7	31	-377			68	34	0.4
	49	28.09.08	morn	mark	1		6.58	6.51	6.47	27.4	28.8	29.5			130	116			
			aftn		1	2	6.74	6.55	6.52	27.3	28.7	29.0	28	-364			68	34	0.4
	50	29.09.08	morn	mark	1		6.79	6.61	6.55	26.0	27.3	27.5			100	90			
			aftn		1	2	6.77	6.62	6.60	28.2	28.5	28.7	30	-370			69	34	0.4
	51	30.09.08	morn	mark	1		6.79	6.64	6.60	25.7	26.8	27.3			90	81			
			aftn		1	2	6.59	6.56	6.51	30.6	30.4	30.7	31	-371			70	34	0.3
	52	1.10.08	morn	mark	1		6.55	6.48	6.46	26.2	27.7	28.2			150	134			
			aftn		1	2	6.49	6.45	6.40	31.0	31.2	31.8	32	-362			68	34	0.4
	53	2.10.08	morn	mark	1		6.42	6.34	6.26	27.3	28.6	29.2			150	134			
			aftn		1	2	6.57	6.47	6.45	31.4	32.6	33.0	31	-375			68	34	0.3
	54	3.10.08	morn	mark	1		6.52	6.49	6.50	29.7	29.9	30.3			150	134			
			aftn		1	2	6.68	6.56	6.53	31.5	32.5	32.8	32	-371			68	34	0.3
	55	4.10.08	morn	mark	1		6.55	6.49	6.45	27.3	28.7	29.4			130	116			
			aftn		1	2	6.48	6.42	6.37	29.2	29.7	30.1	31	-382			68	34	0.4
	56	5.10.08	morn		0	0									160	143			
			aftn		0	0							32						
	57	6.10.08	morn		0										50	45			
			aftn		0	0							32						
	58	7.10.08	morn		0										15	13			
			aftn		0	0							32						
	59	8.10.08	morn		0														
			aftn		0	0							29						
	60	9.10.08	morn		0														
			aftn		0	0							31						
	61	10.10.08	morn		0														
			aftn		0	0							31						
	62	11.10.08	morn		0														
			aftn		0	0							31						
	63	12.10.08	morn		0														
			aftn		0	0	6.45	6.52	6.49	30.6	31.2	32.2	30	-370			68	38	0.3
Phase 3	64	13.10.08	morn	mark	0.5		6.47	6.47	6.44	28.3	29.5	30.3			0				
			aftn		0.5	1	6.66	6.52	6.47	31.7	32.1	33.3	31	-414			65	37	0.3
	65	14.10.08	morn	mark	1		6.59	6.52	6.47	28.2	29.6	30.1			63	56			
			aftn		1	2	6.47	6.54	6.51	33.0	33.5	33.9	26	-431			65	37	0.3
	66	15.10.08	morn	mark	1		6.15	6.50	6.48	27.0	29.6	30.2			184	167			
			aftn		1	2	6.40	6.41	6.37	31.0	31.8	32.4	32	-386			65	40	0.2
	67	16.10.08	morn	mark	1		6.53	6.41	6.38	27.9	29.4	29.6			100	89			
			aftn		1	2	6.67	6.53	6.49	31.4	32.4	32.8	33	-429			65	48	0.3
	68	17.10.08	morn	mark	1.5		6.47	6.44	6.41	28.1	29.3	29.6			180	160			
			aftn		1.5	3	6.55	6.47	6.43	31.9	32.8	33.6	31	-385			63	39	0.3
	69	18.10.08	morn	mark	1.5		6.55	6.52	6.48	27.8	29.5	30.1			210	188			
			aftn		1.5	3	6.51	6.49	6.42	30.1	31.0	30.9	31	-411			63	40	0.2
	70	19.10.08	morn	mark	1.5		6.53	6.43	6.41	28.4	29.7	30.3			200	179			
			aftn		1.5	3	6.49	6.41	6.45	30.0	30.0	30.2	31	-402			61	43	0.1
	71	20.10.08	morn	mark	1.5		6.42	6.38	6.33	28.0	29.8	30.4			182	163			
			aftn		1.5	3	6.52	6.36	6.31	32.4	32.9	33.2	32	-455			60	44	0.2
	72	21.10.08	morn	mark	2		6.44	6.36	6.30	27.3	29.3	29.9			190	169			
			aftn		2	4	6.30	6.39	6.35	32.6	32.8	33.6	32	-440			59	45	0.4

steady state condition marketwaste

	Gas total [l]			
	1260	average [kg/d]		
	gas	ww	ts	vs
	126	20	2.02	1.80
	average gas [l/kg]			
DSM	126	63	623.8	700.0
Normcond.	113.0	56.5	559.2	627.6

Phase 3

73	22.10.08	morn	mark	2		6.27	6.33	6.29	26.9	29.1	29.7			260	232			
		aftn		2	4	6.33	6.37	6.34	32.5	33.1	33.3	32	-409			59	46	0.2
74	23.10.08	morn	mark	2		6.16	6.44	6.38	28.3	29.7	30.4			250	223			
		aftn		2	4	6.31	6.36	6.36	33.6	33.9	34.8	33	-417			58	47	0.2
75	24.10.08	morn	mark	2.5		6.10	6.36	6.34	28.7	30.2	30.7			320	284			
		aftn		2.5	5	6.22	6.38	6.34	33.5	33.7	33.8	32	-396			57	47	0.2
76	25.10.08	morn	mark	2.5		6.35	6.35	6.31	29.2	30.6	30.9			360	338			
		aftn		2.5	5	6.32	6.40	6.36	33.1	32.9	33.0	34	-376			56	49	0.2
77	26.10.08	morn		0		6.35	6.35	6.34	29.6	30.1	30.5			346	306			
		aftn		0	0	6.29	6.38	6.36	33.2	33.4	33.5	33	-381			57	48	0.2
78	27.10.08	morn		0		6.56	6.52	6.47	28.3	28.5	28.9			120	107			
		aftn		0	0	6.79	6.57	6.51	26.8	27.2	27.3	25	-363			59	47	0.3
79	28.10.08	morn		0		6.67	6.60	6.36	27.0	26.8	27.0			80	73			
		aftn		0	0	6.59	6.47	6.47	29.6	30.5	30.9	32	-362			60	46	0.3
80	29.10.08	morn	food	0.5		6.71	6.55	6.57	28.5	28.6	28.8			50	45			
		aftn		0.5	1	6.57	6.43	6.39	31.5	32.7	33.3	32	-368			61	44	0.3
81	30.10.08	morn	food	1		6.34	6.45	6.42	27.5	29.2	29.6			90	80			
		aftn		1	2	6.14	6.42	6.43	32.3	33.2	33.6	28	-357			63	42	0.3
82	31.10.08	morn	food	1		6.04	6.39	6.38	28.5	29.9	30.0			190	171			
		aftn		1	2	6.23	6.39	6.37	32.3	32.8	32.9	32	-363			66	42	0.3
83	1.11.08	morn	food	1		6.27	6.36	6.34	28.1	29.9	30.2			220	196			
		aftn		1	2	6.36	6.41	6.40	32.7	33.7	33.9	32	-349			62	42	0.3
84	2.11.08	morn	food	1		6.25	6.40	6.37	28.9	30.2	30.8			280	249			
		aftn		1	2	6.19	6.38	6.36	31.6	32.6	33.1	30	-360			62	43	0.2
85	3.11.08	morn	food	1.5		6.05	6.33	6.32	28.3	29.7	30.1			250	224			
		aftn		1.5	3	6.21	6.31	6.28	33.1	34.3	34.5	31	-344			61	44	0.2
86	4.11.08	morn	food	1.5		5.96	6.30	6.29	28.8	30.5	30.9			400	357			
		aftn		1.5	3	6.23	6.33	6.31	32.9	33.3	33.4	31	-338			60	45	0.2
87	5.11.08	morn	food	1.5		5.83	6.34	6.31	26.2	28.4	29.1			470	420			
		aftn		1.5	3	5.45	6.24	6.21	27.9	28.5	28.6	26	-339			61	44	0.2
88	6.11.08	morn	food	1.5		6.23	6.43	6.16	26.1	26.6	26.8			280	254			
		aftn		1.5	3	6.24	6.30	6.32	28.5	28.5	28.5	29	-332			62	43	0.2
89	7.11.08	morn	food	2		6.20	6.34	6.32	26.7	27.4	27.4			300	270			
		aftn		2	4	6.12	6.21	6.20	29.3	29.1	29.0	28	-327			62	43	0.2
90	8.11.08	morn	food	2		6.15	6.24	6.23	27.2	27.7	27.7			390	352			
		aftn		2	4	6.25	6.25	6.22	32.1	31.6	31.6	31	-327			58	47	0.2
91	9.11.08	morn	food	2		6.26	6.27	6.26	27.4	28.3	28.6			500	447			
		aftn		2	4	5.99	6.13	6.11	31.6	31.8	31.8	31	-320			56	49	0.2
92	10.11.08	morn	food	2		6.19	6.24	6.24	28.4	29.4	29.8			520	465			
		aftn		2	4	6.27	6.25	6.22	31.8	32.6	33.1	32	-320			57	49	0.2
93	11.11.08	morn	food	2.5		6.13	6.22	6.21	29.3	30.4	30.6			560	499			
		aftn		2.5	5	6.03	6.29	6.26	32.4	34.0	34.2	32	-326			56	49	0.2
94	12.11.08	morn	food	2.5		6.35	6.37	6.36	30.6	31.3	31.6			650	579			
		aftn		2.5	5	6.17	6.23	6.20	33.6	34.6	35.0	32	-328			57	48	0.2
95	13.11.08	morn	food	2.5		6.22	6.46	6.51	30.4	31.8	32.1			670	597			
		aftn		2.5	5	6.24	6.30	6.25	33.4	34.6	35.2	32	-328			57	48	0.2
96	14.11.08	morn	food	2.5		6.01	6.18	6.15	30.9	31.8	32.2			680	606			
		aftn		2.5	5	6.10	6.19	6.16	34.0	35.3	35.6	32	-324			56	48	0.2
97	15.11.08	morn		0		6.32	6.46	6.42	30.8	31.8	32.4			670	597			
		aftn		0	0	6.39	6.42	6.38	32.9	33.9	34.8	32	-336			59	46	0.2
98	16.11.08	morn		0		6.52	6.47	6.43	29.9	31.2	31.9			410	365			
		aftn		0	0	6.58	6.47	6.44	32.9	34.7	35.1	33	-344			63	42	0.3
99	17.11.08	morn		0		6.57	6.49	6.48	29.9	31.1	31.9			270	240			
		aftn		0	0	6.48	6.41	6.40	33.3	34.6	35.5	32	-351			66	39	0.2
100	18.11.08	morn		0		6.82	6.80	6.77	30.4	31.6	32.2			230	205			
		aftn		0	0	6.68	6.69	6.65	33.1	34.4	35.4	32	-320			68	36	0.2
101	19.11.08	morn	food	1		6.69	6.62	6.59	32.7	31.8	32.3			190	169			
		aftn		1	2	6.42	6.71	6.66	32.7	34.0	34.6	31	-368			70	34	0.2
102	20.11.08	morn	food	1		6.37	6.54	6.51	29.9	31.0	31.5			270	241			
		aftn		1	2	6.29	6.55	6.50	33.0	34.8	35.0	33	-353			70	34	0.2
103	21.11.08	morn	food	1		6.25	6.44	6.39	30.4	31.4	31.9			370	328			
		aftn		1	2	6.24	6.27	6.25	33.6	34.6	35.0	32	-344			68	37	0.2
104	22.11.08	morn	food	1		6.27	6.31	6.30	30.4	31.3	31.5			370	330			
		aftn		1	2	6.36	6.44	6.40	33.4	34.6	35.2	32	-344			66	40	0.2
105	23.11.08	morn	food	1		6.42	6.47	6.45	30.4	31.5	32.2			360	338			

			Influent		Effluent	
date	Feed	Feed [kg/d]	CODtot [mg/l]	CODtot [g/d]	CODtot [mg/l]	CODtot [g/d]
18.08.08	food	2	33650	673	7650	153.0
21.08.08	food	2	33600	672	6325	126.5
25.08.08	food	2	25500	510	2250	45.0
28.08.08	food	2	22900	458	1925	38.5
1.09.08	food	2	26150	523	3175	63.5
5.09.08	food	2	21600	432	4525	90.5
8.09.08	food	2	34900	698	7725	154.5
11.09.08	food	1	14250	285	7550	151.0
22.09.08	mark	1	4500	90	2225	44.5
25.09.08	mark	2	5450	109	1063	21.3
29.09.08	mark	2	4850	97	1525	30.5
1.10.08	mark	2	9813	196	1375	27.5
3.10.08	mark	2	7069	141	1070	21.4
16.10.08	mark	2	15750	315	1070	21.4

		Average					
		Influent		Effluent		delta In/ Out	
Feed	Feed [kg/d]	CODtot [mg/l]	CODtot [g/d]	CODtot [mg/l]	CODtot [g/d]	CODtot [mg/l]	CODtot [g/d]
food	2	28328.6	566.6	4796.4	95.9	23532.1	470.6
mark	2	8586.4	171.7	1220.6	24.4	7365.8	147.3

	Influent				delta In/ Out			
	C [g] *	COD [g] *	C [g] **	**Max.gas [Nl] ** **	C [g] *	COD [g] *	C [g] **	**Max.gas [Nl] ** **
Equation * / **	12	32	1	**1.87**	12	32	1	**1.87**
food	212.5	566.6	212.5	**396.6**	176.5	470.6	176.5	**329.5**
mark	64.4	171.7	64.4	**120.2**	55.2	147.3	55.2	**103.1**

* C + O2 (=COD) -> CO2	** 2 C -> CO2 + CH4
12g + (2*16g) -> CO2	(2*12g) = 2M = 2*22.4Nl
12g C = 32g O2	**1g C -> 44.8/24 Nl Gas-Maximum**

					waste 1:1		Influent (diluted)														
day	date	day	Feed	Feed [kg/d]	waste 1:1 TS %	waste 1:1 VS %	Influent TS %	Influent TS [g/l]	Influent TS meas [g/d]	Influent TS [g/d]	Influent VS [%]	Influent VS [g/l]	Influent VS [g/d]	Influent VS [g/d]	Influent CODtot [mg/l]	Influent CODtot [g/d]	Influent CODdisv [mg/l]	Influent CODdisv [g/d]	Influent NH4-N [mg/l]	Influent Ntot [mg/l]	Influent Ptot [mg/l]
8	18.08.08	8	food	2	27.6	82.7	3.5	35.3	706	552	94.5	19.2	384	521.6	33650	673	7725	154.5	25.9		
11	21.08.08	11	food	2	23	87.2	2.6	26	520	460	90.2	20.9	418	414.9	33600	672	9150	183	27.2	76.2	
15	25.08.08	15	food	2	29.6	93.6	3.2	31.7	634	592	93.7	29.7	594	554.7	25500	510	8775	175.5	30.8		9.5
18	28.08.08	18	food	2	24.3	89.4	2.2	21.9	438	486	94.4	20.7	414	458.8	22900	458	7600	152	20.8	84.0	
22	1.09.08	22	food	2	20.6	91.2	2.2	21.5	430	412	91.3	19.6	392	376.2	26150	523	8150	163	37.0		5.1
26	5.09.08	26	food	2	20.2	94.6	2.4	23.8	476	404	92.7	22.1	442	374.5	21600	432	7600	152	35.5	53.8	
29	8.09.08	29	food	2	23.3	95.2	2.6	26.7	534	466	97.4	25.8	516	453.9	34900	698	7067	141.3	39.9		6.4
32	11.09.08	32	food	1	27.6	92	1.3	12.8	256	276	92.9	11.9	238	256.4	14250	285	4275	85.5	36.1		
37	16.09.08	37		0	0	0	0.0	0	0	0	0	0	0	0.0	0	0	0	0	0	0.0	0
43	22.09.08	43	mark	1	8	89.4	0.3	3.2	64	80	83.2	2.7	54	66.6	4500	90	3300	66.0	35.3		
46	25.09.08	46	mark	2	10	89.1	0.3	3.4	69	200	88.8	3.1	62	177.6	5450	109	3263	65.3	19		
50	29.09.08	50	mark	2	13.2	85.5	0.4	4.3	86	264	88.4	3	60	233.4	4850	97	2313	46.3	18.4		
52	1.10.08	52	mark	2	9.2	90	1.1	10.5	210	184	86.1	9.1	182	158.4	9813	196	5338	106.8	23.9	137.8	118
54	3.10.08	54	mark	2	7.6	83.6	1.3	13.1	262	152	83.6	11	220	127.1	7069	141	4550	91.0	44.6	108.6	232
67	16.10.08	67	mark	2	10.6	89.3	1	9.9	198	212	88.3	8.7	174	187.2	10750	215	5950	119.0	26	207.2	136

