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Sandec
Water and Sanitation in
Developing Countries

Zürcher Hochschule
für Angewandte Wissenschaften
zh aw Life Sciences und
Facility Management

USER MANUAL

GUIDANCE FOR OPERATOR OF DRY FERMENTATION PLANTS FOR SOLID WASTE

Appendix E

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05.12.2011

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Content

I_ Introduction

The following manual should provide future managers of the considered biogas plants with all the information needed to start, maintain and end the reaction as well as give them some background information about the whole proceedure.
The guidebook of this plant aims to help nonprofessionals to generate biogas as a renewable resource to cover their energy need, without polluting the environment with additional greenhouse gases. The intention of this method also is to reduce the threat on Ghana's forests because of the use of wood fuels and to generate a use of wastes. The following user manual is a part of the outcome of a bachelor thesis by Swiss students working at K.N.U.S.T. in 2011. To understand the whole context of the plant all results of the thesis (Biogas from solid waste; development and further engineering of dry fermentation technology in Kumasi, Ghana) should be taken into account.
The documentation treats the so called single stage batch process where the plant consists of one or more fermenter assembled with a percolate system and a gas tapping part. In the beginning the feedstock is loaded into the fermenter and the door is closed. For the remaining time of the reaction the door stays closed.

Figure 1: The present pilot plant with its assembly

By that time the process, called anaerobic digestion, which is carried out by different types of bacteria degredading organic material, starts generatinf biogas. This reaction also appears naturally in some environments like moors, manure pits or land fills (Ferreira das Neves, 2009). To create the needed surroundings several conditions must be guaranteed. The first and most important is the absence of oxygen. The working bacteria can only exist in a anaerobic milieu. A further condition is a damp ambience, because the used bacteria live in liquids. Therefore a percolation system must be installed inside the plant (see chapter II_ Preparation and assembly).
The temperature of the organic material influences the time needed for the reaction. The process in this plant prevers a temperature between 30-35° Celsius (Fei-Baffoe, 2006).
The last main condition to be assured is a optimal pH which describes the acidic or basic character of the percolate. This factor should be kept at a value between 6 and 7.5 to assure the right condition for the bacteria. Ways to adjust the pH can be found in the chapter IV_ Reaction observation, treatment and troubleshooting.

During the work on the container the following points should always be kept in mind:
– Avoid sparks, make no fire
– Keep the door closed during the raction
– Let no air enter the pump
– Use both hands if opening or closing a faucet to avoid punctual load
– Control performance of the filter reguliarly
– Keep measurement devices well calibrated
– Kepp the NaOH supply dry
– Keep the electronical connections and equipment dry
– Empty the condensation trap reguliarly
– Control level in the flash back arrestor reguliarly
– Ensure a horizontal state of the gas meter
– Keep the work site clean

II_ Preparation and Assembly

This chapter is subdivided into three parts. *A.* describes the very beginning of setting up a container. *B.* attends to the assembling of the percolation system and *C.* treats the assembling of the gas tapping system.

II_A. Setting up the Container

Table 1: Short description of the assembling of the container

Describtion	Amount
Time	1-2 weeks
Workers	2-3
Site	1
Shovel	1-2
Stone plates / concrete	Ca. 15m^2
Container	1
Transportation truck	1
Welding device	1
Iron rings	17
Anti corrosion paint	3-4 gallons
Brush	2-3
Wood	3* 2,25m*5cm*1.5cm + 2*2.34m*1.5cm*1.5cm
Knive	1
Old bycicle tire	1-2
Epoxy glue	1-2

First of all the site for the plant must be found. It is important to have enough space to bring materials to the fermenter using large transporting vehicles.
When a location is available a fundament is to be prepared. The future container should be in a position to allow the percolate to exit at the container outlet. There should also be some kind of preservation to the subsidence of the container like a concrete surface or ground covered with stone plates.
The next step is to purchase a (second hand) shipping container.
The biggest abundance can be found at bigger ports like the one in Tema (Ghana).

Before buying the container several points should be checked:

- No rust or other signs of corrosion
- A good quality door sealing
- No hanging door
- A floor without gaps/ cracks
- No bumps in the walls

After guaranteeing these conditions, the transportation of the container can be started. Nevertheless it is crucial not to damage the device in any way while transporting it to the site.
If there are any ventilation holes in the container, these need to be welded up, so that no air can enter the plant anymore. Subsequently the inlet for the percolation system and its outlet as well as the gas outlet needs to be prepared. The openings must be the right size to fit a connection to a regular one inch plumbing pipe.
A further welding task is the installation of the bracket for the percolation system.
During the next phase, measures to preserve the condition of the container shall be undertaken.

The following list contains possible measures to ensure a sustainable state of the container but is not mandatory depending on the present state:

- Paint the surface (inside & outside) of the container with an anti-corrosion paint
- Renew sealing of the floor with silicone
- Install an supplementary door frame made out of wood
- Seal the left door wing with silicone
- Use rubber band (for example from an old bicycle tire) to improve air tightness of the door

The Figure above shows the construction of the percolation system as well as of the gas tapping device. The materials used for both systems mainly consist of common plumbing equipment that can be found in any plumbing store.

