METHODOLOGIES & APPLICATION
FROM DOCUMENTED EXPERIENCE

Anaerobic Filter (AF) Design Considerations for Faecal Sludge

Anaerobic Filter (AF)
Design Considerations for Faecal Sludge

is part of the series

Methodologies & Application from Documented Experience
MADE by UPM

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in cooperation with Bangladesh Agricultural University
and University of Science and Technology Beijing,
and with the support of Bill & Melinda Gates Foundation.

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Abbreviations & Acronyms

ABR	Anaerobic Baffle Reactor
AF	Anaerobic Filter
BOD	Biological Oxygen Demand
°C	Celsius degree
CH_4	Methane
cm	centimeter
C/N ratio	ratio of Carbon to Nitrogen in organic material
COD	Chemical Oxygen Demand
CSTR	Completely Stirred-Tank Reactors
d	day(s)
DEWATS	Decentralised Wastewater Treatment System
FFR	Fixed Film Reactor
g	gram(s)
h	hour(s)
HRT	Hydraulic Retention Time
kg	kilogram
l	liter
m	meter
mg	miligram
ml	mililiter
mm	milimeter
m^2	square meter
m^3	cubic meter
NPO	Non Profit Organization
p.d	person day
PVC	Polyvinyl Chloride
Q	flow
Qmax	maximum flow
S	Sulfur
SO_4	Sulfate
SS	Settleable Solids
SRT	Solids Retention Time
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USA	United States of America
Vh	effective capacity
Vmax	maximum velocity
WW	Wastewater
$<$	Less-than sign
$>$	Greater-than sign

Preface

This publication is the result of the technical assistance provided by UPM Umwelt-Projekt-Management GmbH (UPM) and its partners, the Centre for Sustainable and Ecological Sanitation (CSES) of the University of Science & Technology Beijing (USTB), and the Bureau of Socioeconomic Research and Training (BSERT) of the Bangladesh University of Agriculture (BAU) to the United Nations High Commissioner for Refugees (UNHCR), the Department of Public Health Engineering (DPHE) and the local WASH sector in Cox's Bazar, Bangladesh, in cooperation with the Bill & Melinda Gates Foundation.

The goal of this technical assistance assignment was to provide support to the emergency WASH sector and local administration, regarding sanitation and faecal sludge management, with focus on value—recovery in emergency settings, in order to sustainably improve the living conditions of displaced populations an reasonable ability to plan, design and monitor a project as an output d their hosting communities.

The present manual "Anaerobic Filter (AF) Design Considerations for Faecal Sludge" was elaborated in the context of a series of training workshops organised by UPM and its partners in Cox's Bazar based on a Training Needs Assessment implemented among the local WASH community.

The content of this manual was presented as part of the Training "Anaerobic Baffled Reactor and Anaerobic Filters" organized in Cox's Bazar in September 2019. The objectives of the training was to support trainees to gain reasonable ability to plan, design and monitor related project.

Introduction

The first Anaerobic Filters (AF) were developed in the 1960' in the USA to treat industrial wastewater. Ten years later, the technology was adapted to treat domestic and agro-industrial wastewater in Europe and in Asia. The first models were cylindrical tanks constructed of concrete or made of steel. The AF is reliable and resilient; it can resist to significant changes in wastewater qualities and flows.

An AF is a digester often called "fixed bed", because of the presence of fixed supports in the digester which allow the attachment and multiplication of bacteria. The AF DEWATS model is rectangular and baffled like an empty Anaerobic Baffled Reactor (ABR). The main difference is that the majority of the bacteria is fixed on supports in form of biofilms.

Principles

The fixed support in an AF avoids significant losses of bacteria and fresh organic matter in the effluents of the reactor. In comparison, substrate to be treated in biogas digesters, as partly settled sludge, or in completely stirred- tank reactors (CSTR), can be, in both designs, object to short-circuit currents. In an ABR, granules can be washed out by peak-flows, if the flow speed is higher than the settling speed of sludge.

The DEWATS model forces wastewater to follow anaerobic digestion step-by- step through the baffles. An AF is constructed like an ABR, but the baffles are partially filled with support media. On this fixed and porous support, material bacteria multiply and escalate the contacts between organic material, to be digested, and bacterial films. It allows the fixation of bacteria that organize themselves into well-organized granules, composed of hydrolytic, acidogenic and methanogenic bacteria.

The AF combines digestion in sludge and digestion of dissolved solids. Compared to septic tanks or digesters, it improves the solid removal. It could be preceded by bar screens and a settler or an ABR – either in the same construction or separated. The pre- and primary treatment is essential to remove solids and garbage that may clog the filter.

Figure 1 shows a general view and illustration of the principles of an AF.

Figure 2 shows that the Settler or sedimentation tank can be separated or replaced by a septic tank, ABR or digester. An AF can be built above or below ground.