			Averages								
			Influent				Gas	Effluent			
			TS [g/l]	VS [g/l]	VS [%]	COD [g/l]	gas [NL/d]	TS [g/l]	VS [g/l]	VS [%]	COD [g/l]
food		2	26.7	22.6	93.5	28.3	234	3.7	1.7	46.7	4.8
mark		2	8.2	7.0	87.0	7.6	122	2.7	1.3	47.0	1.2

Influent average									
TS 1:1 [%]	TS [g/d]	VS 1:1 [%]	VS [g/d]	CODtot [mg/l]	CODtot [g/d]	CODdisv [mg/l]	CODdisv [g/d]	NH4-N [mg/l]	NH4-N [mg/l]
24.1	482	90.6	450.7	28328.6	566.6	8009.6	160.2	31.0	620.1
10.1	202	87.5	176.7	7586.4	151.7	4282.8	85.7	26.4	527.6

Gas [l/d]	Effluent																		
Gas 24h later [Nl/d]	Effluent TS [g/l]	Effluent TS [g/d]	Effluent TS %	Effluent VS [g/l]	Effluent VS [g/d]	Effluent VS %	Effluent CODtot [mg/l]	Effluent CODtot [g/d]	Effluent CODdisv [mg/l]	Effluent CODdisv [g/d]	Effluent pH	Effluent FOS/TAC (Nordmann)	Effluent NH4-N [mg/l]	Effluent Ntot [mg/l]	Effluent PO4 [mg/l]	Effluent Ptot [mg/l]	Effluent Pb [mg/l]	Effluent Cu [mg/l]	Effluent Cd [mg/l]
194	5.3	106	0.5	2.7	54	51.5	7650	153.0	1750	35.0	6.09	0.62	63.1		198.3	251.0			
208	2.9	58	0.3	1.3	26	44.3	6325	126.5	2600	52.0	6.11	0.70	57.9		181.7	249.0			
216	3.9	78	0.4	1.7	34	43.7	2250	45.0	2300	46.0	6.22	0.22	61.8	116.5	193.3	256.0	0.054	0.000	0.000
245	2.8	56	0.3	1.3	26	45.3	1925	38.5	1575	31.5	6.05	0.11	59.3		137.0	237.0	0.072	0.000	0.000
244	4.3	86	0.4	2.1	42	48.0	3175	63.5	1275	25.5	6.27	0.18	76.0		151.0	245.0			
273	3.2	64	0.3	1.3	26	41.3	4525	90.5	3750	75.0	6.46	0.15	87.0	201.6	165.0	248.0			
256	3.3	66	0.3	1.8	36	52.7	7725	154.5	1450	29.0	6.18	0.11	92.0		151.0	240.0	0.093	0.000	0.000
161	3.7	74	0.4	2.1	42	57.3	7550	151.0	3050	61.0	6.36	0.09	96.0	134.4	192.5	258.8	0.061	0.000	0.000
97	0	0	0.0	0	0	0.0	0	0.0	0	0.0	0.00	0.00	0.0	0.0	0.0	0.0			
108	2.7	54	0.3	1.3	26	47.8	2225	44.5	1075	21.5	6.51	0.03	84.3		144.0	231.3	0.036	0.000	0.018
92	2.8	56	0.3	1.1	22	40.6	1063	21.3	950	19.0	6.59	0.03	80.3	205.0	143.5	197.5			
81	2.5	50	0.3	1	20	42.4	1525	30.5	537.5	10.8	6.55	0.07	79.8		148.5	185.0			
134	2.7	54	0.3	1.4	28	51.9	1375	27.5	1150	23.0	6.46	0.07	83.0	180.3	152.0	262.0			
143	2.5	50	0.3	1.1	22	42.1	1070	21.4	515	10.3	6.50	0.10	105.8	160.2	150.0	200.0	0.095	0.000	0.013
160	3.2	64	0.3	1.9	38	58.2	1070	21.4	430	8.6	6.38	0.11	79.8	215.0	145.0	272.0	0.057	0.006	0.021

Effluent average											
TS [%]	TS [g/d]	VS [%]	VS [g/d]	CODtot [mg/l	CODtot [g/d]	CODdisv [mg/l]	CODdisv [g/d]	NH4-N [mg/l]	Ntotal [mg/l]	PO4 [mg/l]	Ptotal [mg/l]
0.4	73.43	46.7	34.9	4796.4	95.9	2100	42.0	71.0	150.8	171.2	248.1
0.3	54.8	47.0	26	1220.6	24.4	716.5	14.3	85.7	190.1	147.2	224.6

Digester low				
Digester low TS [g/l]	Digester low TS [%]	Digester low VS [g/l]	Digester low VS [%]	Digester low CODtot [mg/l]
				37500
24.4	2.4	19.3	78.9	36625
24.4	2.4	21.2	86.9	17625
28.5	2.9	25.2	88.2	36025
21.4	2.2	17.9	83.6	17975
16.1	1.6	12.6	78.1	22425
0	0.0	0	0.0	0
15.6	1.6	12.5	80.2	18075
8.6	0.9	6.7	71.3	12450
18.5	1.9	14.6	79.1	29150
23.5	2.4	18.7	79.4	27750

B ARTI

B1 List of installed ARTI plants

Biogas No.1
Location: ARTI – TZ Office DSM
Commissionsed on 5/11/2006
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.2
Location: Mama Shimboni Resi. Mbezi Beach
Commissionsed on 22/2/2007
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.3
Location: COSTECH DSM (Dr. Raphael Resi)
Commissionsed on 11/4/2007
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.4
Location: Mr Kasianjo Resi. Kunduchi Beach
Commissionsed on 11/4/2007
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.5
Location: Prof. Beda Resi. Kunduchi Beach
Commissionsed on 26/4/2007
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.6
Location: Mr. Fabian's Residence, Kibamba
Commissionsed on 2/5/2007
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.7
Location: Mr. Theodor Resi. Mbezi Beach
Commissionsed on 6/6/2007
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.8 & 9
Location: Kinasi Lodge, Mafia Island
Commissionsed on 31/10/2007
Capacity: Digestor 2000ltr,
Gas Holder 1500 ltr each

Biogas No.10
Location: JKT Mugulani, DSM
Commissionsed on 29/12/2007
Capacity: Digestor 2000ltr,
Gas Holder 1500 ltr

Biogas No.11
Location: FOT Project, Kyela
Commissionsed on 04/01/2008
Capacity: Digestor 1500ltr,
Gas Holder 1000 ltr

Biogas No.12
Location: SIDO Office, Mbeya
Commissionsed on 23/01/2008
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.13
Location: St George Sec.School, Mbagala
Commissionsed on 06/03/2008
Capacity: Digestor 3000ltr,
Gas Holder 2500 ltr

Biogas No.14
Location: Prof. Kohi's Farm House,
Commissionsed on 11/03/2008
Capacity: Digestor 2000ltr,
Gas Holder 1500 ltr

Biogas No.15
Location: FOT Orphanage, Mburahati
Commissionsed on 11/03/2008
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.16
Location: JKT Ruvu, Mlandizi
Commissionsed on 14/03/2008
Capacity: Digestor 2000ltr,
Gas Holder 1500 ltr

Biogas No.17
Location: Mama Sijaoana Resi, Masaki
Commissionsed on 05/05/2008
Capacity: Digestor 2000ltr,
Gas Holder 1500 ltr

Biogas No.18
Location: Mr Mwaipaja Resi, Opp. Airport
Commissionsed on 06/05/2008
Capacity: Digestor 2000ltr,
Gas Holder 1500 ltr

Biogas No.19
Location: ARTI-UG Office, Kampala
Commissionsed on 23/07/2008
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No.20, 21 and 22
Location: St. Mary's Sec. School, Kitende, UG
Commissionsed on 24/07/2008
Capacity: Digestor 5000ltr,
Gas Holder 4000 ltr -1 system
Digestor 2500ltr,
Gas Holder 2000 ltr - 2 systems

Biogas No. 23
Location: JET-UG Office, Kampala
Commissionsed on 25/07/2008
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No. 24
Location: Ardhi University, DSM
Commissionsed on 25/07/2008
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No. 25
Location: Feed the children Office, DSM
Commissionsed on 23/08/2008
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

Biogas No. 26, 27 & 28
Location: Azania Sec. School, DSM
Commissionsed on 1/09/2008
Capacity: Digestor 4000ltr,
Gas Holder 3000 ltr – 3 systems

Biogas No. 29
Location: Sadaani Safari Lodge, Sadaani
Commissionsed on 20/09/2008
Capacity: Digestor 3000ltr,
Gas Holder 2500 ltr

Biogas No. 30
Location: Resi. Of Mrs. Mwanahamisi, Mbezi
Commissionsed on 22/09/2008
Capacity: Digestor 1000ltr,
Gas Holder 750 ltr

B2 Documentation of installation

1. Cut off the top of the digester (HDPE-Tank 1000l) *1/2*
2. Cut out holes of the top (HDPE-Tank 750l) *3*
3. Drill hole Ø 3.5” for inlet *4/5*
4. Drill hole Ø 2” for the overflow *6*
5. Drill hole Ø ¾” for sample-outlet -> put in the tank connector *7*
6. Male and Female Socket for Inlet -> Araldite on both sides, tighten *8-10*
7. Araldite of sample-outlet-connector
8. General Purpose Epoxy Compond, 2-components (M-Seal) -> sealing from the inside of inlet *11*
9. Cut 20” of 3”-pipe for inlet inside the digester -> clue it (era) and stick it in *12-16*
10. Make the hole of outlet bigger with blade -> glue in connector with Araldite *17/18*
11. Cut 5” of 2”-pipe for outlet -> clue it (era) to the connector and glue the elbow on it *19-22*
12. Cut 24” of 2”-pipe for outlet -> glue with era *22*
13. Cut 9” of 3”-pipe -> glue it to inlet connector, glue connector to T, glue reduction to T *23*
14. Cut 6cm of 2”-pipe -> glue to the reduction *23*
15. Glue the ball valve on *24*
16. Cut 46” of 3”-pipe for the inlet -> glue it on T *27*
17. Glue nut to the sample-outlet-connector, glue cock to nut *28-30*
18. Drill ¾” hole on top of gasholder -> make it bigger with blade *25/26*
19. Glue the connector in this hole, attach bucknut from the inside *27*
20. On the outside: Glue nut to connector, union to nut, ebow to union *28*
21. Put two bricks inside of digester along the inlet pipe *30*
22. Fill the digester with water -> check if water-tight *29*
23. Mix 70 kg of cowdung with water and make it homogenous, remove staw *32-35*
24. Fill in the 300 of effluent from an existing plant *36*
25. After filling, put the gasholder into the digester *37*
26. Open the gas-valve -> the gasholder sinks down into the digester *38*

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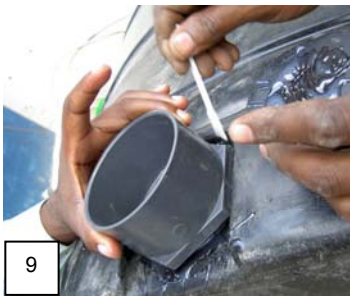
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Joint Environmental Techniques

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Taking Care of Your Compact Biogas System

Thank you for buying an ARTI Compact Biogas System (CBS). Once the technicians have delivered, installed and commissioned the biogas, it will be your responsibility to properly feed and care for it. This guide will help you with this so that you can enjoy free energy and live peacefully with the environment.

Feeding

The best way to understand how to feed the biogas system is to think of it as a cow. A cow needs food and water to live just like your biogas system. A cow eats grass; a biogas eats kitchen food waste. The more starch in the food waste (Example of starchy foods are: potato and carrot peels, left over ugali, rice, spaghetti and beans) and sugars (Example: rotten fruit) the more gas it will produce. Like a cow, the food must be made small so it will fit in the feed pipe. No food should be larger than your thumb nail. A cow has teeth to make the food smaller, you will need a knife, a blender or a meat mincer to chop the food up yourself. A cow also needs water to swallow its food and so does your biogas. You must mix the food for your biogas with water so that it can go into the digester (stomach) smoothly. If you don't mix with water, it will get blocked. Finally, like a cow, your biogas needs to be fed every day. If you feed your biogas regularly and properly care for it using the below instructions, your biogas will run faithfully for many years to come.

Please only put food waste into the biogas system: bones, soaps, detergents, plastics and other objects may block or kill the bacteria and stop gas production

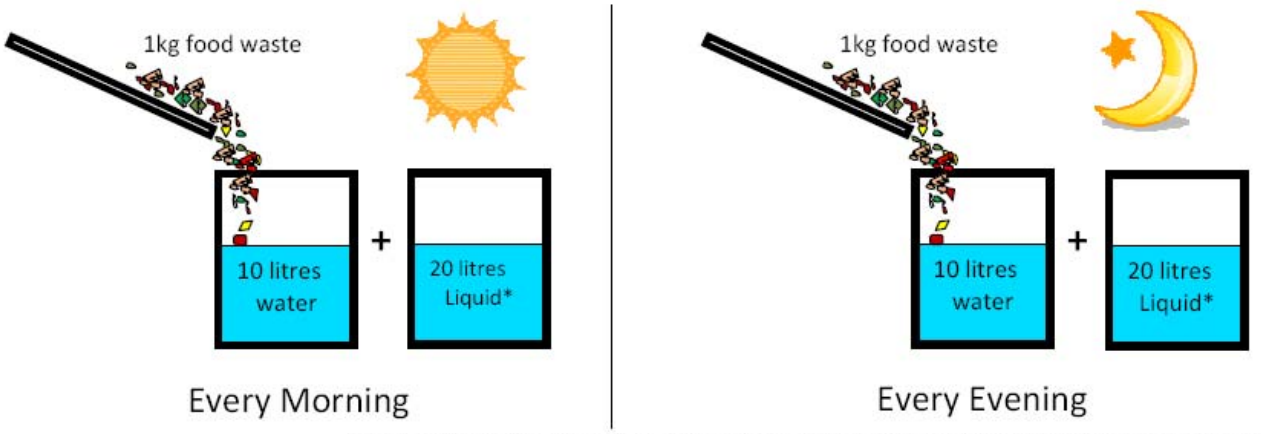
Nema's Biogas: *For every 1000 litres of digester you must feed 2kg of food waste per day. Please try to follow this rule to ensure you get the most gas production.*

Every day Nema feeds her biogas two times, 1kg in the morning and 1kg in the evening. Doing so has provided her with 1.5 hrs cooking per day for the last 2 years.