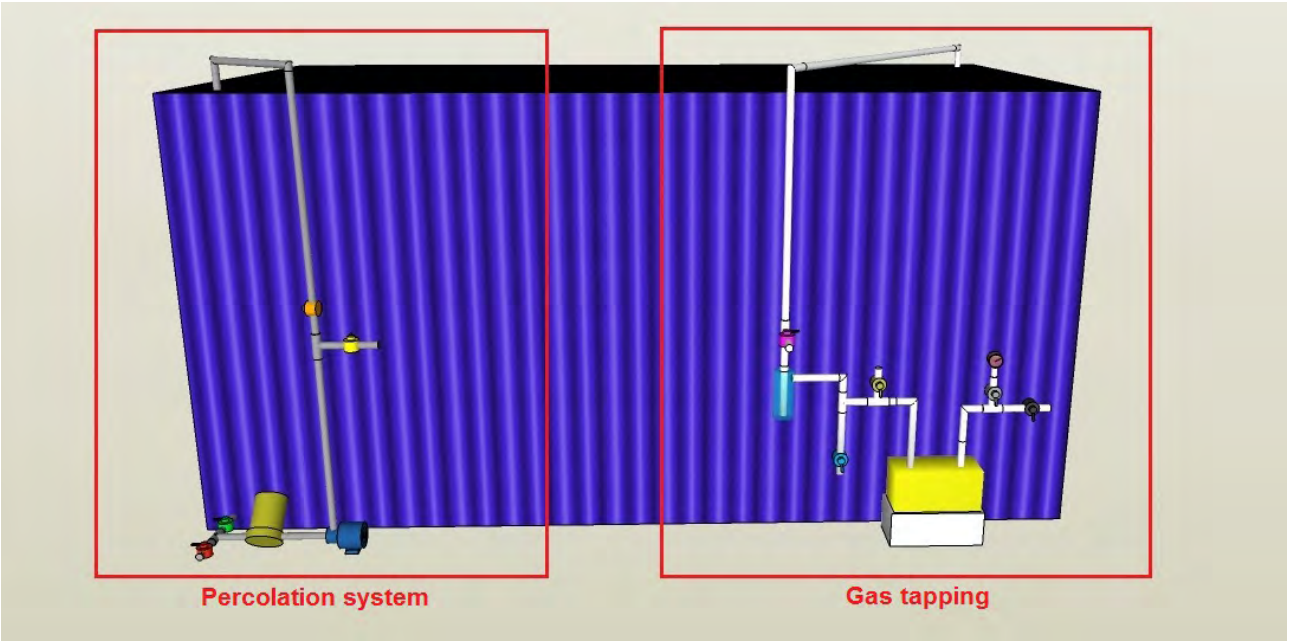

Figure 2: Model of the container with its two main work systems

II_B. Setting up the Percolation System

Table 2: List of the material used to assemble the percolation system

Describtion	Amount
Time	1-2 days
Workers	1-2
Pipe	3* 6m
Faucet	4
Percolate collection pipe	1
T-element	3
Elbow	5
Cap	2
Filter module	1
Filter	1
Pipe connection (with thread)	6
Transition part (2.5 inch to 1 inch)	1
Transition part (1 inch to 0.5 inch)	1
Pump	1
Plastc box	1
Inlet connection	2
Rubber hose	1
PVC-glue	1
Measuring tape	1
Drilling device	1

The following illustration shows the setting of the percolation system. A connection is installed between the green faucet (outlet seen on Fig.2) and the percolate collection pipe on the inside of the container (see Fig.5). The following part is a T-element which leads to the red faucet (inlet for the filling with liquid). This faucet is then connected to a transition part that is hooked up to a rubber hose. The part to the right leads to the filter compartment. It consists of a hard plastic shell with an inlet and an outlet. The percolate flows through the inlet where it passes the filter itself and exits to the right. It then enters the pump and flows up to the actual inlet of the percolation system. The pipe leading to the top of the container encloses a T-element which directs to the yellow faucet. This part is set up to take percolate samples for measurements and monitoring of the process. There is a further faucet installed above the mentioned T-element to prevent the pump from sucking air, while starting it manually. On top of the pipe there is an elbow part needed and a further piece of pipe to lead to the inlet connection. To link the inlet with the pipe an additional elbow part is put in place. Generally all parts of the percolation system (and of the gas tapping parts) which are stuck together and not screwed should be glued together with PVC- glue to make sure no leaking occurs.

Figure 3: The percolation system with flow direction

After the percolate enters the container it must be distributed over the feedstock as regularly as possible on the inside. This can be achieved by installing two pipes on the ceiling. The pipes must reach to the very back of the fermenter. They can be fixed to the roof by metal rings, which are welded to the ceiling as mentioned above (see Figure 4).

The pipes leading to the back of the fermenter contain holes on the side with a width of two mm. The punctures are positioned on the sides of the pipes and have different distances starting with 20 cm in the beginning and decreasing towards the back to 7cm. The very end of the pipes must be connected with an appropriate piece.

The inlet connection is hooked up to a pipe connection with a thread which is glued to a short piece of pipe that is connected to an elbow. After that part a further piece of pipe follows which is connected to a T-element. The one exit leads to the first percolate pipe and the second to a further piece of regular pipe. On the end of this part an elbow is attached that is connected to the second percolate pipe.

Figure 4: Percolation system inside the container

Now only one part is missing to ensure the percolate floats back to the outlet without carrying solids of relevant size to the pump. To make sure this does not happen, a percolate connection pipe should be installed on the bottom in the fore of the fermenter. This part has to be connected to a transition part that leads to the outlet of the percolate system. The pipe should also be modified by drilling holes into it (2mm). The openings will serve as the inlet of the percolate.

The pipe is comparable to a drainage where the percolate is drained out of the feedstock and then led to the outlet. With this last part the percolation system is completed.

Figure 5: The percolate outlet port (collection pipe)

II_C. Setting up the Gas Tapping System

Table 3: List of the material used to assemble the gas tapping system

Describtion	Amount
Time	1-2 days
Workers	1-2
Pipe	1* 6m
Valve	6
T-element	4
Elbow	6
Pipe connection (with thread)	1
Gas inlet connection	1
Transition part (1inch to 0.5 inch)	3
Gas meter	1
Pressure gauge	1
Dräger	1
Rubber hose	2* 0.5m
Water bottle	1
Hose clip	2
PVC-glue	1
Epoxy glue	1
Old bicycle tire	1
Knive	1

After assembling the percolation system, the gas measurements should be installed.
The outlet of the gas is located on top of the container. Next to the connection a short piece of a one inch pipe should be installed (see Figure 6) which is attached to an edge connection.

Figure 6: Gas outlet port from the container roof

Following this part a further piece of pipe is needed which is also joined to an edge part. This piece of pipe must reach to the edge of the container so that the pipe leading the gas to the measurements can be linked to it.