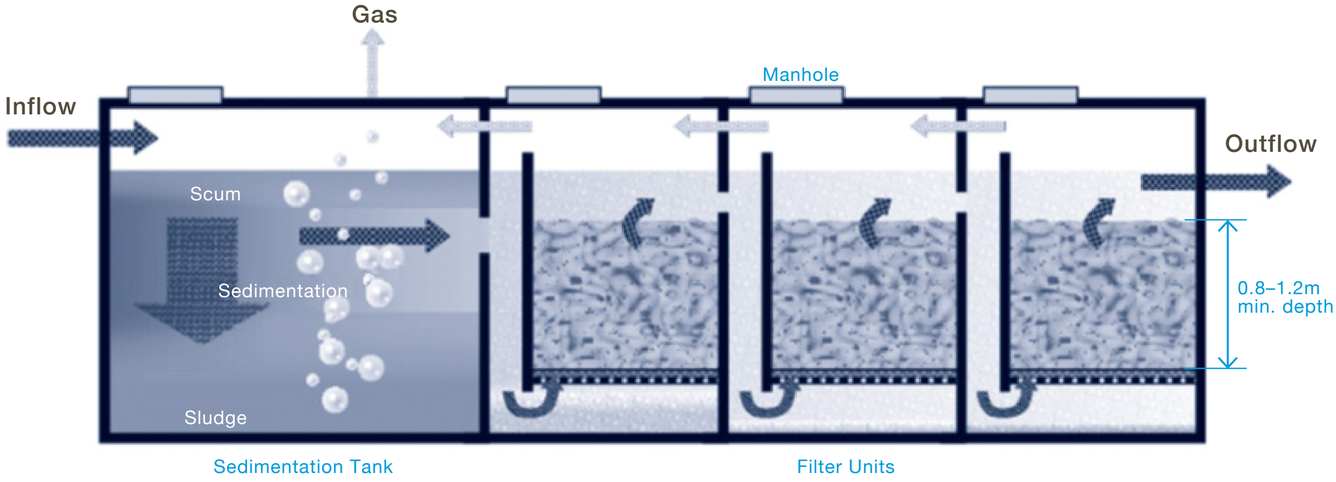


FIGURE 1: Flow principle of anaerobic up-flow filter, with pre-settler. [1]

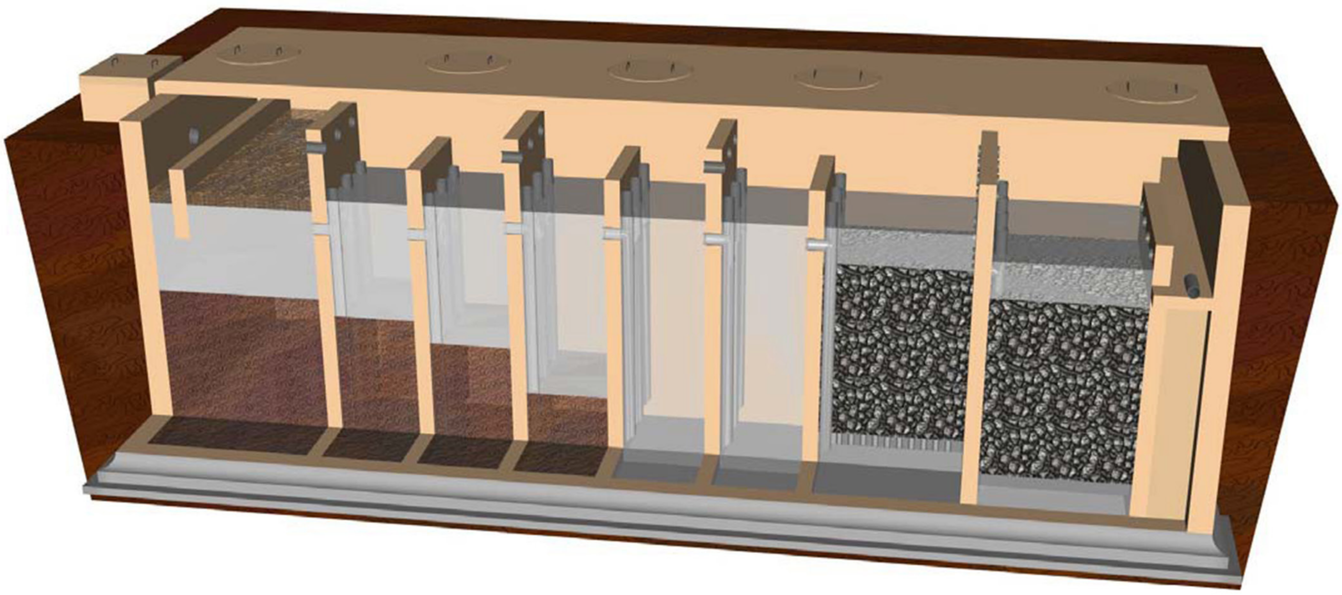


FIGURE 2: Anaerobic filter combined with a settler (1st chamber) and an ABR (2nd to 6th chamber). [2]

[1] Source: BORDA, 2009.
[2] Source: Andreas Schmidt, BORDA, 2005.