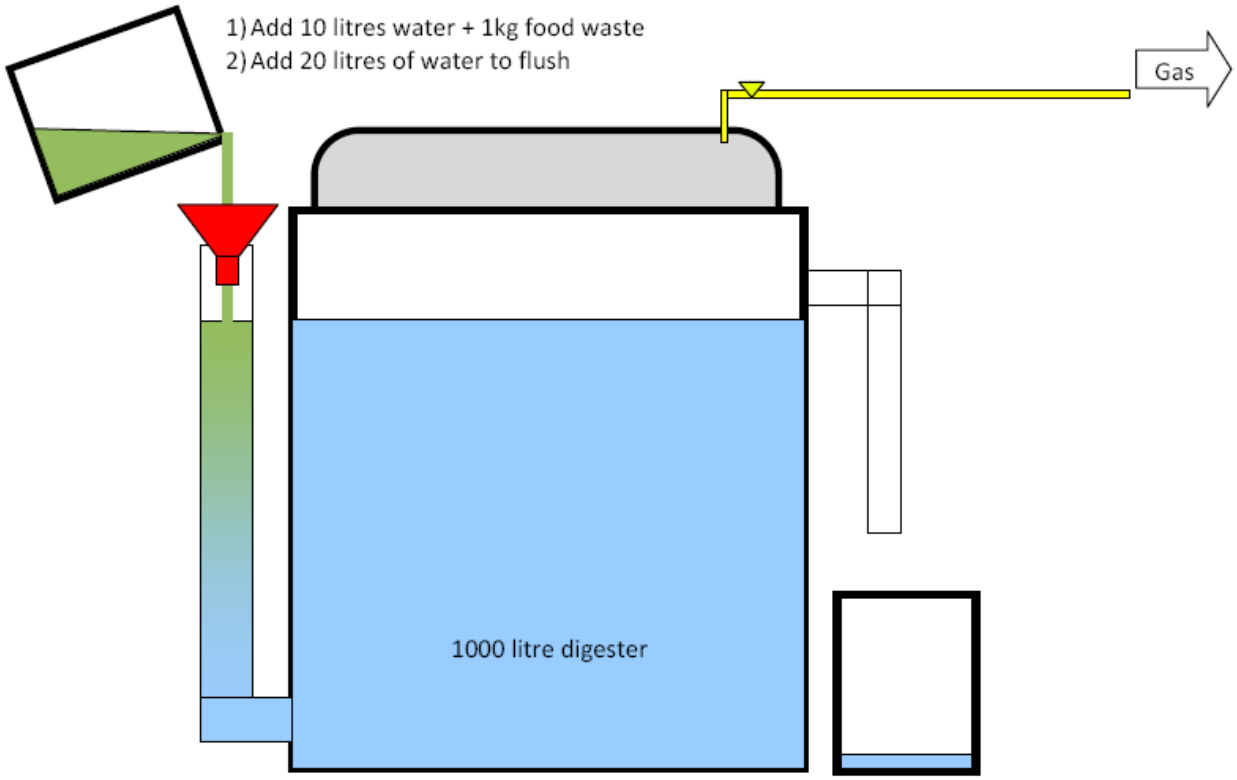
Everyday Nema collects the food waste from the last night's dinner. Usually this waste is a mixture of left over ugali or rice, potato peels, vegetables and the fruit peelings from making juice. Nema chops all the food into small pieces using a kitchen knife, measures out a one kilo, mixes it with 10 litres of water and feeds it into the digester through the feed pipe.

Once the biogas is fed Nema then refills the 10 litre bucket with water(or the liquid collected from the overflow pipe) and flushes it down the feed pipe into the digester to make sure the food waste has entered all the way. Nema repeats the process in the evening. If she does not have enough waste from her own kitchen she collects food waste from the local bar or fruit seller outside the house to make sure she has a full kilo to feed the biogas.

Example of operation for the 1000 litre unit

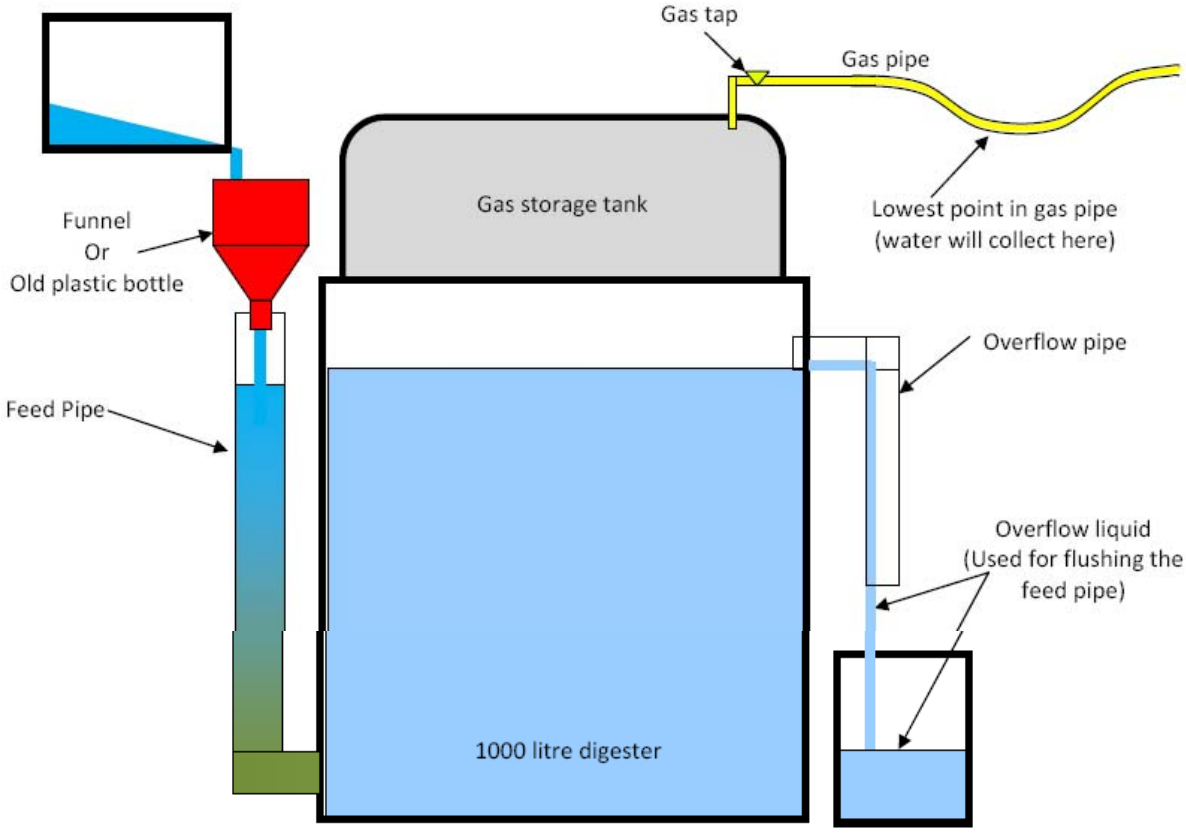


* The amount and type of liquid required can be seen in the table on the following page.



Tips for getting the most gas from your unit.

- Try and feed the unit once in the morning and once in the evening this will allow more gas to be made.
- Adding more food than recommended will NOT produce more gas as it will harm the bacteria and actually slow gas production.
- Instead of clean water, you can also use the overflow liquid to feed the biogas. This will save you water and improves how the digester works as the overflow liquid already has the good bacteria inside it.



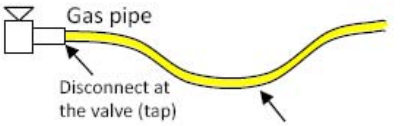
Daily Recommended Feeding Schedule			
Tank Size	Morning	Evening	Flushing after each feed
1000 litre	1 kg feed stock + 10litres of water	1 kg feed stock + 10litres of water	20 litres overflow liquid (or water)
1500 litre	1.5 kg feed stock + 10litres of water	1.5 kg feed stock + 10litres of water	20 litres overflow liquid (or water)
2000 litre	2 kg feed stock + 15 litres of water	2 kg feed stock + 15 litres of water	20 litres overflow liquid (or water)
3000 litre	3 kg feed stock + 20 litres of water	3 kg feed stock + 20 litres of water	30 litres overflow liquid (or water)
4000 litre	4 kg feed stock + 30 litres of water	4 kg feed stock + 30 litres of water	40 litres overflow liquid (or water)
5000 litre	5 kg feed stock + 40 litres of water	5 kg feed stock + 40 litres of water	60 litres overflow liquid (or water)

Trouble Shooting

If your biogas is having problems, please continue to feed it properly while working to fix it. If you have followed the below steps and still cannot fix it yourself, please call us so that we can send a technician to help you.

Gas not coming out of burner

Biogas has a small amount of moisture (water) and sometimes this moisture collects in the hose going from the gas holder to the stove and blocks the gas. To fix this, close the valve on the top of the gas storage tank, disconnect the hose from the valve, shake out the water and reconnect the hose back to the valve. The water usually collects where the hose hangs lowest so make sure you have checked the whole length of the hose.



Lowest point in gas pipe (water will collect here)

Checking for gas leaks

If you notice your gas is finishing quickly, or the gas holder is not rising you may have a gas leak. If you do have a gas leak it is most likely leaking from the gas valve on top of the gas holder tank. First of all, smell around the valve area to try and pinpoint where the gas is leaking from. If this does not work, slowly pour dish soap mixed with a little water around the fittings while looking for air bubbles coming from the tank. If you see air bubbles, you have a leak. To fix the leak, simply buy some "M" Seal, or contact cement and apply to the area with the leak. Once the sealant dries, check again for any leaks.

Apply soapy water were valve meets tank

Unblocking of feed pipe

If you do not chop the food into small enough pieces or if you don't use enough water your feed pipe will get blocked. This sometimes happens and to fix the problem, but is easy to fix. Simply take a piece of garden hose and push it down the feed pipe, push and back and forth until the blocked food is out of the way. Once this is done, remove the hose and flush 10 litres of water down the feed pipe to ensure the entire blockage is removed. If the water does not go down and the pipe is still blocked, repeat the process until the water goes into the tank.

Service Contacts

It is important to us that your Compact Biogas System is working properly. If you have any questions or need service please call our qualified technician, or the contacts at the top of this page. Thank you.

JET Compact Biogas Technician: Godson 0712 533 088

B4 ARTI Service Check list

Date:	Service by:
Location: Plant Number:	Plant volume (digester/gasholder):
Inlet Blockage checked and deblocked **O** Funnel checked **O** If there is no, leave one there or advise them to use one	**Overflow** Blockage checked and deblocked **O** Is pipe loosely connected to tank? checked and tightened **O** Overflow-bucket checked **O** If there is none, ask for one or advise them to use one
Gasholder Weight applied? If not, apply half a brick and explain the operator the reason for it checked **O**	**Gas leakage** Gas tap leaking (→ smell) checked **O** Gas hose leaking (→ follow the hose and check for damage and smell) checked **O** Gas hose proper attached to stove? checked **O**
Gas hose Condense water? checked and water removed **O** Drain attached: yes **O** no **O** If no, attach one at the lowest point	**Stove** Burning properly (blue flame & stable) checked **O**
Overall impression In use yes **O** no **O** Well maintained yes **O** no **O** Needs more instruction yes **O** no **O** Location too shady yes **O** no **O** Remarks:	**Interview with operator** Nature of daily feedstock? Daily amount: Pre-treatment: cut **O** blended **O** nothing **O** If nothing, advise them to do it and explain why Amount of water for dilution: Cooking hours per day with biogas: Problems:
Technical data pH of effluent: (6.2 - 7.5 OK) Temperature effluent: (25 – 38°C OK)	General satisfaction: Recommendation for improvement: Questions:

B5 ARTI: Results of inspection tours

Date	21.10.2008	21.10.2008	20.10.2008	20.10.2008	20.10.2008	20.10.2008	20.10.2008	20.10.2008	21.10.2008	20.10.2008	20.10.2008	20.10.2008	20.10.2008	20.10.2008
Origin of Sample (ARTI-#)	#1	#2	#3	#4	#5	#6	#7	#14	#15	#17	#18	#24	#25	#26
	ARTI office	Mr.Potnis	Mr.Raphael(son)	Kasianjo	Prof. Beda	Mr.Fabian	Mr.Theodor	Prof.Kohi	Mama Lena	Mama Sijaoana	Mr.Mwaipaja	ARDHI	FeedTchildren	Azania
Digester size	1000	1000	1000	1000	1000	1000	1000	1000	1000	2000	2000	1000	1000	4000
Sample origin [digester height]	Effluent	Effluent	Effluent					Effluent	Effluent	Effluent	Effluent	Effluent	Effluent	Effluent
status	working	working	working	not working inlet (dogs)	not working	not working	not working	inlet blocked	gas-tab broken	overfed, flushing	working, inlet bit blocked	working	inlet blocked	working, new
pH	6.26	6.78	6.47					7.6	6.48	4.15	6.88	6.31	6.61	6.46
Temperature [°C]	33	30.8	28.6					36	31.3	31.8	33.5	33.2	31.3	31.2
Redox [mV]	-503	-270	-420					37	-312	-182	-437	-455	-174	-366
TS [g/l]	**1.63**	**3.68**	**2.25**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**2.42**	**#DIV/0!**	**17.47**	**3.07**	**1.79**	**8.83**
TS [%]	**0.16**	**0.37**	**0.22**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**0.24**	**#DIV/0!**	**1.75**	**0.31**	**0.18**	**0.88**
VS [g/l]	**0.968**	**2.255**	**1.261**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**1.318**	**#DIV/0!**	**11.124**	**1.800**	**0.981**	**7.351**
VS [%]	**59.26**	**61.34**	**56.10**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**54.55**	**#DIV/0!**	**63.69**	**58.56**	**54.84**	**83.30**
weight crucible [g]	46.371	28.627	29.264						34.666		29.779	28.631	30.525	50.123
weight filled [g]	95.940	60.999	65.739						84.749		61.152	64.745	65.182	102.359
weight sample [g]	49.569	32.372	36.475	0.000	0.000	0.000	0.000	0.000	50.083	0.000	31.373	36.114	34.657	52.236
weight total after 105°C [g]	46.452	28.746	29.346						34.787		30.327	28.742	30.587	50.584
weight sample after 105°C [g]	0.081	0.119	0.082	0.000	0.000	0.000	0.000	0.000	0.121	0.000	0.548	0.111	0.062	0.461
weight total after 550°C [g]	46.404	28.673	29.3						34.721		29.978	28.677	30.553	50.2
weight sample after 550°C [g]	0.033	0.046	0.036	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.199	0.046	0.028	0.077
COD total [mg/l]	**3270**	**3340**	**790**	**0**	**0**	**0**	**0**	**0**	**2640**	**0**	**5640**	**1130**	**2020**	**#WERT!**
Dilution factor	10	10	10	10	10	10	10	10	10	10	10	10	10	10
intermediate result [mg/l]	327	334	79						264		564	113	202	overrange
NH4-N [mg/l]	**95.5**	**93**	**117**	**0**	**0**	**0**	**0**	**364**	**119**	**63.5**	**312**	**73**	**67.5**	**45**
Dilution factor	50	50	50					200	50	50	200	50	50	50
intermediate result [mg/l]	1.91	1.86	2.34					1.82	2.38	1.27	1.56	1.46	1.35	0.9
Ntot [mg/l]														
Ptot [mg/l]	**78.0**	**166.0**	**244.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**94.0**	**0.0**	**304.0**	**272.0**	**368.0**	**314.0**
Dilution factor	200	200	200					200	200	200	200	200	200	200
intermediate result [mg/l]	0.39	0.83	1.22						0.47		1.52	1.36	1.84	1.57
Pb [mg/l]		**0.036**	**0.08**						**0.136**					
Cu [mg/l]		**0**	**0.021**						**0.018**					
Cd [mg/l]		**0.003**	**0.005**						**0**					
VFA/TAC ratio [Nordmann]	**0.09**	**0.05**	**0.11**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**0.09**	**0.11**	**#DIV/0!**	**0.12**	**0.11**	**0.15**	**0.65**
Init.pH (50ml Sple+50ml dist.H2O)	6.52	7.22	7.21					7.88	6.63		7.06	6.98	6.76	6.18
H2SO4 (0.1N) Initial pH - pH 5 [ml]	6.3	12	11.8					17.8	8.2		24.1	8.5	8.1	6.5
H2SO4 (0.1N) pH5 - pH 4.4 [ml]	0.4	0.4	0.6					0.7	0.5		1.1	0.5	0.6	1.5
VFA (Nordmann) [mg/l]	57.8	57.8	124.2	-75	-75	-75	-75	157.4	91	-75	290.2	91	124.2	423
TAC [mg/l]	630	1200	1180	0	0	0	0	1780	820	0	2410	850	810	650