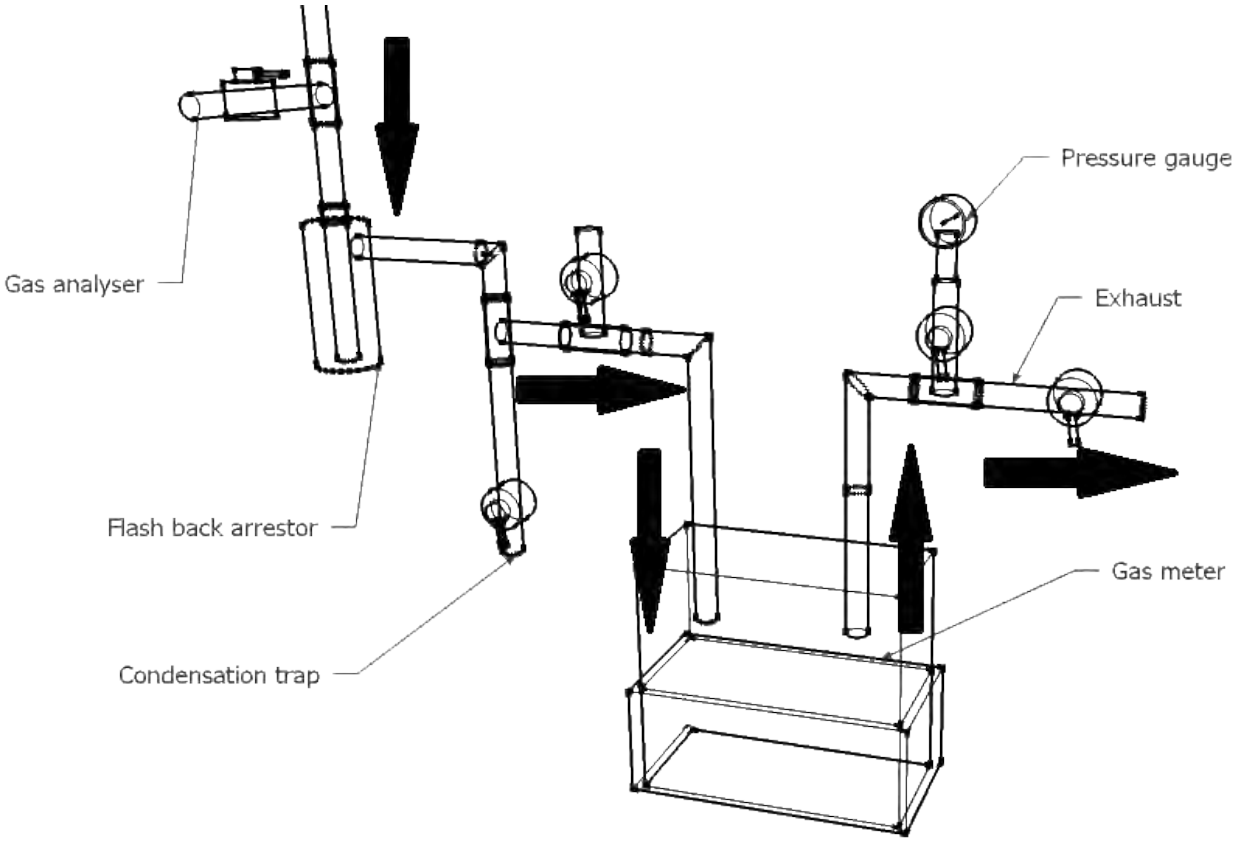

Figure 7: Model of the gas tapping system with the gas flow in black arrows

The first part of the measurements division is a faucet to control the gas flow. Following this device, a T-element leading to a piece of pipe that is connected to a further faucet is foreseen. This part is used to connect a gas analyser to the system.
Further down the pipe should be connected to the flash back arrestor (see Figure 8). This element prevents any sparks from entering the fermenter. This is achieved by letting the gas pass through water which is filled into an ordinary bottle trap. The gas enters the trap through a pipe part which is connected to the lid of the bottle trap and reaches to the bottom of the device where it exits the pipe part. It then flows up to the top of the compartment where an outlet pipe is placed. This gets connected to the condensation trap.

The gas coming from the fermenter can still contain some water (steam) which could harm the gas meter. Therefore a condensation trap is installed in advance (using a T-element) see Figure 8. This component consists of a simple piece of hose (vertical) which is followed by a piece of pipe and a valve that is used to empty the condensation trap from time to time. Both ends of the hose are connected to transition parts and should be tightened with a hose clip. The horizontal opening of the T-element is connected to an additional T-element where another faucet is positioned to link a device for gas analyses. Subsequently an elbow part is connected to the T-element which is linked to a piece of pipe. This pipe finally leads to the inlet of the gas meter see Figure 8.

The gas meter is used to count the liters of gas produced. To make sure it registers the gas flow, the gadget must be installed levelled. The inlet and outlet of the gas meter are linked to transition parts using a pipe connection with a thread on one side. The device is sheltered in a plastic box to prevent water damage. The transition part on the gas meter outlet leads to an elbow element that is connected to a short piece of pipe directing to a T-element.

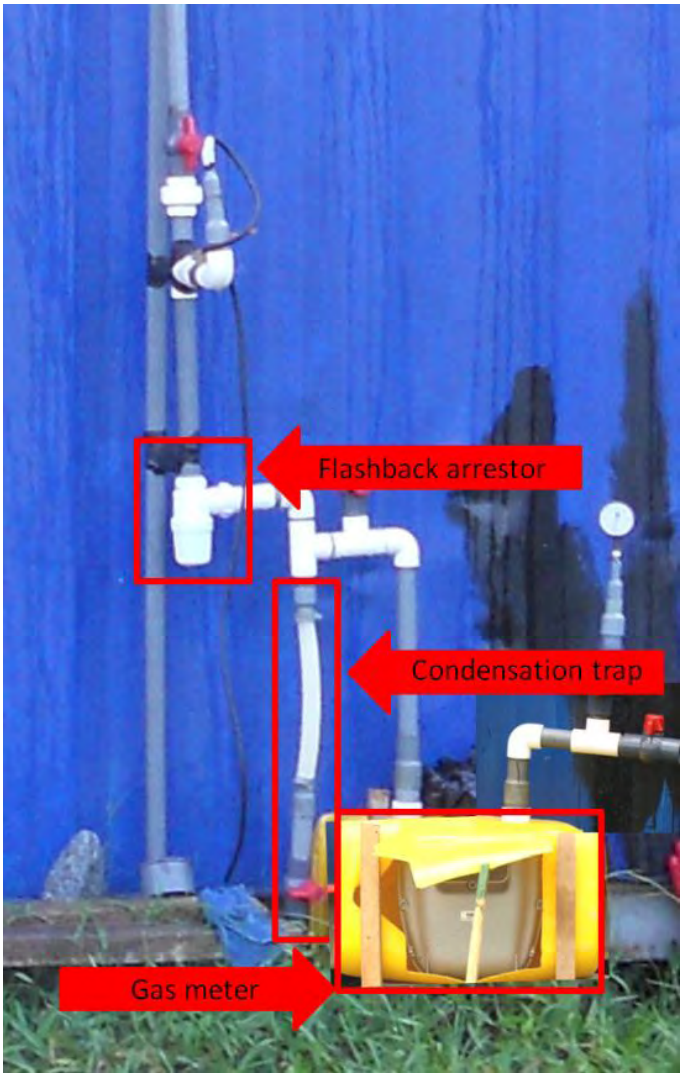

Figure 8: Gas tapping system

The last two parts of the measurements section consist of a faucet and a connection for a pressure gauge on the one opening of the T-element (see Figure 8). The final element (on the second opening of the T-element) is a faucet to control the outlet of the gas. It has to be closed for example while analysing the gas.

Finally a gas storage device could be installed as ultimate module.

III_ Loading

Table 4: Short process description with necessary materials

Describtion	Amount
Time	1 day
Workers	2-5
Wheel barrel	2-3
Peek	1-2
Showel	1-2
Silicon	2-3 tubes
Percolat outlet port	1
Lock	1

The loading of the container is the last possibility to easily take influence on the later reaction. Therefore the preparations in advance are important. As soon as all the materials are calculated and present, the loading can be startet. At this moment a representative sample including all the materials, is taken. It will be used for COD, TS and VS analysis.

Table 5: Possible contents and some estimation of their amount

Material describtion	Estimated amount
Organic waste	6-8t
Coarse woody material	10-50kg
Cow dung (can be used as inoculent)	0-8t
Inoculent (usually from previous reactions)	6-8t
Calciumcarbonate	3-6kg
Percolate (usually from previous reactions)	750-1000L
Water	750-1000L

Step 1:

The coarse and woody material if present is placed on the floor.

Step 2:

Organic waste and inoculent from previous reactions are filled into the container (if no inoculent use cow dung).

The easiest way to do this is using a weel barrel (therefore build a ramp with a wooden board to enter the container), with the help of some additional worksmen, alternately one load of each ingredient is added.

Figure 9: Loading of the container using a wheel barrel

Figure 10: Loading and preparing of layers inside the container

This leads to diagonal layers of the materials shown in Figure 11.

Step 3:

Calciumcarbonate is added to help keeping the reaction within a comfortable pH-range (pH-buffering). The whole amount is spread between the layers during the loading.

Step 4:

After loading the mentioned materials into the container, the sealing is checked.

Step 5:

The percolat outlet port is assembled.

Step 6:

Optional; To lessen pressure on to the door, right in front of it some wooden loggs can be placed. (see Figure 12)

Step 7:

Then silicon is poured on the sealing, where later the door will tighten with it.

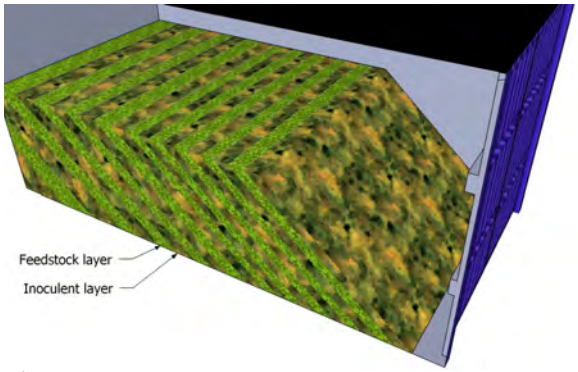

Figure 11: Modell of the loaded container

Figure 12: Loaded container after assembling the percolate outlet port

Figure 13: Silicon sealing using a silicon gun

Step 8:

The door gets closed and locked.

Figure 14: Door prepared to be closed

Step 9:

Optional. Additionaly the door can be pressed closer with a wooden block that is arrested.

Step 10:

Percolat and water are added using the percolation system. The detailed describtion of this step can be found in Reaction observation, treatment and troubleshooting, Fill the Pump with water and Adding liquids during the reaction.

Step 11:

The last thing to do is to programm the time switch that automatically controls the percolation. Then the initial state of the plant, described in Reaction observation, treatment and troubleshooting, is set (see Figure 15).

The time switch consists of 48 tiny red switches, of which each one controls the electricity during 30 min. If this red switch is positioned in the outer circle, the electricity will pass this very moment and therefore the pump will run. An additionaly switch on the side can turn the automatical mode on and off.

Figure 15: Time switch connected to the pump

IV_ Reaction Observation, Treatment and Troubleshooting

This chapter is subdivided in three parts. *A.* is the percolate system and *B.* is the gas tapping, see Figure 2. Both will be described with their standard position (initial state) in which they should be kept during ordinary process. Then the different situation like sampling for analysis purposes and other things follow. Procedures that repeatedly need to be done are marked with a red star. In the end there is part *C.* about typical errors that may occur and situation requiring a certain treatment with guideline for troubleshooting.

IV_A. Percolation System

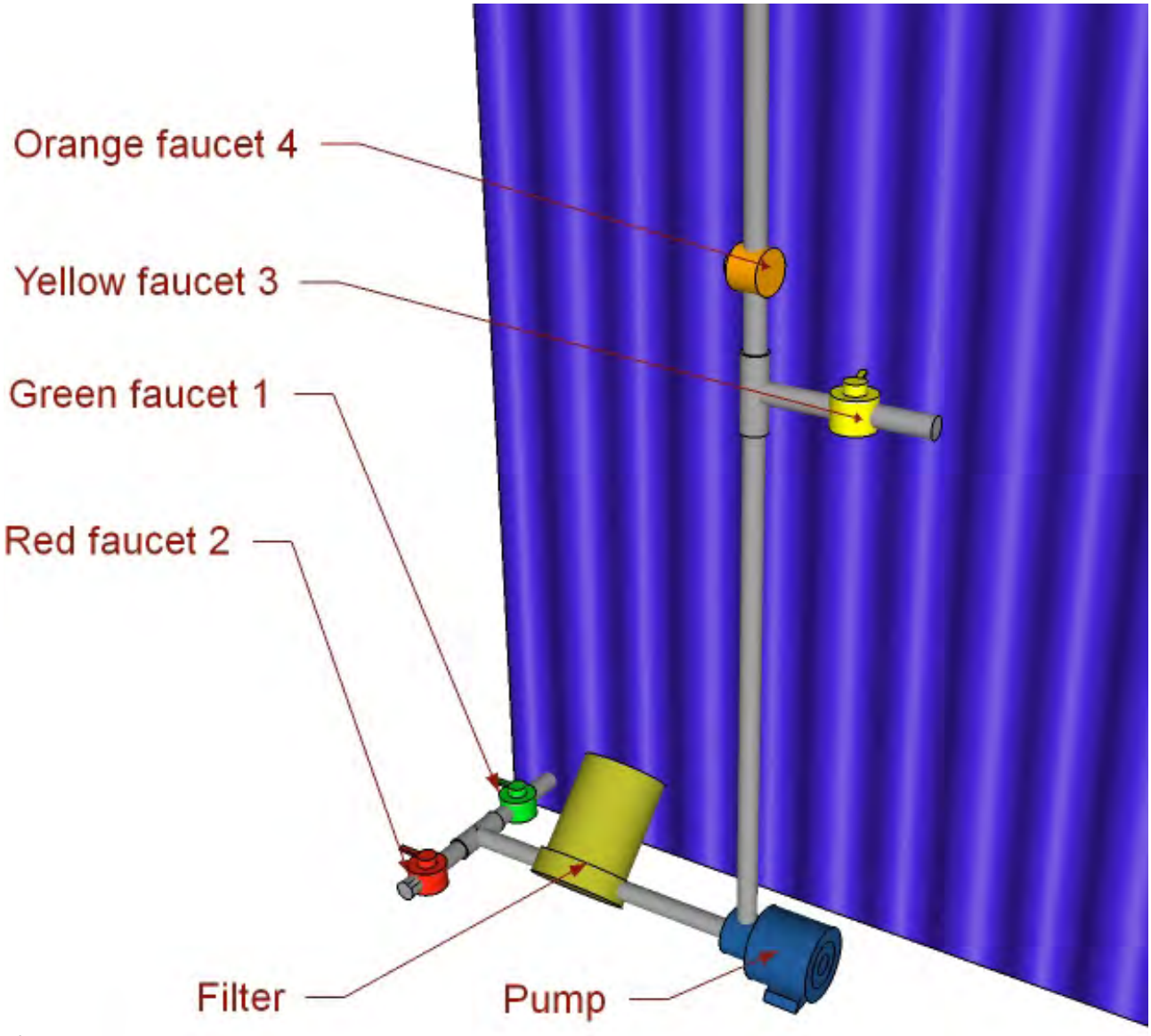

Figure 16: Model of the percolation system with legend

Initial State Percolation System

During the reaction the percolation system has to be in the following state to perform properly.