In

Date	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008	27.10.2008
Origin of Sample (ARTI-#)	#1	#2	#3	#4	#5	#6	#7	#14	#15	#17	#18	#24	#25	#26
	ARTI office	Mr.Potnis	Mr.Raphael(son)	Kasianjo	Prof. Beda	Mr.Fabian	Mr.Theodor	Prof.Kohi	Mama Lena	Mama Sijaoana	Mr.Mwaipaja	ARDHI	FeedTchildren	Azania
Digester size	1000	1000	1000	1000	1000	1000	1000	1000	1000	2000	2000	1000	1000	4000
status	working	working	working	working	working	not working	working	not working	working	working	working	working	working	working, new
pH	6.5	7.5	7	6.5	5	<5	7	7	6.5	5	6.5	6.5	7	6.5
remarks		new platform	H2Oheater	stove not con.		overfed	4th time new	rural (pigfood)	H2O drain				H2Odrain	

Questionnaire for User of ARTI–Compact Biogas plant in Tanzania

Date: ……..
Name of Interviewee: ……..……..……..……..
Location: ……
……Tel: ....……..
……

General information

Volume Digester: …… Volume of Gasholder: ……..
Date of Installation: …… Cost: ……...
Motivation of purchase: ……..
Knowledge of ARTI-system: ……..
Size of household: ……..
……

Feedstock

Composition: …… Origin (co-operation): ……...
Pre-treatment: ……..……
Daily amount: …… Time: ……..
Amount of Water (Dilution): ……
Responsible person for feeding (+ cooking): ..……...
Daily time effort for feeding: ……...
Former way of disposing waste: ……
……

Gas

Daily production: ……..
Hours of cooking: …… When: ……
Food cooked: …… For how many people: ……
Application of weight on gasholder: ……....
Gasholder ever fully emptied: ……
……

Energy

What energy source is substituted (former energy source): ……
Amount of substitution (kg,l): ……
Cost savings through substitution: ……
Biogas sufficient for cooking (which additional energy is used): ……
Expenses for wood/charcoal/LPF per month: ……
Differences of cooking with BG & charcoal/wood/LPG: ……
……

Effluent

Utilization: ..... Plants: ……

Experiences: ……....

……

Problems

Leaks: ……

Broken parts: ……

Blockages: ……

Stove: ……

Stop of BG-production/restarts: ……..…….

Seasonal changes/rainy season: ……..……

Flies/mosquitoes: …….

Bad odour: ……

Other problems: ……..……..

Contact/Service ARTI: ……..……...

……....

Various

Expectations fulfilled: ……..

Would you recommend it: ……..... Why (not): ……

Interest of other people: …….

Suggestions for improvement: ……....

……

……

……

……

Remarks

……

……

……

……

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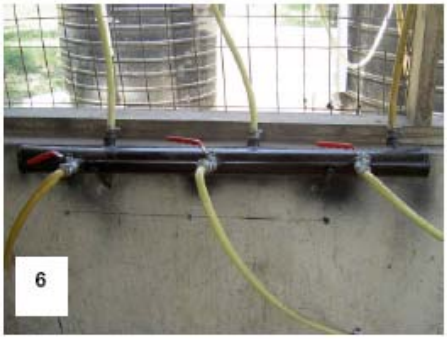
……

…….

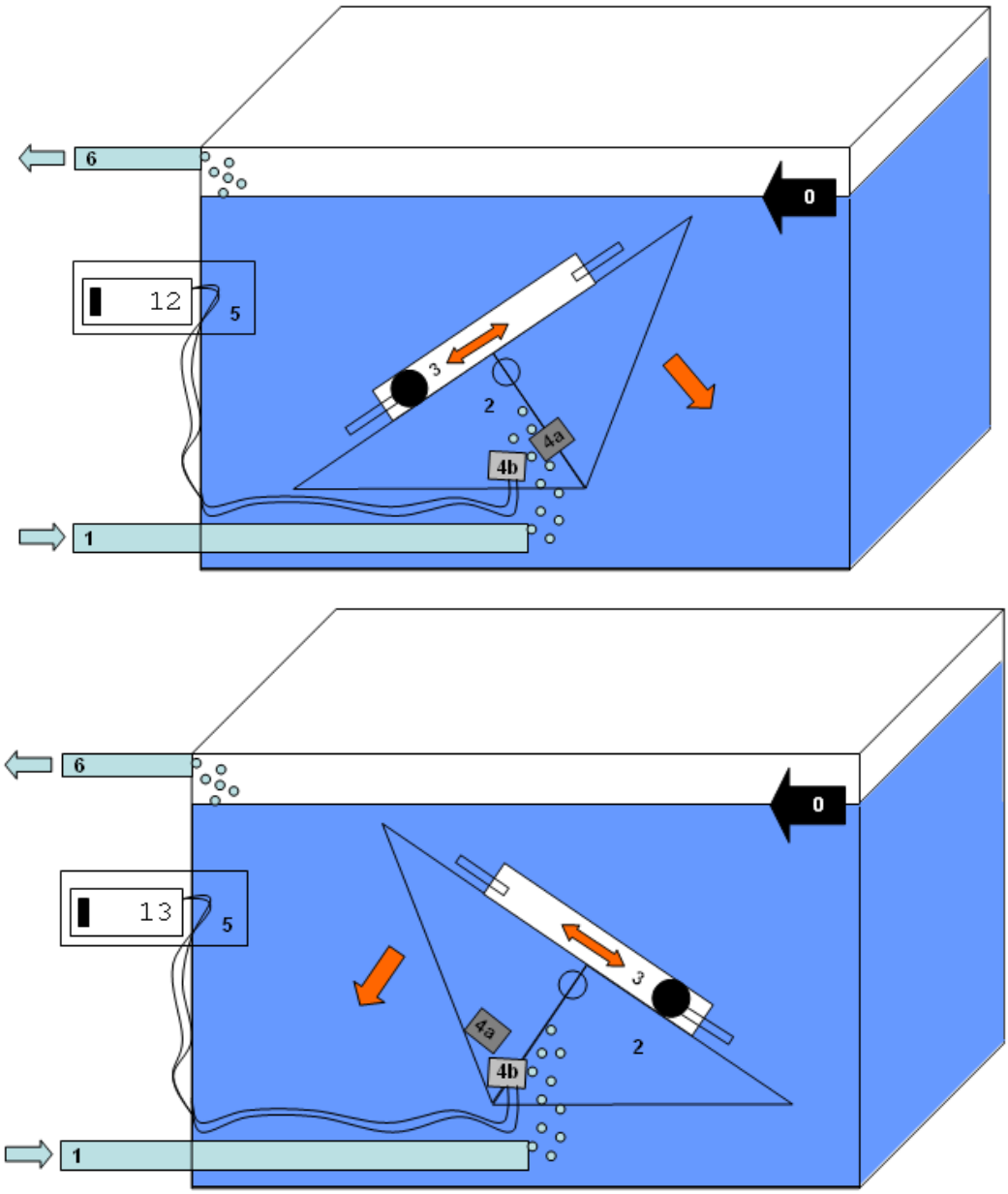
B7 Institutional ARTI CSB at AZANIA Secondary School, Dar es Salaam

1 The whole plant: three 4000l digesters with 3000l gasholder
2 Feeding platform
3 Man-hole at the overflow to avoid blockage
4 Kitchen with the 3 self-constructed biogas stoves
5 Welded stove
6 Condense water trap (water release on the down side)



C VARIOUS

C1 Rocking displacement gasmeter (scheme)

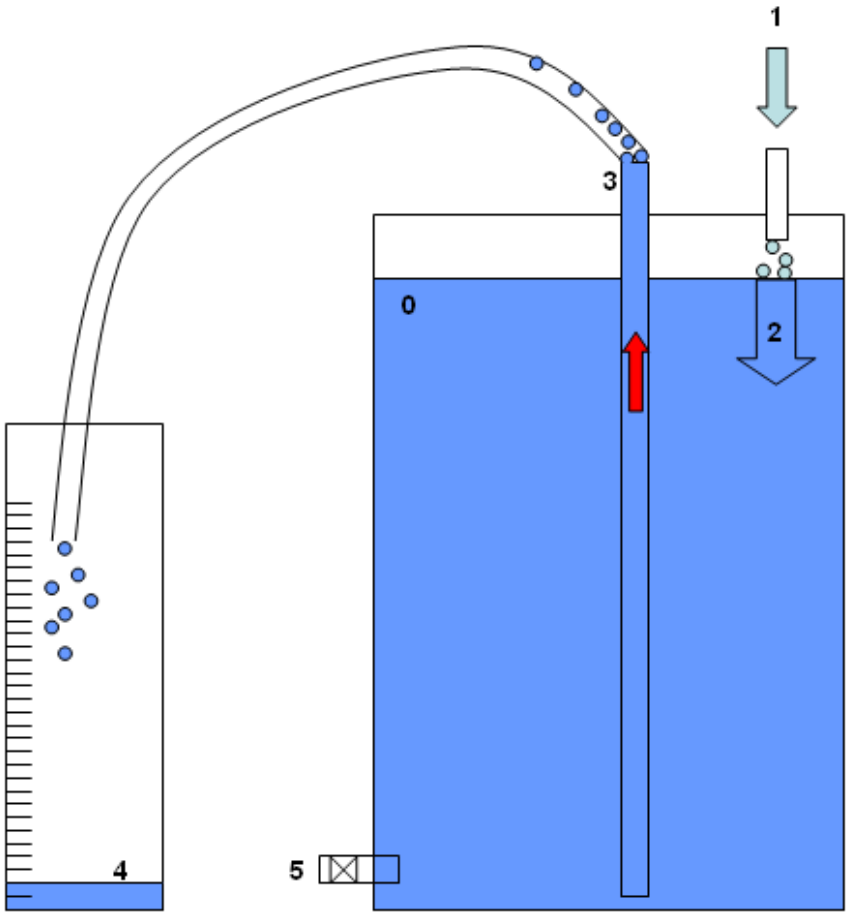


The measurement of gas quantity can be accomplished by a rocking gas meter with a defined constant gas volume, which electronically counts the number of shifts.

Legend

0	Water level
1	Gas Inlet
2	Defined volume, which can be filled with gas (zB.120ml)
3	Metal bullet in cover, prevents the rocker to only tip halfway
4 a&b	Electronic impulse transfer
5	Meter
6	Gas outlet

C2 Positive displacement (scheme)



The positive displacement method allows the measurement of water quantity per time, which is displaced by the incoming gas.

Legend

0	Airtight container, filled with water (zB. 20l)
1	Gas inlet
2	The incoming gas increases the volume whereby the water is pressed downwards
3	Water outlet with attached hose
4	Measuring cylinder, in which the displaced water lands
5	Water inlet (for the refilling of fresh water)

C3 Biogas-Versuchsanlage Trubschachen

Hintergrund

Dem Umweltingenieurstudent Christian Lohri der Zürcher Hochschule für Angewandte Wissenschaften (ZHAW) wurde als Vorbereitung für seine Bachelorarbeit in Tansania der Aufbau einer einfachen Biogas-Versuchsanlage in Trubschachen ermöglicht. Die Anlage zur Vergärung fester organischer Abfälle wurde durch Robert Wingeier (Wingeier Haustechnik AG, Trubschachen, BE) finanziert und mit tatkräftiger Unterstützung von Stefan Lukunic im Juni 2008 gemeinsam errichtet.

Aufbau (siehe Plan)

Die Biogasanlage besteht aus einem PE-Fermenter ($1m^3$) mit manuellem Rührwerk und angeschlossenem Gasfolienspeicher ($1.2m^3$). Um die Temperaturschwankungen zu minimieren wurde der Fermenter mit Glaswolle isoliert, einer Wellblechwand verkleidet und einem Deckel aus verzinktem Stahlblech abgedeckt. Das Einlassrohr zur Fütterung der Bakterien sowie das Überlaufsrohr wurden aus Geberitrohr angefertigt. Das manuelle Rührwerk zur Durchmischung des Fermenterinhaltes und zur Aufbrechung eines allfälligen Schwimmdeckels wurde mit einer Stopfbüchse montiert (siehe Detailansicht). Zur Überwachung des Druckes wurde am Fermenter ein Manometer angebracht. Die Verbindung zum Folienspeicher besteht aus einer 8mm-Gasleitung, an welcher dank zwei 3-Weghähnen verschiedene Gasmessgeräte angebracht werden können. Der aufblasbare Folienspeicher befindet sich in einem Metallgerüst, wobei das darin enthaltene Gas mittels aufgetragenen Gewichten komprimiert werden kann.

Kosten

Der PE-Fermenter der Firma Hug&Zollet AG, Bösingen (FR) kostete rund CHF 1000.-, ebenso teuer war der Gasfolienspeicher von Sarna Plastec, Sarnen (OW). Die restlichen Materialien kosteten ebenfalls knapp CHF 1000.-. Summa summarum belaufen sich die Materialkosten der Anlage auf ca. CHF 3000.-

Unterhalt

Der Fermenter wurde einmalig mit 850 l unverdünnter, stroharmer Rindergülle gefüllt, um die zur Biogasproduktion notwendigen Bakterien einzubringen. Diese wurden täglich mit 1-2kg organischer Abfälle (Rüstabfälle und Speisereste) gefüttert, was Biogasmengen von 200-300l pro Tag ergaben. Idealerweise wird die Fütterungsmenge in 2-3 Tranchen pro Tag zugegeben und vorgängig mit Hilfe eines Küchenmixers zerkleinert. Um zu verhindern, dass die frisch zugegebene Masse im Einlaufrohr steckenbleibt und sich im Fermenter nicht durchmischt, werden nach jeder Fütterung 2-3 Kessel Fermenterinhalt nachgeschüttet. Da das flüssige Fermentervolumen durch die Höhe des Überlaufrohres vorgegeben ist (850l) entweicht bei jeder Fütterung die zugegebene Menge des Fermenterinhaltes, welche als nährstoffreicher Pflanzendünger (Stickstoff und Phosphor) genutzt werden kann.

Mit einer Kombisonde wurden täglich der pH-Wert (ca. 7), die Temperatur (zwischen 20 und 25°C) und das Redoxpotential (um -350mV) des Fermenterinhaltes gemessen und festgehalten.

Biogas

Bei zugegebenen 1-2kg organischen Abfällen (Feuchtmasse) ergaben die Gasmengenmessungen Resultate zwischen 200 und 300l Gas pro Tag (bei einem Trockensubstanzanteil von 20% entspricht dies ca.0.2 – 0.4 kg Trockensubstanz).

Folgende Rechnungen zeigen, dass die tägliche Fütterung bis auf maximal 30kg Frischmasse hochgefahren werden können, wodurch eine tägliche Gasproduktion von ca.$2.5m^3$ zu erwarten wäre.