- The green faucet 1 is open.
- The red faucet 2 is closed.
- The yellow faucet 3 is closed.
- The orange faucet 4 is open.
- The filter is assembled with a functional and therefore unsoiled filter that is assembled correctly.
- The pump is connected to the electricity using the time switch. The time switch is set and turned on the automatical mode (describtion of the time switch can be found in III_ Loading, Step 11.

Float the Pump with Water

Table 6: Short description to float the pump with water

Description	Amount
Time	10 min.
Workers	1
Bucket	1
Garden hose	1 x 5m, 1x 20m

To run the percolation system the first time, before starting, the pump needs to be flooded. The easiest way to do this is by using water. Starting from the initial state the following steps have to be performed.

Step 1: A bucket of water gets filled with water from the tap near the container (app. 5m, depending on hose length).

Step 2: To the opening at the red faucet 2 a hose is connected.

Step 3: This hose is connected loosly to an other hose, witch is hocked on to a water tap. The two hoses are hocked together where the bucket of water from step 1 is placed.

Step 4: The red faucet 2 is opened.

Step 5: The water tap is opened, water runs through the hose.

Step 6: By the time the water is visible inside the filter the green faucet 1 is closed. This decreases the probability of captured air.

Step 7: The water is now pressed through the pump and fills the hole system until it exits trough the sprinkels inside the container. The pump is now floated with water and ready to be switched on.

Running the Percolation System the first Time

Table 7: Short description to run the percolate system the first time

Description	Amount
Time	30 min
Workers	2
Bucket	2
Garden hose	1 x 5m, 1x 20m

At this moment the fermenter inside is still dry and no percolate has entered. To run the fermentation, water and percolat from previous reaction will be added.

Step 1: At the moment the pump gets switched on manually, a second person has to tear the loosely connected hoses appart. This must take place inside the bucket under the water surface. To make sure the pump sucks no air.

Step 2: The previously calculated amount of water is added portionaly. By filling up one bucket up to a level that is kept note of while, the content of the other one is beeing pumped in.

Step 3: Alternately the buckets get filled and emptied, so one worker can take note of the amount that gets pumped in.

Step 4: By the time the necessary quantity is reached, the green faucet 1 is opened.

Step 5: Right after the red faucet 2 is closed.

Step 6: The percolation is running now. To reach the initial state only the set up pump has to be switched to the automatical mode (for advise see III_ Loading Step 11).

Percolat Sample * (twice a day)

Table 8: Short description to take a sample from percolate

Description	Amount
Time	5 min
Workers	1
Sample flask	1
Hach HQ40d Multimeter	1

During the reaction some (in process control) IPC has to be performed, to gain information about the reaction and its progress. The sample will be measured twice daily in pH, temperature and redox potential. App. every 7 days a COD (Chemical oxygen demand) measurement is carried out. Outgoing from the initial state the following steps have to be performed.

Figure 17: Percolate analyses in progress

Step 1: The pump is switched from automatical to manual mode and then turned on.

Step 2: The percolation starts when the sprinkling inside the container is audible, then the yellow faucet 3 is opened carefully.

Step 3: By holding the sample flask under the pipe outlet at the yellow faucet 3 app. 200-300ml of percolate is sampled.

Step 4: The yellow faucet 3 is closed.

Step 5: The pump is switched from manual to automatic mode.

Step 6: The electrode of the Hach HQ40d Multimeter is placed inside the sample, switched on and measured. (ON-button, green-Read-button)

Step 7: (every 7 days) For the COD, the sample is filled into a plastic bottle, which is labelled with the name of the sample and the date. The analysis is carried out by the civil engineering laboratory.

Adding Liquids during the Reaction

Table 9: Short description of liquid addition during the reaction

Description	Amount
Time	15 min (depending on the substance)
Workers	1
Bucket (1 x adding, 1 x water)	2
Garden hose	1
Plastic bottle	1

During the reaction it is impossible to add any solids, unless they are dissolved. Though for liquids an adding is possible over the percolation system. By the time the liquid is prepared in a bucket, starting from the initial state the following steps have to be performed to add the substances to the fermenter. Depending on the liquid the operator should wear rubber gloves and safety goggles during the adding.

Step 1: The garden hose is connected to the opening at the red faucet 2.
Step 2: Fill the hose with water until there is no air in it anymore , using a small plastic bottle of water.H
Step 3: Holding the open end closed with a finger the hose gets submerged in the liquid to be added (make sure the hose remains in place).
Step 4: The pump mode is switched from automatical to manual. The percolation starts running.
Step 5: The red faucet 2 is opened.
Step 6: The green faucet 1 is closed. The pump will now suck in the liquid over the percolation system.
Step 7: As soon as the adding has been accomplished the system should be rinsed with approximately 20 l of water (except if water has been added).
Step 8: The green faucet 2 is opened.
Step 9: The red faucet 1 is closed.
Step 10: The pump mode is switched from manual to automatical. The initital state is recreated.

Figure 18: Filling the garden hose connected to the percolation system with water

Exchange the Filter * (app. every seven days)

Table 10: Short description of exchanging the filter

Description	Amount
Time	5 min
Workers	1
Fresh filter	1

Due to the suspends in the percolate the pump is protected by a filter. This filter needs to be exchanged approximately every ten days or if pollution is visible. To exchange the filter, starting from the initial state the following steps have to be performed.

Step 1: The pump is switched from automatic to manual mode and starts running.

Step 2: As soon as the spinkling is audible the pump is switched off again.

Step 3: At once the orange faucet 4 is closed.

Step 4: The green faucet 1 is closed.

Step 5: The filter unit can be opened, the percolate inside is lost.

Step 6: The new filter is placed, ensure accurate fitting.

Step 7: The filter unit is closed thightly.

Step 8: The green faucet 1 is opened.

Step 9: The orange faucet 4 is opened, the percolate captured in the pipes float the pump and the filter.

Step 10: Test the filter by switching the pump to manual mode, and let it run. Switch it back on automatical to retrieve the initital state. By doing this, the proper function of the filter can be tested (no leaking). If this is not the case, repeat the whole procedure starting at Step 2.

IV_B. Gas Tapping

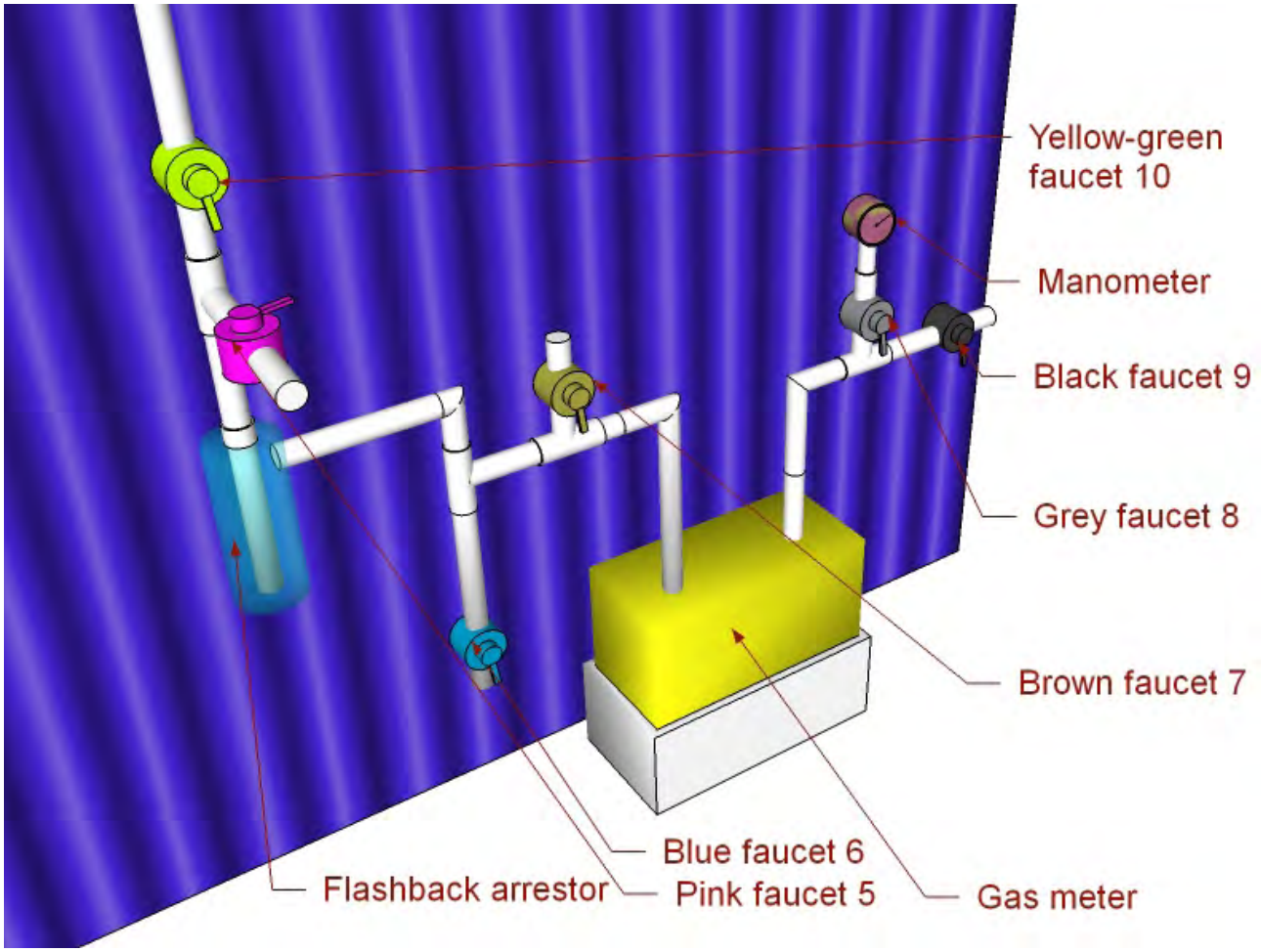

Figure 19: Model of the gas tapping system

Initial State Gas Tapping

During the reaction the gas tapping system has to be in the following state to perform properly.

- The flashback arrestor is filled with enough water to be sure, the open end of the hose is submerged in water.
- The pink faucet 5 is closed.
- The blue faucet 6 is closed.
- The brown faucet 7 is closed.
- The grey faucet 8 is closed.
- The black faucet 9 is open.

Fill Flash Back Arrestor

Table 11: Short description of filling the flash back arrestor

Description	Amount
Time	5 min
Workers	1

To successfully avoid the ignition of possibly flammable gas exiting the fermenter, the flash back arrestor needs to be filled with water. Starting from the initial state the following steps have to be performed to adjust the water level in the flash back arrestor.

Step 1: To avoid any gas to exit the fermenter whilst the flash back arrestor is unscrewed, the yellow-green faucet 10 is closed.
Step 2: The bottom part of the bottle trap is screwed off.
Step 3: Water is filled into the cup-like part.
Step 4: The part gets screwed on again.
Step 5: Yellow-green faucet 10 is opened again.

Empty Condensate Trap * (every day if gas is produced)

Table 12: Short description to empty the condensate trap

Description	Amount
Time	5 min
Workers	1

The vapour condensed from the gas, is collected in the condensate trap. From time to time, at least once a week, the trap needs to be emptied. To empty it starting from the initial state the following steps have to be performed.

Step 1: The blue faucet 6 is opened. The condensate exits the system.
Step 2: The blue faucet 6 is closed again.

Gas Measure * (twice a day)

Table 13: Short description for the gas measurement

Description	Amount
Time	20 min
Workers	1
Dräger X-am 7000	1
Pump attachment for Dräger	1

To keep track on the reaction inside the fermenter, the gas quality is measured twice a day. This is also possible if the reaction does not yet produce gas, thanks to the Dräger X-am 7000 being equipped with a pump. Starting from the initial state the following steps have to be performed.

Step 1: The Dräger device is turned on (push green button for 3sec). Let it equilibrate the sensors.

Step 2: Run fresh air calibration of the Dräger (Menu – Fresh air calibration).

Step 3: The black faucet 9 is closed.

Step 4: The hock up for the Dräger device is connected to the inlet at the pink faucet 5.

Step 5: The pink faucet 5 is opened.

Step 6: The pump device is attached to the Dräger and the pump starts. (The Dräger records time of the pump running).