Aufenthaltszeit: Reaktorvolumen / zugeführtes Substrat
$0.85\ m^3$ / ($0.03m^3$ / Tag) = 28 Tage

Gaspotential: 30kg Frischmasse mit 20%Trockensubstanz ergeben 6kg Trockensubstanz / Tag / $0.85m^3$ Flüssigvolumen
→ 7.1 kg Trockensubstanz / m3 / Tag

Bei 500l Gas pro kg Trockensubstanz ist dabei täglich mit $3.5m^3$ Biogas zu rechnen

Die Gaszusammensetzung betrug einen Monat nach Instandsetzung 60% Methan, 30% Kohlendioxid, 0.5% Sauerstoff, 25 ppm Schwefelwasserstoff. Die restlichen 9-10% setzen sich vorwiegend aus Wasserdampf zusammen.

Durch einen angeschlossenen Gasgrill kann das Biogas zum Kochen gebraucht werden. Geplant ist, dass ein biogasbetriebener Durchlauferhitzer die Energie in einem Wasserbecken speichern wird (Heizwert von Biogas: 4-7kWh/m^3, abhängig vom Methangehalt).

Hinweise

- Es muss darauf geachtet werden, dass der Fermenter, der Gasspeicher und die Übergänge absolut gasdicht sind.
- Um den Fermenterinhalt auf einen optimalen pH-Wert von 7-7.5 zu heben wurde 30% Natronlauge zugegeben.
- Die Biogasproduktion hängt in erster Linie ab von der Substratzusammensetzung, der Gärtemperatur und der Aufenthalts zeit des Substrates im Fermenter.
- Das Temperaturoptimum von 36°C ist in der Schweiz ohne externe Energiezuführung kaum zu erreichen. Folgedessen wird versucht, den Temperaturunterschied zwischen Tag und Nacht durch Isolation so gering wie möglich zu halten.
- Der FOS/TAC-Wert (Flüchtige Organische Säuren / Total Anorganic Carbon) ist eine hilfreiche Kenngrösse zum frühzeitigen Erkennen von biologischen Störungen und kann mit Hilfe einer Titration durchgeführt werden.
- Ein Überdruckventil sollte am Fermenter montiert sein, welches sich bei einem Druck von 50mbar öffnet und das Gas freigibt. Weil sich bis zum Erreichen dieses Druckes die Flüssigkeit im Fermenter um 50cm gesenkt, bzw. im Einlauf- und Überlaufrohr um 50cm angehoben hat, muss darauf geachtet werden, dass diese zwei Rohre 50cm über die Gärflüssigkeitsoberfläche ragen.
- Es wird beabsichtigt, einen Kondenswasserabscheider gefüllt mit Eisengranulat zwischen Fermenter und Gasspeicher zu installieren. Dies verhindert einerseits eine Wasseranreicherung im Gasspeicher, andererseits findet eine Entschwefelung statt, indem sich der Schwefel am Eisen bindet. Das gesättigte Filtermaterial (z.B. Stahlwolle) muss ausgetauscht oder durch Erhitzen regeneriert werden. Bei der Verwendung des Biogases in einer geschlossenen Küche ist das Gas unbedingt zu entschwefeln.
- Überschüssiges Gas sollte stets sauber abgeflammt werden, da es sich dabei um ein starkes Treibhausgas handelt.
- Um die Biogasproduktion von unterschiedlichen Substraten zu testen, können Ballonversuche durchgeführt werden. Dabei werden 1.5l PET-Flaschen mit Fermenterinhalt gefüllt und den einzelnen Flaschen unterschiedliche Substrate beigemischt. Daraufhin werden die Ballone luftdicht an den Flaschen befestigt. In den folgenden Tagen kann die Gasentwicklung anhand der Ballonfüllung beobachtet werden.
- Im Winter produzieren die Bakterien aufgrund der tiefen Temperaturen kaum Gas und werden in ihrer Anzahl dezimiert. (Gefrieren des Fermenterinhaltes vermeiden). Im Frühling kann die Anlage mit sorgfältig steigender Fütterung wieder in Betrieb gebracht werden.

Kontakt

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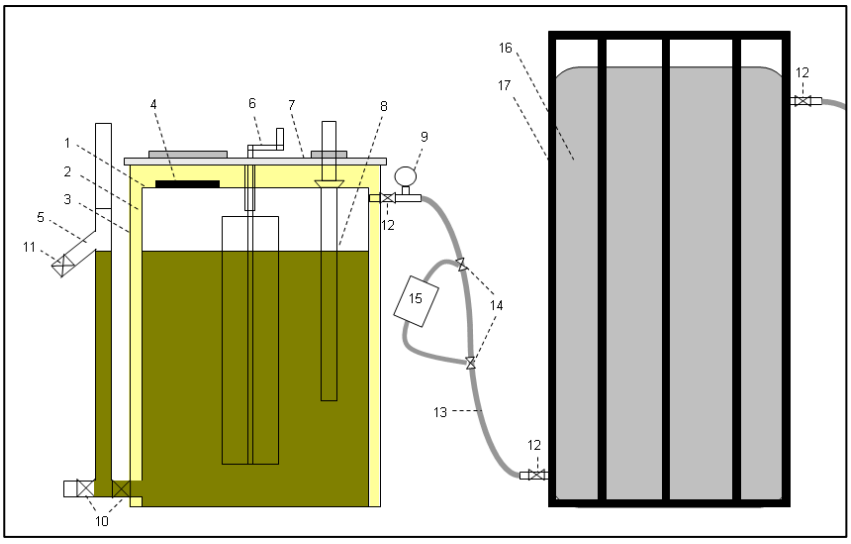
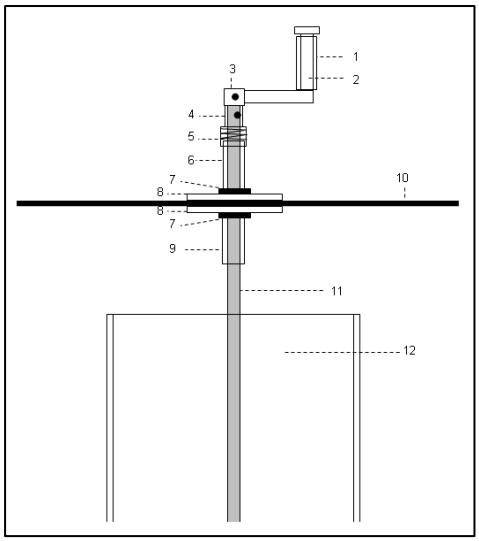
Christian Riu Lohri, Stadelstrasse 23, 6048 Horw, Tel: 041 340 39 06, riu.lohri@gmail.com





1	Fermenter: PE-Tank transparent 1000l (1350mm, Ø 1080mm, 8mm dick)
2	Glaswolle
3	Welllblechabdeckung
4	Fermenterdeckel Ø 410mm
5	Überlaufrohr Geberit Ø 63mm, auf der Höhe von 850l
6	Kurbel für manuelles Rührwerk (Inox 340mm*900mm*1mm)
7	Deckel aus verzinktem Stahlblech (Ø 1250mm)
8	Einlassrohr Geberit (800mm+300mm, Ø 63mm)
9	Manometer mbar
10	2“ Kugelhahn
11	1½“ Kugelhahn
12	½“ Kugelhahn
13	Gasschlauch (Ø 8mm)
14	3-Weg Kunsstoffhahn
15	anschliessbare Gasmessgeräte
16	Gasfolienspeicher 1200l (1500mm, Ø 1000mm)
17	Gasspeichergerüst aus Wasserrohr ½“ (1820mm)

1	Rohr Inox (Ø 17mm)
2	Kurbel Inox (Ø 14mm)
3	Hülse Inox (Innen-Ø 14mm, Aussen-Ø 17mm)
4	Hülse Inox (Innen-Ø 20mm, Aussen-Ø 30mm)
5	Stopfmutter mit Stopfband (Innen-Ø 20mm, Aussen-Ø 30mm)
6	Messinghülse für Rührwerkführung Ø ?? (150mm)
7	Mutter GF ¾“
8	Flansch Stahl (100mm*100mm*1mm)
9	Messinghülse für Rührwerkführung Ø ?? (100mm)
10	Fermenterdach PE
11	Rührwerkstange Inox Ø 20mm
12	Flügel Inox mit angewinkelten Enden (900mm*170mm“1mm)

Day J.A., Harrison A.D., de Moor I.J. (2003): Guides to the freshwater invertebrates of southern Africa, Volume9: Diptera; Water Research Commission, South Africa

CHAPTER 4

CULICIDAE

by

M. Coetzee

The mosquitoes belong to the family Culicidae of the suborder Nematocera. Adults can be distinguished from other similar flies by the conspicuous, forwardly-projecting proboscis, numerous appressed scales on the body, legs and wing veins, and a fringe of scales along the posterior margins of the wings (Service, 1980). Mosquitoes play an important role in the transmission of human diseases such as malaria, filariasis and various arboviruses. Hence they are one of the best studied families within the Diptera. Only female mosquitoes suck blood as they need the protein to develop their eggs. Not all species are blood-suckers, however, and indeed, all females of the subfamily Toxorhynchitinae need only the nectar of flowers in order to develop egg batches. Male mosquitoes do not have mouthparts that are adapted for piercing skin and therefore do not suck blood. Males can be distinguished from females by their very hairy antennae. Mosquito larvae are recognized by having a distinct head, thorax and segmented abdomen.

THE SOUTHERN AFRICAN CULICID FAUNA

Mosquitoes are classified into the Order Diptera, Family Culicidae and three subfamilies —Anophelinae, Toxorhynchitinae and Culicinae (Knight & Stone, 1977). In southern Africa (i.e. south of the Zambezi River) there are more than 220 species of mosquitoes belonging to 13 genera arranged in all three subfamilies (Gillies & Coetzee, 1987; Jupp, 1996). This is fairly well representative of the general mosquito fauna in the African region. There are no genera endemic to southern Africa and only about 30 species endemic to the sub-region. Adult females are easily identified to subfamily by posture, the shape of the proboscis and the length of the maxillary palps (Figs 4.1A–C).

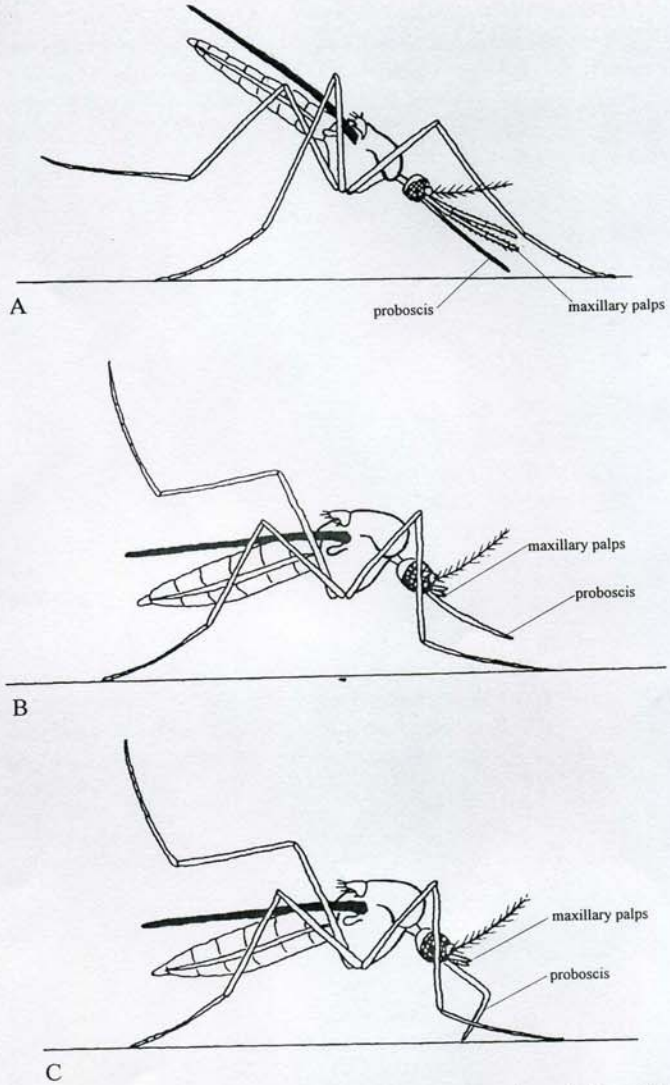


Fig. 4.1. Typical body shapes and resting positions of adult mosquitoes. **A**, anopheline—with abdomen at an angle of 45° to substrate and maxillary palps as long as proboscis; **B**, culicine—with abdomen parallel to substrate and maxillary palps shorter than proboscis; **C**, toxorhynchitine—posture similar to that of culicinines, but proboscis distinctly bent in the middle.

BIOLOGY

Some species of *Culex* can survive for long periods without laying eggs, e.g. when over-wintering. The occasional blood meal will be taken but the female will only venture out of her refuge once the environmental conditions are conducive to egg-laying. Some species of mosquitoes can lay their first batch of eggs without taking a blood meal but thereafter need a blood meal for every egg-laying. Mosquitoes of the genus *Malaya* have a curious feeding behaviour: they suck honey-dew from cocktail ants (*Crematogaster* spp.) by inserting their proboscides into the mouths of these ants when they open their jaws (Service 1990). Like *Toxorhynchites* adults, they do not need blood to develop their eggs.

Female mosquitoes can lay from 30 to 300 eggs at a time, depending on the species. Some species (e.g. of *Culex* and *Anopheles*) deposit their eggs directly onto the surface of the water (Figs 4.2A & C), while others, such as *Aedes* spp., lay their eggs just above the water level on damp substrates (Figs 4.2B). Such eggs can usually withstand desiccation. Eggs (Fig. 4.2A–C) are normally blackish in colour and ovoid, but there is considerable variation: for example, *Toxorhynchites* eggs do not turn black after being laid (Muspratt 1951), while some species of *Mansonia* have skittle-shaped eggs (Service 1980).

Mosquito larvae live in a wide range of habitats including temporary rain pools, artificial water containers, reservoirs, swamps and slow-moving streams. They are filter feeders, feeding on yeasts, bacteria, protozoans and other micro-organisms. Larvae go through four moulting stages and development from first instar larva to pupa may last from seven to 30 days depending on the species and temperature. Living larvae

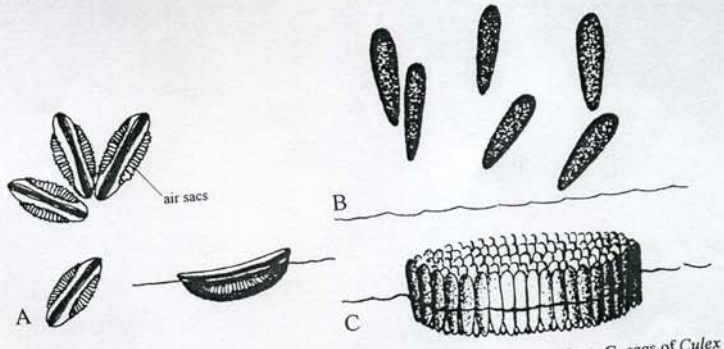


Fig. 4.2: **A**, eggs of *Anopheles*, float on water surface; **B**, eggs of *Aedes* do not float; **C**, eggs of *Culex* are laid as a raft, which floats on water surface.

of *Anopheles* can be recognized by their feeding and breathing positions at the surface of the water (Fig. 4.3A): they are surface feeders, lacking a breathing tube or siphon, and therefore lie parallel with the meniscus of the water. Culicine larvae usually browse over the substratum looking for food and only come to the surface of the water to breathe (Fig. 4.3B). Species of the genera *Mansonia* and *Coquillettidia* have highly specialized respiratory siphons (Fig. 4.6G) that pierce roots or stems of aquatic vegetation to obtain oxygen from air cells in the aerenchyma tissue of the plants.

Pupae of all mosquitoes are comma-shaped (Fig. 4.4A) and capable of brisk movement, using the paddles at the tip of the abdomen. They do not feed during this stage. They breathe through respiratory trumpets on the cephalothorax (Fig. 4.4A), pupae of *Mansonia* and *Coquillettidia* having modified trumpets (Fig. 4.8F) for breathing through plant stems. The pupal stage usually lasts two to three days.

IDENTIFICATION OF IMMATURE CULICIDAE

Larvae

Mosquito larvae (Fig. 4.5A) can be distinguished from all other dipterous larvae because they have a thorax in which all three segments are fused and which is wider than either the head or the abdomen. They also have a complete head capsule and only one pair of functional spiracles at the tip of the siphon or, in the case of the Anophelinae, at the tip of the last abdominal segment.

The head bears a pair of one-segmented lateral **antennae** (Fig. 4.5A) with an apical brush of six setae and one or more **subapical setae** (Figs 4.6D & F) that sometimes define a stouter basal portion from a more

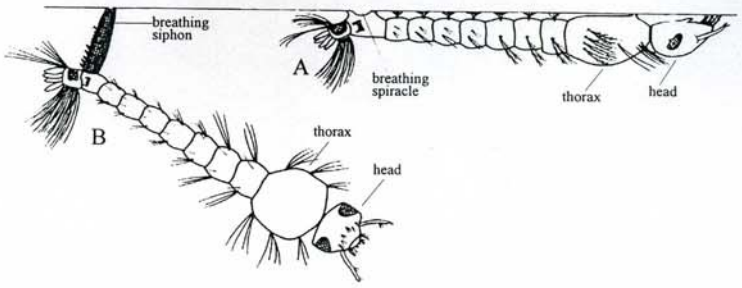


Fig. 4.3. Mosquito larvae: posture and feeding behaviour. **A**, anopheline: lying parallel with the meniscus of the water and feeding from the surface. **B**, culicine: breathing through a siphon, with head hanging downwards and feeding from deeper waters.

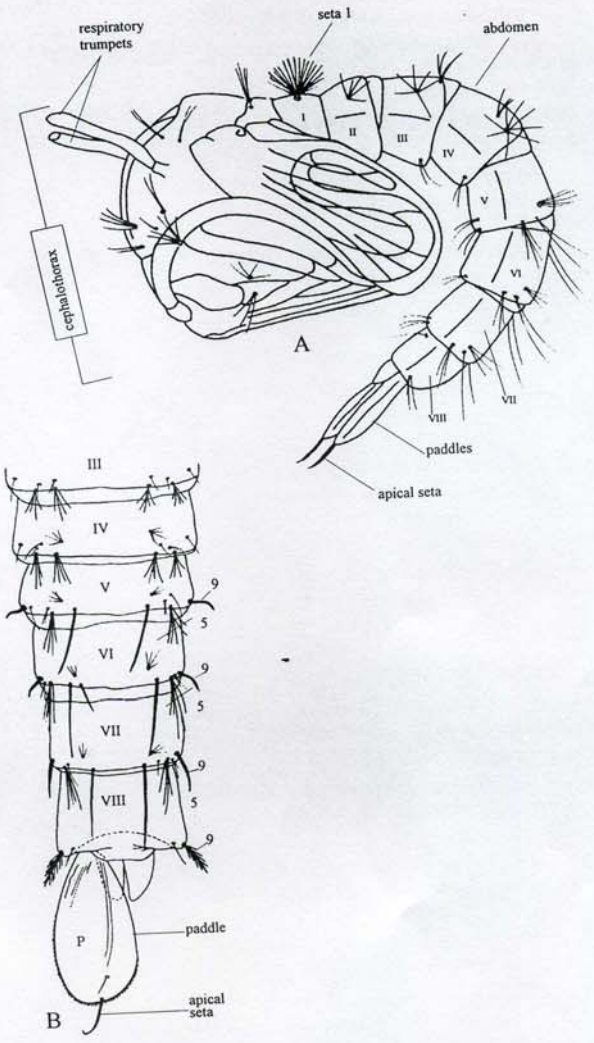


Fig. 4.4. Typical mosquito pupa: **A**, whole animal (lateral view); **B**, abdomen (dorsal view).

flexible distal portion. Mosquitoes are particle/filter feeders, the mouthparts bearing lateral **palatal brushes** (Fig. 4.5A) that may be modified to form a series of stout teeth (Fig. 4.6C) in predatory forms. Setae on the dorsal surface of the head may be well- (Fig. 4.6D) or poorly- (Figs 4.6F & 4.6H) developed, and may be single or branched, sometimes being many-branched (e.g. Figs 4.6D, F & H). The positions of setae are described by numbers, as indicated in Fig. 4.6F.

The **thorax** (e.g. Fig. 4.5A) consists of three fused segments.

The **abdomen** consists of ten apparent segments—the ninth being fused with the eighth—and numbered with Roman numeral I–X. The posterior end is usually asymmetrical, with a **respiratory siphon** (called the **spiracular apparatus** in Anophelinae) extending dorsally from segment VIII (Figs 4.5B, 4.5C). On the siphon, setae of taxonomic significance include the **subdorsal** and **subventral tufts** (Figs 4.7B–4.7D) and on segment X, setae, or groups of setae, numbered 1–4 (see Figs 4.7E–4.7G).

Segment VIII may bear a series of setae forming a **comb** laterally (Fig. 4.5C), while the inner (ventral) surface of the siphon usually bears another series of setae known as the **pecten** (e.g. Fig. 4.5C). The abdominal segments bear a number of setae, annotated in Arabic numerals, of which those occurring postero-laterally on the dorsal surface that are numbered '1' (e.g. Figs 4.5A & 4.6A) are of taxonomic significance at the generic level, particularly if they are **palmate** (shaped like a palm-leaf: Figs 4.5A & 4.6A). A **chitinous plate** (Fig. 4.6A) may be present on the dorsal surface of one or more abdominal segments.

Pupae

The head and thorax are united to form the **cephalothorax**, bearing a pair of **respiratory trumpets** (Fig. 4.4A), which may be flared (Fig. 4.8B) or parallel (Fig. 4.8E) at the tip. The length of the trumpet is divided into a distal **pinna** and a proximal **meatus**. The pinna is the part of the trumpet from the apex to an imaginary line drawn more or less perpendicular to the longitudinal axis at the most proximal margin of the spiracular opening, and may be modified (Fig. 4.8F). The meatus (e.g. Fig. 4.9E) is the part of the trumpet from the base to the imaginary line. The basal portion may be tracheated, i.e. have distinct transverse striations on the external surface (Fig. 4.8F, 4.9E).

The **abdomen** consists of eight obvious segments, the ninth and tenth being much reduced, sometimes visible as small lobes fused to segment VIII. Segments IX and X are usually indistinct and are normally ignored for taxonomic purposes, except in the case of *Toxorhynchites* spp. in which two distinct setae are found on Segment X (Fig. 4.8C). The positions of abdominal setae of taxonomic significance are numbered 1, 5 and 9 (Fig 4.4B). Setae 5 on segments IV to VI may be finely setose, giving the

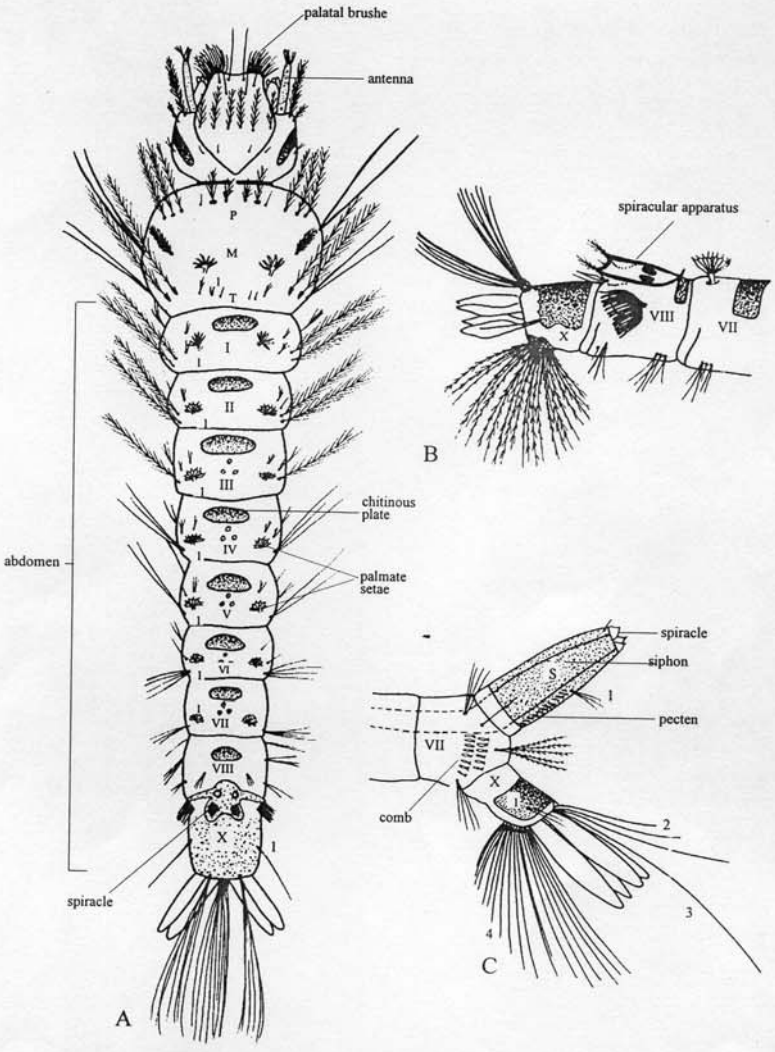


Fig. 4.5. Mosquito larvae. **A**, typical anopheline, whole animal (dorsal view). **B-- C**, terminal segments of abdomen showing breathing apparatus and salient features (note that abdominal segment IX is fused to segment VIII and is never indicated in illustrations): **B**, typical anopheline; **C**, typical culicine.

appearance of being 'frayed' (Fig. 4.8J). Posteriorly, the abdomen bears a pair of **paddles** (e.g. Figs 4.4A, 4.4B), used in swimming. Each of these may or may not bear a single large **apical seta** (e.g. Figs. 4.4B, 4.8A), have a border of fringing setae (e.g. Fig. 4.8C, 4.9B) be **cleft** (indented) at the tip (e.g. Figs. 4.8H, 4.8I) and/or be **excavated** medially near the base (e.g. Figs 4.8K, 4.9K).

KEY TO THE GENERA OF FOURTH-STAGE SOUTHERN AFRICAN CULICID LARVAE

Note: Except where specified, the genera are well represented over the whole southern African region (i.e. south of the Zambezi River). *Anopheles, Culex* and *Aedes* have the greatest number of species. The recent revision of the Culicinae and Toxorhynchitinae by Jupp (1996) is recommended for further information and that of Gillies & de Meillon (1968) and Gillies & Coetzee (1987) for the Anophelinae.

Keys and illustrations used here are adapted from Edwards (1941), Hopkins (1952) and Mattingly (1971).

SOUTHERN AFRICAN CULICID LARVAE: KEY TO TAXA

1 Respiratory siphon absent (Figs. 4.3A, 4.5B); seta 1 on most abdominal segments palmate (Figs 4.5A, 4.6A) (Subfamily **Anophelinae**) ..... *Anopheles* (*c.* 50 species)

– Siphon present (Figs 4.3B, 4.5C); seta 1 never palmate 2

2. Large lateral chitinous plate present on abdominal segment VIII (Fig. 4.6B) 3

– No such plate present (Subfamily **Culicinae**) 5

3. Palatal brushes comprise about ten strong curved spines (Fig. 4.6C); abdominal comb and pecten absent (Fig. 4.6B) (Subfamily **Toxorhynchitinae**) ..... *Toxorhynchites* (two species)

– Palatal brushes not modified as above, consisting of a large number of very fine setae (e.g. Fig. 4.5A); comb set on edge of lateral chitinous plate; pecten present or absent (Subfamily **Culicinae**) 4

4. Antennae very large, greatly flattened, about a quarter as wide as long (Fig. 4.6D); siphon with a pair of long curved spines apically (Fig. 4.6E) ..... *Aedeomyia* (two species)

– Antennae neither large nor flattened; siphon without spines apically ..... *Uranotaenia* (16 species)

5. All head setae poorly developed (Figs 4.6F, 4.6H); siphon conical with serrated saw-like processes towards the apex (Fig. 4.6G) 6

– Head setae well developed (Fig. 4.6D); siphon lacking serrated, saw-like processes towards the apex 7

Southern African psychodid fauna

Sixteen genera of Psychodinae are known from sub-Saharan Africa, represented in South Africa by twenty-three species, but probably many more await discovery. Duckhouse & Lewis (1980) comment that some South African species may show an affinity with far southern species in Australia and South America, but the bulk of the fauna is closer to that of the Palaearctic region. Of 20 recognized genera only three are endemic. Two of these genera fall within the Psychodinae. The largest genus is the cosmopolitan *Psychoda*, of which at least two species, *Psychoda alternata* and *P. severini*, are found in South African sewage purification works, together with the cosmopolitan *Clogmia albipunctata* (also known as *Telmatoscopus albipunctatus*). Large masses of sewage flies shedding wing hairs have been held responsible for causing asthma in sewage workers. *C. albipunctata* is also attracted to decaying carcasses and has been involved overseas in human myiasis (disease or injury caused by infestation by larval dipterans that are not necessarily parasitic (Smith & Thomas 1979).

Larvae of the genus *Pericoma* are found in mountain waterfalls in both the Cape Fold Belt and Drakensberg mountain ranges.

Biology

The eggs of only a few species have been described. In the genus *Psychoda* the number of eggs laid in a mass varies from 20 to more than 100. The rate of hatching varies greatly, probably depending on water temperature. Reported rates vary from 34–48 hours to 6–14 days. Larval development is rapid and the pupal stage lasts for only a few days. Thus populations can build up very quickly in sewage filters and other grossly polluted waters.

Identification of larvae and pupae

No keys are available to aquatic larvae and pupae. The most useful reference to the southern African representatives of the group is Duckhouse & Lewis (1980).