Step 7: The values are observed during ten minutes. During this time they stabilise, however the best values observed are noted (highest CH_4, lowest CO_2, and lowest O_2).

Step 8: After the reading the pink faucet 5 is closed.

Step 9: The black faucet 9 is opened.

Step 10: The Dräger is disconnected to the inlet at the pink faucet 5. Though the pump device remains attached for another 10 min to flush the sensors.

Step 11: The Dräger is turned off (hold two blue buttons for 3sec).

Figure 20: Gas measurement using Dräger X-am 7000

Gas Meter * (twice a day)

Table 14: Short description to read the gas watch

Description	Amount
Time	1 min
Workers	1

The gas watch performs a continous measurement of the quantity of the gas running through it. The watch can not be set to zero, therfore the values have to be read and the initital value has to be subtracted.

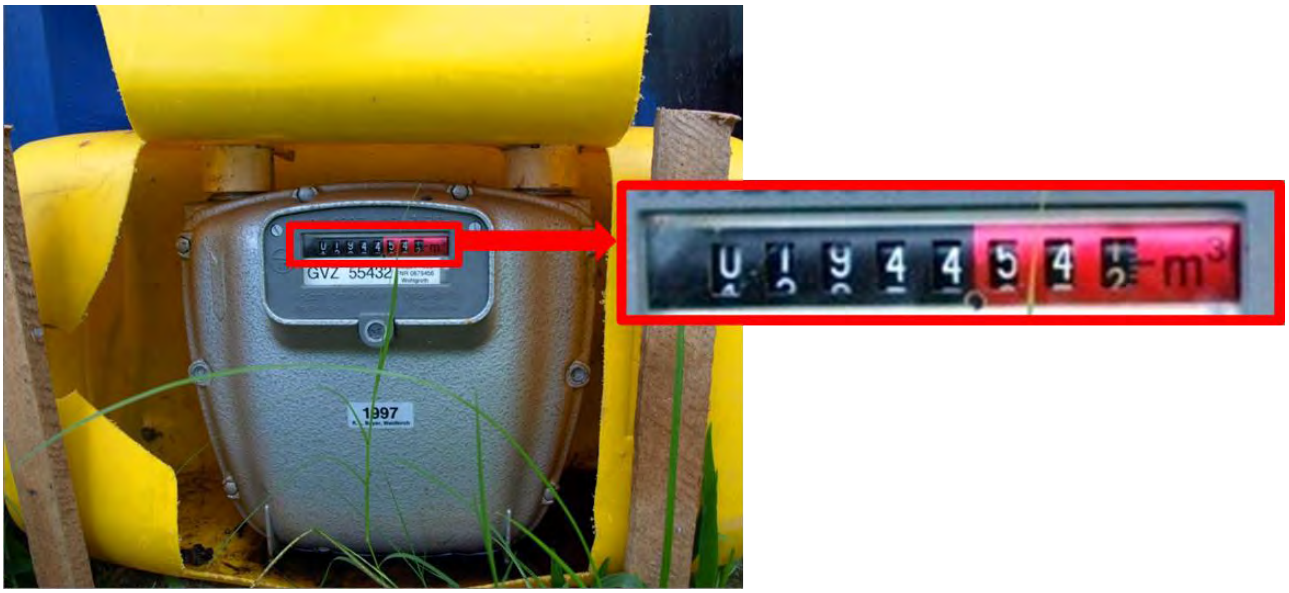

Figure 21: Gas meter and the reading

Starting from the initial state the following steps have to be performed.

Step 1: The blend of the container where the gas watch is set in is lifted up.

Step 2: The whole number is read from the watch and recorded.

IV_C. Errors & Troubleshooting

Inconsistent Percolation

The failure is noticeable if during the percolation the sound inside the fermenter is on and off. Visually it is also possible to see the percolate running intermittently through the filter. Start with the procedure from top to bottom in the trouble shooting table.

Table 15: Trouble shooting for inconsistent percolation

Possible reason	Solution
Faucets are not in the right position	Adjust the faucets to initial state
Filter is clocked	Exchange the filter
Filter is not placed accurate	Adjust the placement
Pump sucks air	Check the connections
Not enough Percolat	Add percolat / water

Percolation is not starting

This failure is present if the pump has started but no percolation sound occurs inside and no percolate passes the filter.

Table 16: Trouble shooting for percolation error

Possible reason	Solution
Faucets are not in the right position	Adjust the faucets to initial state
Pump has run dry	Float the pump
No Percolate in the fermenter	Add Percolate
The pump is clogged	Follow the instruction in IV_C

Pump is not starting

This failure is noticeable if the pump mode is switched from automatically to manual and the pump is not yet running.

Table 17: Trouble shooting for pump error

Possible reason	Solution
Power cut	Check the functioning of the Lamp at the pole where the pump is connected to.
Some switch is not in the right position	Check all the switches
Some wire has a failure	Check the wires and connections
The time switch or the pump is faulty	Replace or repair the faulty device

PH-Value too low (< 6)

During the reaction of the biogas production the substances of the feedstock are decayed in several steps to methane. Some of the intermediate products are represented as acids. The challenge about this is that the microorganisms to decompose those acids into methane are sensitive to low values of pH. If the bacteria get affected, the reaction acidifies itself as the produced acids are not decayed anymore. Therefore the pH-value is to be kept artificially on a high level above 6 during the reaction. The most efficient treatment is to add a solution of sodium hydroxide.
As a matter of precaution the project members should wear safety goggles as well as rubber gloves whilst working with sodium hydroxide to prevent damages.

Table 18: Short description to correct pH-value

Description	Amount
Time	15 min
Workers	1
Bucket (1 x NaOH, 1 x water)	2
Garden hose	1
Plastic bottle	1
Scale	1
Sodium hydroxide	0.5 – 1.5 kg
Water	Ca.50 l

Figure 22: Weight the sodium hydroxide

If the treatment is performed for the first time in a current reaction the starting quantity should be low. It is recommended to start with 0.5 kg dissolved in 30l of water. The highest concentration should not extend 1.5 kg per 30l according to safety issues. Starting from the initial state of the percolation system see IV_A. in the manual, the following steps have to be performed.

Step 1: The amount of sodium hydroxide is measured using the scale

Step 2: 50l of water are kept ready in a 100l bucket

Step 3: The sodium hydroxide is slowly stirred in. Attention: Heat is produced!

Step 4: After preparing the sodium hydroxide sollution, the adding is performed as described in IV_A. (Adding liquids during the reaction).

Figure 23: Dissolving sodium hydroxide in water

The Pump is clogged

Table 19: Short description of unclogging the pump

Description	Amount
Time	15 min
Workers	2
Wrench	2

Solids that have passed the filter might block the pump and stop its functioning. In this case the solids need to be removed. Starting from the initial state of the percolation system see IV_A. in the manual, the following steps have to be performed.