Ptychopteridae

phantom craneflies

Figs 2.6A, B

The Ptychopteridae form a very small family, similar to the true craneflies, except for a detail of the venation of the wings. Adults are usually 10–15 mm long and pale-coloured with darker wing markings. The larvae (Fig. 2.6A) are elongate and bear an unsegmented respiratory siphon

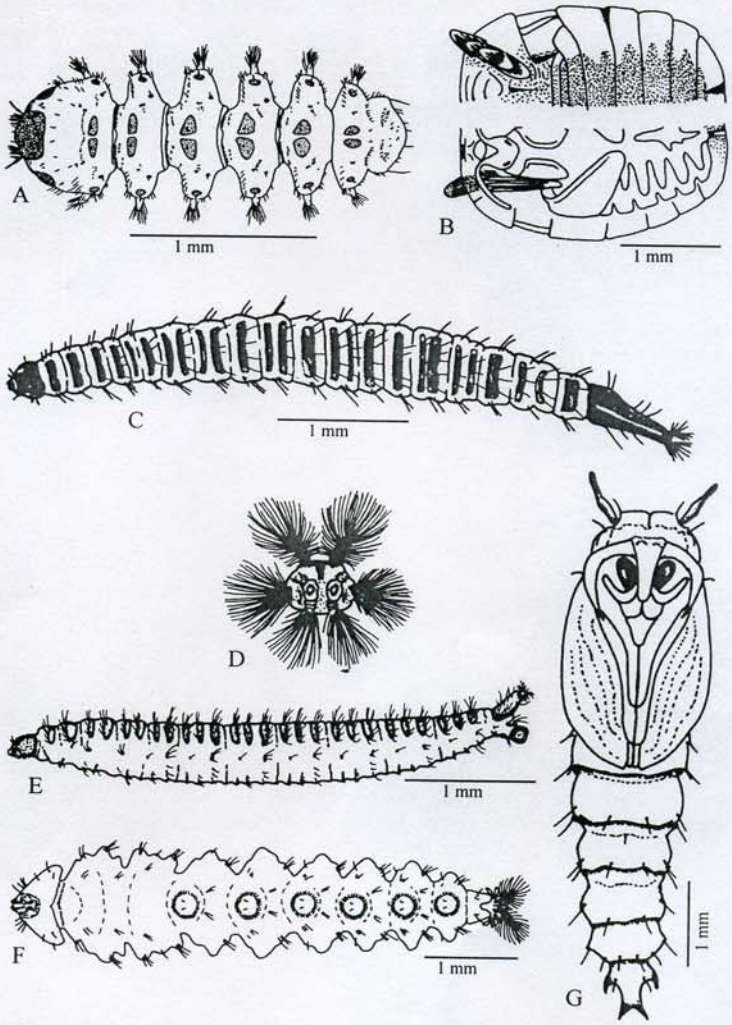


Fig. 2.5. A–B, Blephariceridae. **A,** larva of *Elporia* sp. in dorsal view; **B,** pupa of *Elporia* sp. in dorsal (upper) and ventral views. **C–G,** Psychodidae: **C–F,** larvae: **C,** *Clogmia albopunctata* in dorsal view; with **D,** spiracular disc in posterior view; **E,** *Pericoma* sp. in lateral view; **F,** *Telmatoscopus* sp. in ventral view; **G,** pupa of *Clogmia albipunctata* in ventral view. A redrawn from Stuckenberg (1955); B original; C, D, F, G redrawn from Hennig (1950); E redrawn from McAlpine et al. (1981).

piercing and sucking or sponging.

thorax, consisting of fused segments and one ir of wings. The hind pair of wings are placed by a pair of club-shaped organs, own as halteres, which are used for balance. There are three pair of legs (fore, mid, and nd).

abdomen, which is segmented.

ife cycle is one of complete metamorphosis in there is usually an egg, a larval, and a pupal from which the adult emerges,

Sandflies:	*Phlebotomus, Lutzomyia* species
Blackflies:	*Simulium* species
Horseflies:	*Chrysops* species
Midges:	*Culicoides* species
Tsetse flies:	*Glossina* species
Houseflies:	*Musca* species
Blowflies:	*Chrysomya, Cochliomyia, Cordylobia, Wohlfahrtia, Dermatobia* species

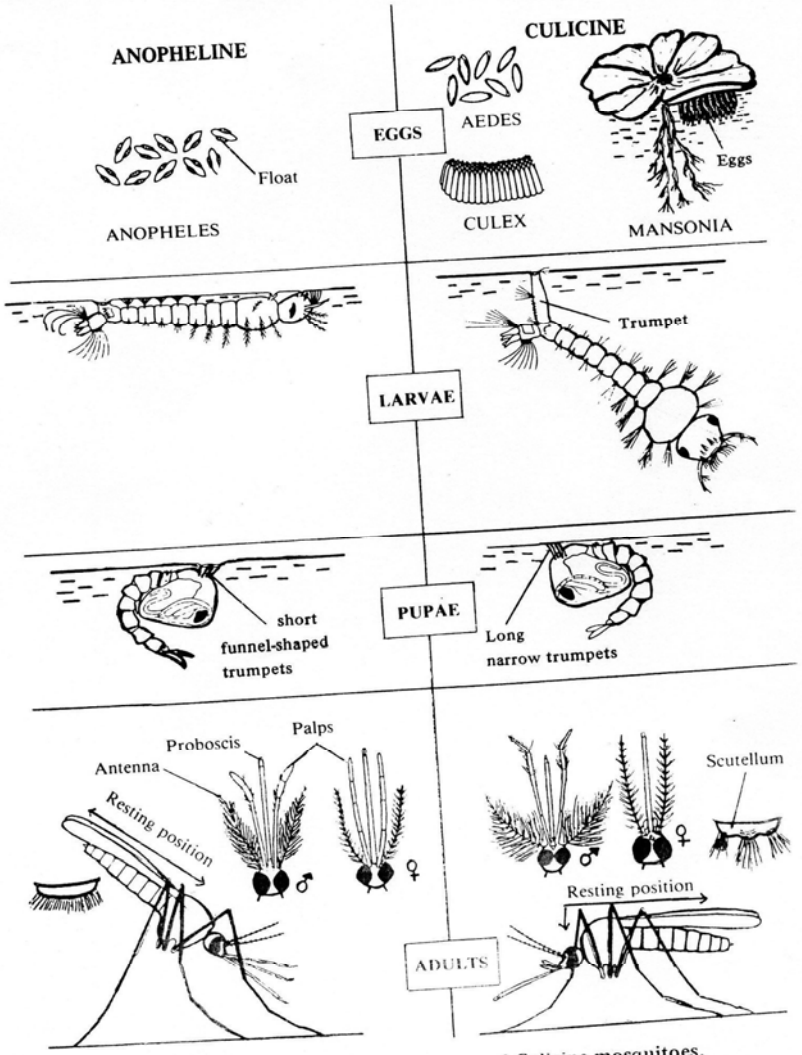


Fig. 23.1 Distinguishing features of Anopheline and Culicine mosquitoes.

mosquitos transmit malaria, dengue fever, filariasis, yellow fever and viruses

23:3 MOSQUITOES

Mosquitoes are the most widespread of the medically important insects. The tropical diseases they transmit are responsible for much illhealth and loss of human life. By frequenting human dwellings, some species are serious pests of man. Many species of mosquito, however, are more attracted to animals and do not feed from humans.

Female mosquitoes, by needing blood for egg production, are responsible for transmitting disease. Male mosquitoes do not bite and therefore they do not transmit disease. They live on plant juices.

Appearance
Mosquitoes differ from all other flies by their scaly wings and by possessing a long proboscis which in the female is adapted for piercing and sucking. They are delicate, small insects with long thin legs.

The long proboscis has a rigid palp on each side which varies in length according to sex and species (see Fig. 23.1). The antennae in the male are covered with long hairs, while the antennae of the female are less hairy.

The wings show characteristic venation and spotting with light and dark scales according to species. The thorax and legs of some mosquitoes are beautifully patterned.

Life cycle
For most species of mosquito, the life cycle from egg through the larval stage to the adult takes about 10-14 days. For *Mansonia* species the life cycle takes up to 3 weeks. Different groups of mosquitoes lay their eggs by various methods in different patterns as shown in Fig. 23.1. The lifespan of an adult mosquito is generally 3-4 weeks, although it may be reduced in nature due to natural enemies.

Classification of mosquitoes
The mosquitoes of medical importance are divided into:

- Anopheline mosquitoes which contains the important genus *Anopheles*.
- Culicine mosquitoes which contain three important genera, *Aedes*, *Culex*, and *Mansonia*.

The main differences between Anopheline and Culicine mosquitoes are shown in Fig. 23.1.

ANOPHELINE MOSQUITOES

Anopheles species
Anopheles mosquitoes are vectors of:

- Malaria
- Bancroftian and Brugian filariasis.
- Arboviruses of a few febrile and encephalitic diseases.

Feeding habits
Most *Anopheles* mosquitoes are twilight or night feeders although a few are also day feeders. Some species of *Anopheles* feed and rest indoors, some feed out of doors, while others feed indoors and rest out of doors. Anopheline mosquitoes rest with the body sloping forwards (see Fig. 23.1).

Breeding sites
The breeding sites of *Anopheles* mosquitoes are very varied. They include permanent or temporary pools, swamps, seepages, rice fields, tree-holes, ditches, and reservoirs. Some species require sunlight while others need shade for their breeding.

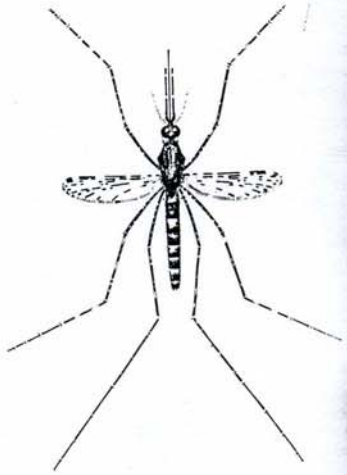


Plate 23.1 *Anopheles* mosquito *(A. gambiae).* Abou x5 true size. *Reproduced from Common African Mosquitoes and their Medical Importance, Gillett, J. D., Heineman Medical Books.*

CULICINE MOSQUITOES

***Aedes* species**
Aedes mosquitoes are vectors of:

- Bancroftian filariasis.
- Jungle and urban yellow fever.
- Dengue, including dengue haemorrhagic fever.
- Arboviruses of many febrile and encephalitic diseases such as yellow fever, Rift Valley Fever, Chikungunya, and Sindbis.

Adults are ornate with patterned legs, thorax, and abdomen (see Plate 23.2). Their wings are spotted.

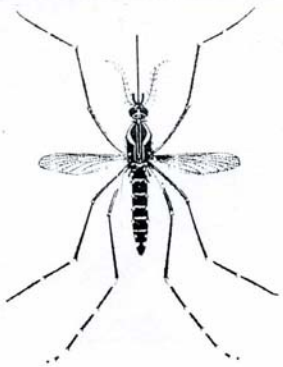


Plate 23.2 ***Aedes*** **mosquito** ***(A. aegypti).*** **About x4 true size.** *Reproduced from Common African Mosquitoes and their Medical Importance, Gillett, J. D., Heineman Medical Books.*

Feeding habits
Aedes mosquitoes feed during the day or night, indoors and out of doors.

Breeding sites
The breeding sites of *Aedes* mosquitoes include stagnant water in dark tree holes, coconut shells, old tins, bamboos, pots, axils of leaves of banana trees, or in mud holes made by land crabs. Forest mosquitoes breed high up in the trees, in holes, or in bamboos.

Culex species
Culex mosquitoes are vectors of:

- Bancroftian filariasis.

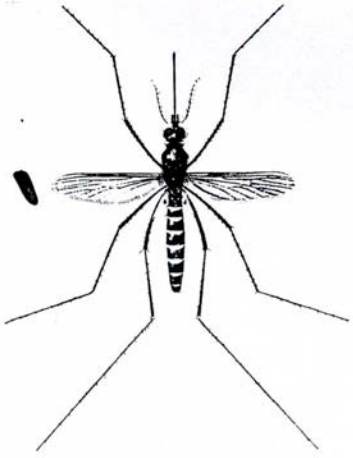


Plate 23.3 ***Culex*** **mosquito** ***(C. fatigans).*** **About x4 true size.** *Reproduced from Common African Mosquitoes and their Medical Importance, Gillett, J. D., Heineman Medical Books.*

- Arboviruses of several febrile and encephalitic diseases such as Sindbis, Spondweni, West Nile fever, Western Equine and Japanese encephalitis.

Adults are not ornate.

Feeding habits
Many *Culex* mosquitoes are attracted to animals. They are mostly indoor night feeders.

Breeding sites
Culex mosquitoes breed in latrines and in waste water containing organic material, including natural collections of water around houses, in swamps, water tanks, and in temporary muddy pools and ponds.

Mansonia species
Mansonia mosquitoes are vectors of:

- Brugian filariasis
- Bancroftian filariasis

Adults are of moderate size and strongly built.

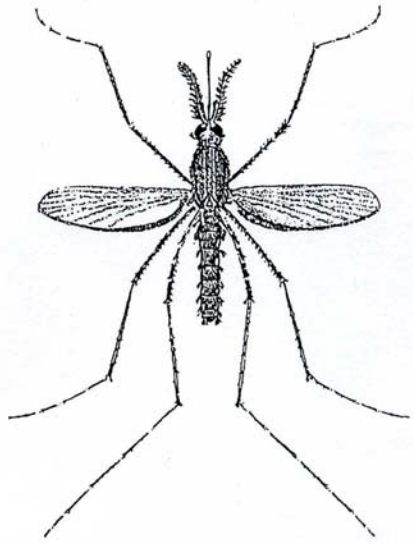


Plate 23.4 ***Mansonia*** **mosquito** ***(M. uniformis).*** **About x5 true size.** *Reproduced from Common African Mosquitoes and their Medical Importance, Gillett, J. D., Heineman Medical Books.*

They are black-brown and yellowish with a characteristic speckled appearance due to the broad asymmetrical light and dark scales which clothe their wings (see Plate 23.4). The legs show pale markings and white bands.

C5 Compost Quality Standards

EAWAG/SANDEC & Waste Concern (2006): Decentralised Composting for Cities of Low- and Middle-Income Countries, A Users' Manual, Dhaka (Bangladesh) and Dübendorf (Switzerland)

Annex 8: Compost Quality Standards

Comparison of compost quality standards for compost used in agriculture from Switzerland, India and Great Britain (2006)

Criteria	Switzerland Association of Swiss Compost Plants (ASCP)	India Indian Institute for Soil Science (04 Task Force)	Great Britain PAS 100 (BSI) and Apex-Standard*
Indicators for Maturity/ Stability			
pH	< 8.2	6.5 – 7.5	7.5 - 8.5*
Organic Matter	< 50%	> 16% C_{org}	30 - 40%*
NO_3-N/ NH_4-N ratio	> 2	—	
C/N ratio	> 21:1	20:1	15:1 - 20:1*
Dry weight	> 50%	75 – 85%	65 - 55%*
Decomposition	feedstock unrecognisable, except for wood	dark brown no odour	—
Plant compatibility	planting tests (cress, salad, beans, ...)		20% below control
Respiratory Test	—	< 15 mg CO_2-C per 100 g TOC/ day	< 16 mg CO_2/g organic matter/ day
Indicators for Nutrients			
Phosphorous (P_2O_5)	> 0.7%	0.5 – 0.8%	25 - 40 mg/l*
Potassium (K_2O)	-	1-2%	0.5 - 0.7%*
Total Nitrogen	> 1% DS**	> 0.8% DS	0.7 - 1.0%*
NO_3-N	> 40 mg/kg WS	—	15 - 120 mg/l*
NH_4-N	> 300 mg/kg WS	—	1 - 5 mg/l*
Indicators for Pollution			
Impurities	< 1%, no visible plastic, glass or metal	< 1% inert material and foreign matter	< 0.5% of total air-dried sample by mass
Cadmium (mg/kg DS)	1	5	1.5
Chromium (mg/kg DS)	100	50	100
Copper (mg/kg DS)	100	300	200
Lead (mg/kg DS)	120	300	200
Nickel (mg/kg DS)	30	50	50
Mercury (mg/kg DS)	1	2.5	1
Zinc (mg/kg DS)	400	500	400

* Apex is a voluntary standard, launched by three of the UK's biggest waste management firms.
** DS = dry solids

C6 Condense water drains

Gas hose drains for Condense water on ARTI-biogas plants on household level

The objective is to find simple solutions for ARTI-operators to avoid having to remove the hose from the gasholder each time condense water is blocking the gas hose (occurs approximately once a week when plant is fed as recommended). Frequent and improper removal of the hose leads to an increased risk of loosening or breaking the gas-tap.

(pictures on the left: Drain closed when using the gas; pictures on the right: Drain open to remove water)


Model "Triple-valve": + convenient
- valve locally unavailable, not visible when to drain, no water reservoir


Model "Hose-cast": + simple, cheap, stable
- not visible when to drain, no water reservoir


Model "PET-bottle": + cheap, visible when to drain, water reservoir (trap)
- unstable & critical transition between tube and bottle (clued), not "dog-proof" ;-)

All condense water drains need to be airtight and placed at the lowest point of the gas hose.
Before draining, it is recommended to close the gas tap on the gasholder.

Christian Lohri
20 Oct.2008

D PRESENTATION

Bachelor Thesis
Christian Lohri
Zurich University of Applied Sciences, Switzerland
Institute of Natural Resource Sciences
15 January 2009

Research on Anaerobic Digestion of Organic Solid Waste at Household Level in Dar es Salaam, Tanzania

Supervisors
Prof.Dr.Urs Baier, **ZHAW** Zurich University of Applied Sciences
Yvonne Vogel, **EAWAG** Swiss Federal Institute of Aquatic Science and Technology
SANDEC Water and Sanitation in Developing Countries

Prof. Dr. G.R. Kassenga, **ARDHI** University, Dar es Salaam
Dr. S.M Mgana, **ARDHI** University, Dar es Salaam

Content

1. Introduction

1.1 Context

- BSc Student of Natural Resource Sciences in Wädenswil
  → Bachelor Thesis
  → 5 months in Dar es Salaam for research
- **Collaboration of**

Life Sciences und Facility Management
eawag aquatic research
Sandec Water and Sanitation in Developing Countries

1. Introduction

1.2 General background and Objective

- **Rapid population growth and urbanisation worldwide**
  → increase of solid waste generation
- **Solid waste composition in developing countries**
  → up to 70% organic, biodegradable matter
- **Uncontrolled dumping**
  → uglification of living area
  → pollution of surface & groundwater
  → attraction of disease vectors
  → emission of odours and methane (major greenhouse gas)

1. Introduction

1.2 General background and Objective

- **Objective**

→ To assess the suitability of the
ARTI Compact biogas plant →→→→→
as treatment option
for organic solid waste
at household level
in urban areas
of developing countries

1. Introduction

1.3 Methodologies

- Literature review
- Installation and operation of ARTI biogas plant at ARDHI
- Laboratory analyses

Laboratory of Environmental Engineering at ARDHI

- Inspection of installed ARTI plants in DSM

2. Background information

2.1 Solid waste and energy management in DSM

- **Solid waste generation**
  2500t/d in DSM
  1360t/d by households (56% of total) → 0.4kg/c/d (2kg per average HH)
  → organic fraction: 67-78%
  (Mbuligwe&Kassenga, 2004; Kaseva&Mbuligwe, 2005)

- **Current practises**
  48% of total waste is collected
  (Kassim&Ali, 2006)

2. Background information

2.1 Solid waste and energy management in DSM

- **Energy use in Dar es Salaam**

Charcoal
- Average family (5 members): 2.8kg/day → 2 bags/month (TZS 70'000)
  → **TZS 840'000/year**

Preferences in use of cooking fuel in DSM in 2001

	First choice [% of homes]	Second choice [% of homes]	Third choice [% of homes]
Charcoal	69	25	3
Kerosene	25	53	5
Electrical power	4	6	17
LPG	1	2	0
Others	1	14	75

(Sanga, 2003)

Consequences
- Deforestation -1%/year (6kg of wood for 1kg charcoal)
- Erosion of fertile land
- Respitory health problems

(Schmitz, 2007)

2. Background information

2.3 ARTI Compact biogas system (CBS)

- **Household plant:** 1000l digester
  750l gasholder

  Set-up time: 3.5 hours
  Price: 850'000 TZS (550 €)

3. Material & methods

3.1 Feedstock and feeding plan

- Food waste
  → TS: 24%
  → VS: 91%

Students canteen ARDHI

- Market waste
  → TS: 10%
  → VS: 88%

Mwenge fruit/vegetable market

3. Material & methods

3.1 Feedstock and feeding plan

- Feeding plan/experimental design

Week	Month	Phase	Topic/Feedstock	Amount per feed [kg]	Total daily feed [kg/d]	Water feed [l]
31	July	Phase 1	Installation &start-up			
32	August		Start-up			
33			Foodwaste	0.15 - 1.0	0.3 - 2.0	ca.3
34				1.0	2.0	
35						
36	September	Phase 2				
37				0.5	1.0	
38			Marketwaste	0.5	1.0	ca.3
39				1.0	2.0	
40	October					
41			pause			
42		Phase 3	Marketwaste (max)	0.5 - 1.5	1.0 - 3.0	ca.8
43				2.0 - 2.5	4.0 - 5.0	
44	November		Foodwaste (max)	0.5 - 1.0	1.0 - 2.0	ca.8
45				1.5 - 2.0	3.0 - 4.0	
46				2.0 - 2.5	4.0 - 5.0	
47						
48		Gasholder removal: examining stratification, sludge & exact digester volume				

3. Material & methods

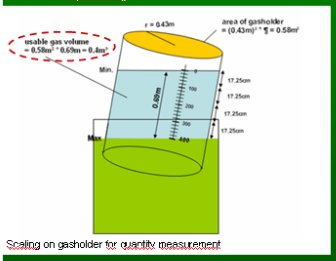
3.2 Analysed parameters

	Feedstock	Effluent
• pH	(x)	x
• Temperature	(x)	x
• Redox-Potential	(x)	x
• Total Solids (TS)	x	x
• Total Volatile Solids (VS)	x	x
• Total Chemical Oxygen Demand (CODtotal)	x	x
• Dissolved Chemical Oxygen Demand (CODdissolved)	x	x
• Ammonium-Nitrogen (NH4-N)	x	x
• Total Nitrogen (Ntotal)	x	x
• Total Phosphorus	x	x
• Orthophosphate (PO4)		x
• Heavy metals (Pb, Cd, Cu)		x
• Volatile Fatty Acids (VFA)		x
• Alkalinity		x
• Ratio VFA / Alkalinity (AVTIC)		x

3. Material & methods

3.2 Gas quantity and quality

- **Gas quantity**



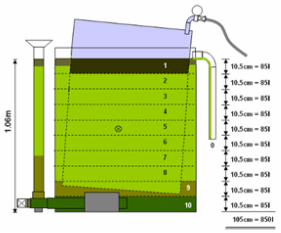
Scaling on gasholder for quantity measurement

- **Gas quality**
  → Dräger X-am 7000 (CH4, CO2, O2, H2S, NH3)

4. Results

4.1 Research plant

- **Stratification**



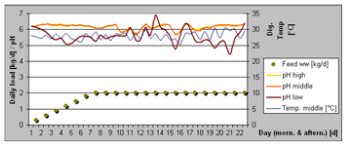
Height no.	TS [g/l]	TS [%]	VS [g/l]	VS [%]
0 effluent (high)	3.65	0.37	1.47	40.26
1 surface	74.11	7.41	60.58	42.74
2	3.33	0.33	1.42	38.71
3	3.37	0.34	1.30	38.85
4	3.62	0.36	1.41	37.24
5 middle	3.33	0.33	1.24	43.44
6	3.29	0.33	1.43	40.88
7	3.47	0.35	1.42	45.00
8	3.25	0.32	1.46	45.00
9	5.28	0.53	3.16	59.75
10 bottom (low)	41.17	4.12	32.68	79.36

Stratification of digester liquid

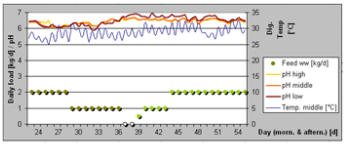
4. Results

4.1 Research plant

- **pH and temperature in digester**



Phase 1
Pure feedstock flushed with water
No feedback of effluent



Phase 2
(enhanced feeding procedure)
Mixing feedstock with water
Feedback (20l) of effluent

4. Results

4.1 Reseach plan: Reduction of waste

- **Food waste (2kg/d)**

	Influent 20l/d	Digester: Reduction	Effluent 20l/d
TS	0.482kg/d	-84.9 %	0.073kg/d
VS	0.451kg/d	-92.2 %	0.035kg/d
COD	0.567kg/d	-83.1 %	0.096kg/d

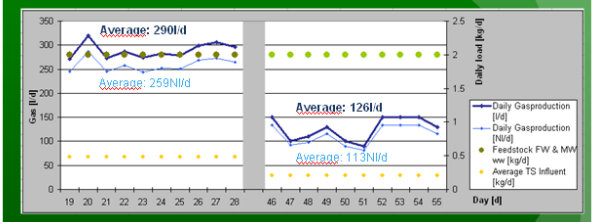
- **Market waste (2kg/d)**

	Influent 20l/d	Digester: Reduction	Effluent 20l/d
TS	0.202kg/d	-72.8 %	0.055kg/d
VS	0.178kg/d	-85.3 %	0.026kg/d
COD	0.152kg/d	-84.2 %	0.024kg/d

4. Results

4.1 Research plant

- **Gas quantity**

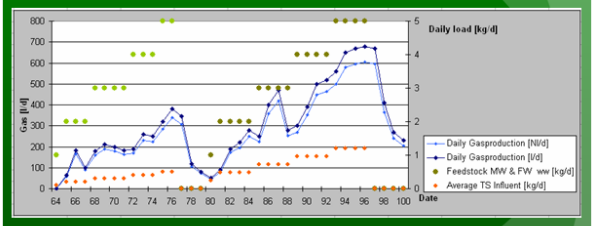


Food waste Market waste

4. Results

4.1 Research plant

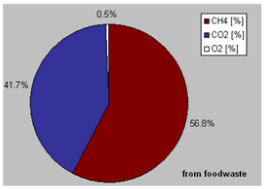
- **Proportional increase:**
  Daily feed and gas production



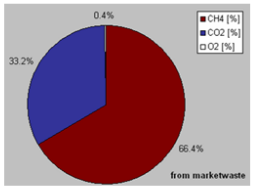
4. Results

4.1 Research plant

- **Gas quality**



H2S: >100ppm
NH3: >200ppm



H2S: >100ppm
NH3: >200ppm

Average gas composition resulting from 2kg/d FW and MW

Literature
CH4 content: **Foodwaste: 45-61%** **Marketwaste: 62%** (Eder&Schulz, 2006)
Organic fraction of solid waste: 55-60% (Mata-Alvarez, 2003)

4. Results

4.1 Research plant

- **Daily running time of burner**
- **Feedstock: 2kg kitchen waste (50% food waste, 50% market waste)**

  → 200l of biogas (61%CH4)
  → ca. 45 min of cooking/day

- Average cooking time: 2.5 hours/day/HH

  → Substitution of 1/3 of cooking time per day
  → 1/3 of daily expenses for cooking
  = 23'000 TZS/month

  → **Amortisation period of CBS: 3 years**

4. Results

4.1 Research plant

Effluent from AD of
Food waste (resp.market waste)

		Compost Quality Standards
pH:	6.3 - 6.4	< 8.2
TS:	3.7g/l (resp. 2.7g/l)	
TS:	0.3 - 0.4%	
VS:	47%	> 50%
CSB total:	5140mg/l (resp. 1380mg/l)	
C:	1800mg/l (resp. 460mg/l)	
C/N-ratio:	12 (resp. 2.4)	> 21:1
N total (TKN):	150mg/l (resp. 190mg/l)	> 1% of TS (37mg/l, resp. 27mg/l)
NH4-N:	71mg/l (resp. 86mg/l)	
P total:	248mg/l (resp. 225mg/l)	> 0.7% of TS (26mg/l, resp.19mg/l)
PO4:	171mg/l (resp. 147mg/l)	
Pb:	0.07mg/l	< 120mg/kg
Cu:	0.00mg/l	< 100mg/kg
Cd:	0.01mg/l	< 1mg/kg

4. Results

4.2 ARTI-inspection tours

- **First tour 18/19 October 2008**

Plant no.	2	3	4	5	6	7	14	15	17	18	25	30
Digester size	1000	1000	1000	1000	1000	1000	1000	1000	2000	2000	1000	1000
Inspection 20./ 21.10.2008	OK	OK	X	X	X	X	X	X	X	OK	X	OK

→ **4 out of 12 CBS in operation**

→ Poor maintenance

→ Insufficient instructions and follow-up service

4. Results

4.2 ARTI-inspection tours

- **Second tour 27 November 2008**

Inspection 27.10.2008	OK	OK	OK	OK	X	OK	X	OK	OK	OK	OK	OK

→ **10 out of 12 CBS in operation**

- **Result of**
  → Follow-up service by ARTI-TZ (for free)
  → Workshop for ARTI-technicians
  → Customer manual in English and Kiswahili

4. Results

4.2 ARTI-inspection tours

- **Invertebrates in digester**

  → Identification at Zoology Dept. (DSM University)

ca.90%
Species of *Psycodidae* family
→ engl. sewage flies
→ not biting
→ no serious disease transmitter

ca.10%
Culex species
→ Most widespread mosquito in DSM
→ vector of filarial parasites

Anopheles → not found

→ **No serious health threat**

5. Conclusion

5.1 Assessment

of the suitability of the **ARTI Compact biogas plant** as treatment option for organic solid waste at household level in urban areas of developing countries (e.g. Dar es Salaam)

- Criteria
  - → Technical aspects
  - → Economical aspects
  - → Environmental aspects
  - → Socio-cultural and political aspects
  - → Safety issues

5. Conclusion

5.1 Assessment

→ Suitability: Technical aspects

TECHNICAL ASPECTS	Very low	Low	OK	Good	Very good
Local availability of material					X
Suitability of parts used			X		
Biological performance					X
Simplicity of operation				X	
Optionality of follow-up service		X			
Climatical suitability					X
Average				X	

Biological performance	Foodwaste	Marketwaste
ARTI research plant:	572 Nl/kg VS	628 Nl/kg/ VS
Literature:	450 Nl/kg VS 400-1000 Nl/kg VS	200 – 500 Nl/kg/ VS (Eder&Schulz, 2003) 400 – 600 Nl/kg/ VS (Deublin, 2008)

5. Conclusion

5.1 Assessment

→ Suitability: Economical aspects

ECONOMICAL ASPECTS	Very low	Low	OK	Good	Very good
Widespread affordability (investment cost)	X				
Savings through energy substitution			X		
Potential market viability				X	
Poverty reduction potential	X				
Average		X			

5. Conclusion

5.1 Assessment

→ Suitability: Environmental aspects

ENVIRONMENTAL ASPECTS	Very low	Low	OK	Good	Very good
Reduction of organic waste					X
Reduction of deforestation (charcoal use)					X
Benefits from organic fertilizer					X
Awareness rising potential (nutrient circle)					X
Reduction of greenhouse gas emissions				X	
Average					X

5. Conclusion

5.1 Assessment

→ Suitability: Socio-cultural and political aspects

SOCIO-CULTURAL AND POLITICAL ASPECTS	Very low	Low	OK	Good	Very good
Acceptance and reputation of biogas					X
Awareness of waste segregation		X			
Change of daily routine			X		
Political support			X		
Average			X		

5. Conclusion

5.1 Assessment

→ Suitability: Safety issues (nuisances)

SAFETY ISSUES	Very low	Low	OK	Good	Very good
from explosion				X	
from disease spreading (mosquitoes)			X		
from toxic effects of CH4 and CO2				X	
from H2S				X	
Odour					X
Average				X	

5. Conclusion

5.1 Assessment

→ Concluding suitability overview

OVERVIEW: Suitability assessment	Very low	Low	OK	Good	Very good
Technical aspects					X
Economical aspects		X			
Environmental aspects					X
Socio-cultural and political aspects			X		
Safety issues				X	
Conclusion				X	

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Thank you!

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Mama Adela (Mwenge market)
Security guards at the site

... and everybody else for your interest!

Additional

ARTI CBS installed up to date

Quantity	Digester size	Location	Level
10	1.0m3	9 in DSM, 1 in Mbeya	Household
1	1.5m3	Kyela	Household
3	2.0m3	DSM	Household
2	3.0m3	Saadani (Safari Lodge) Mbaoala (Kinasi Lodge)	Institutional
4	2.0m3	2 on Mafia Island (Kinasi Lodge) 2 in DSM (army campus)	Institutional
3	3.0m3	DSM (Azania Sec. School)	Institutional
1	4.0m3	DSM (Bethsaida Sec. School)	Institutional
1	1.0m3	DSM (ARTI-office)	Demonstration
1	1.0m3	DSM (ARDHI University)	Research

Additional

Institutional CBS at AZANIA Secondary School, Dar es Salaam

- Sec. School with 500 students
- Three 4000l digester (gasholder 3500l)
- Twice 25kg of daily feed per plant