Step 1: The power is turned off.

Step 2: The green faucet 1 is closed.

Step 3: The orange faucet 4 is closed.

Step 4: The red faucet 2 is opened to release the liquid inside the pump.

Step 5: The connections of the pump to the pipe system are unscrewed.

Step 6: Before removing the pump make sure one person stabilises the percolation pipes, otherwise sealing can get damaged.

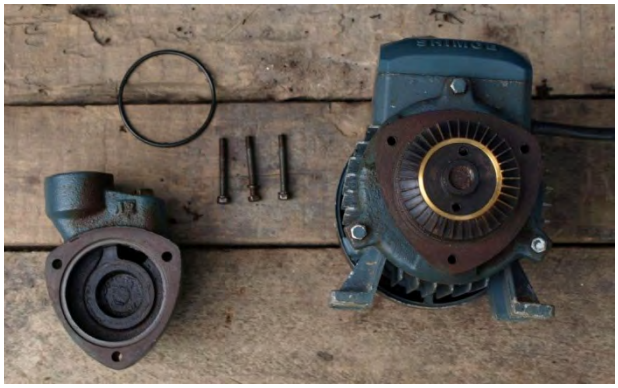

Figure 24: Percolation pump disassembled for cleaning

Step 7: Open the pump using a wrench.

Step 8: Reassemble the pump, again make shure to stabilise the pipes.

Step 9: The red faucet 2 is cosed.

Step 10: The green faucet 1 is opened.

Step 11: The orange faucet 4 is opened.

Step 12: The power is turned on again.

V_ Unloading

Table 20: Process short description with necessary material

Describtion	Amount
Time	1 day
Workers	2-5
Wheel barrel	2-3
Fully assembled fermenter	1
Peek	1-2
Showel	1-2
Garden hose	1
Water supply	1
Polytank 300l	2-3
Sample buckets	App. 6
Dräger	1
Exhaust source	1
Plastic cover	1
Broom	1
Cloth	1-2

Before unloading a batch, the further procedure should be clear. It is important to know whether the material is reused or not. Feedstock is called digestate after the reaction and is commonly used to inoculate the following reaction. Also the percolate from the dismissed process should be stored to inoculate the next batch if there are no other specific plans for inoculation, this procedure is described within Step 1 to 7. Preliminary to the described procedure (app. 12 hours before starting) the automatic percolation, performed by the time switch, needs to be turned off. This helps to release the percolate from the fermenter in little time. Starting from the initial state of the percolation system the following steps have to be performed.

Step 1: A hose is tapped to the percolate sample outlet port, at the yellow faucet 3.

Step 2: The orange faucet 4 is closed.

Step 3: The pump is switched from automatic to manual mode and the pump starts running.

Step 4: Right away, the yellow faucet 3 is opened to release the percolate into buckets (see Figure 25).

Step 5: If the pump starts to suck air through the percolation outlet port, the pump is turned off for 30 min and re-started after the percolate has covered the outlet port again.

Figure 25: Releasing the percolate from the container

Step 6: Step 5 is repeated 1-2 times.

Step 7: Pump is turned off and disconnected, all the electrical parts from the fermenter are removed and turned off.

Step 8: Flush the container with air or another gas, preferably CO_2 or N_2:
While opening the container an explosive mixture of gases can occur. To prevent from creating a dangerous environment, the container should be hooked up to a device producing exhaust like a car or a generator. To control the content of the plant, the Dräger can be installed as usual to the gas measurement compartment. The exhaust pipe should be connected to an inlet of the fermenter and let run until the gas analyser shows that only the wanted gas is exiting through the gas outlet. During the whole process of flushing and opening it is very important to remove all kind of electrical devices and to turn off the power supply to avoid electrical sparks, as well as to refrain from making fires on the site.

Step 9: Open the container:
Before opening the container, the Dräger should be disconnected from the measurement compartment and placed in front of the fermenter on top of the door. This helps to ensure a safe gas composition. Then the lock can be removed and the door can be opened carefully. It is recommended to open it only a crack wide and wait for a few minutes. During this time the out coming gas can be controlled via Dräger. If no danger occurs the door can be opened completely. Following that, the fermenter should be ventilated for about one day to make sure no harming gases to the works men are remaining inside. Until the door will be closed again it should be supported to lessen the weight and prevent it from hanging.

Step 10: Test the percolation:
To control the state of the sprinkler system, the red faucet can be connected to a hose which is linked to the water supply. Then the pump needs to be started. Through the open door the performance of the sprinkler system can be controlled. If the liquid exits the pipes with too much pressure, more openings have to be drilled. If the water does not reach to the very back of the container, some of the holes can be closed with insulating tape. If many openings are clogged, the drillings need to be enlarged.

Step 11: Check the digestate (decayed feedstock):
To control the execution of the digestion, the digestate needs to be controlled. This can be done by inspecting the material visually and examine the degree of degradation. A further parameter to be checked is the wetness of the material. If the digestate is evenly moist, the percolation system fulfilled its purpose. Where dry spots can be discovered the sprinkler system was inadequate.

Step 12: Take samples of the digestate for COD:
To get an impression of the evenness of the performed fermentation samples should be taken from different sections of the container (back, centre, front, top, middle, and bottom). The digestate samples should then be labelled and stored separately and labelled with their origin point.

Step 13: Unload the container:

To be able to enter the container easily the wooden logs next to the door should be removed. Then the percolation collection pipe shall be unlinked. Following that, the unloading of the digestate can be started (see Figure 27). Placing a wooden board at the entrance enables the works men to push the wheelbarrows straight inside the fermenter. The discharged material should be placed near the container in the shape of a compact pile. It is important to make sure that only as little material as possible does come in contact with oxygen to prevent harm for the bacteria on the inside of the pile. If available the heap should be covered with a plastic to protect the material from environmental influences.

Figure 26: Sampling the digestate (reacted feedstock)

Figure 27: Unloading of the digestate

Step 14: Clean the container:

As preparation for eventual maintenance the container shall be cleaned properly. The inside should therefore be hosed down with water and remaining solids shall be swept out of the fermenter (see Figure 28). If the dirt on the walls is significant these parts should not only be sprinkled but also swept with a broom. Following the cleaning part, the fermenter should be dried, using a cloth. After that the plant should be left to dry overnight.

Figure 28: Cleaning of the container for eventual maintenance

VI_ References

Fei-Baffoe Bernard Double stage dry-wet fermentation of unsorted municipal solid waste [Buch].- Cottbus: Brandenburg University of Technology Cottbus, 2006.

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List of Figures

If no other source is declared, the figures were generated by the authors themselves in the time period of the bachelor thesis.

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