Advantages & Disadvantages

Advantages

- High concentration of bacteria in the biofilm increases the biological robustness of AF compared to anaerobic settler or septic tank; this enhances the digestion rate.
- Separation of the solids (deposited in the settler or in the "blanket") allows a long "Sludge Retention Time" (SRT) for a deep digestion; the liquid can circulate in short "Hydraulic Retention Time" (HRT).
- No electrical energy is required, if there are natural slopes.
- Low capital costs & low operational costs.
- High reduction of BOD and solids.
- Low sludge production.
- Low reduction of nutrients, thus outflow appropriate for reuse in agriculture.
- Moderate area requirement; can be constructed underground.
- HRT shorter than in biogas digesters allows to reduce AF volume and its area requirement (1 to 1.5 m^2/daily flow m^3).
- Anaerobic digestion produces biogas which could be valorized as fuel.
- Relative simplicity (no moving part, nor mechanical mixing or filling material); easy to construct.
- High performance.
- Despite short HRT in the AF (2–3 days), it can be fed in batches – such as 1 batch per hour. Bacteria are fixed on the supports and resist to hydraulic shocks.

Disadvantages

- Requires engineering design and construction skills.
- Low reduction of pathogens; effluent and sludge require further treatment and/or appropriate discharge because they are contaminated by pathogens and pollutants.
- Desludging every year or at least every 2 years; even more often if the daily flow of SS is high —generally with COD higher than about 3,000 mg/l and HRT lower than 3 days.
- Sludge level on the bottom slab must be regularly checked through the manholes or the lateral pipes.
- Sludge has to be pumped through manholes or via lateral pipes; this operation requires energy.
- Risk of clogging depends on pre- and primary treatment; in case of clogging, filter media must be removed from the baffles and cleaned.
- Wastewater up-flow velocity in the media is limited at 2 m/h; the surface area of the baffles then increases quickly with the daily flow.
- Biogas produced must be used or evacuated properly.
- As biological treatment, inoculation or maturation phase could be long; adding of sludge from another AF or septic tank can reduce this starting period. Feeds should be limited during the first weeks.

TECHNOLOGIES

Pre-treatment

Screening devices such as bar racks and screens should be installed to remove coarse material - rocks, sticks, leaves, plastics and other debris, that would damage pumps or settlers.

TECHNOLOGIES

Primary treatment

A primary treatment is generally achieved in a biogas settler, which is a gas tight septic tank with low hydraulic retention times of less than 3 hours, or in a biogas digester, if the COD concentrations are very high - more than 20,000 mg/l. This classical digester can be divided in a series of tanks. The total HRT can be more than 20 days (at minimum 25°C in the liquid). Biogas may be collected and used as energy source.

To regulate the flow in the AF, the feeding must be distributed over a minimum of about one feed per hour or even more evenly (with pre-flow buffer tanks, or settler). If the feedings are made by batches in case of the desludging is done by trucks, then at least one pre- storage tank must be installed. It should be equipped with pumps or valves (manual or automatic) to properly regulate flow rates to the AF. Biogas digesters, Imhoff tanks or settlers can play a limited role as flow buffers.

In a typical settler, the biological treatment will have bacteria digesting 25 to 50% of organic matter (BOD, COD) in the liquid and reducing the volume of sludge. The mechanical treatment applied by the settler will retain floating greases and sediment.

TECHNOLOGIES

Construction

The core of an AF is the baffle composed, from bottom to top, by (1) a distribution zone for the incoming flow to be spread in (2) a zone filled with filling media as bacterial support placed on a perforated slab, and (3) a zone containing the outflow and the biogas collection chamber. The bacterial support is below the liquid level and a space is reserved on the top for the accumulation of foam, if any.

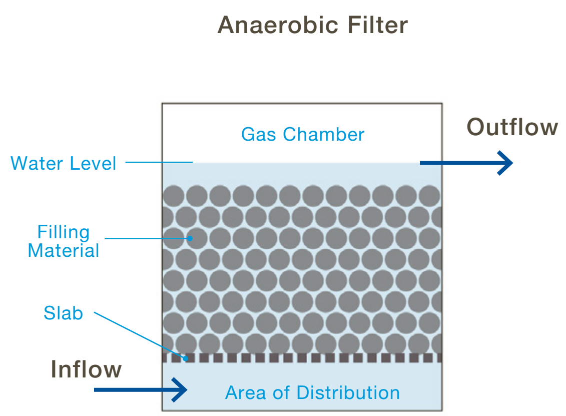


FIGURE 3: Cross-section view of an Anaerobic Filter. [3]

[3] Source: Epuval NPO.

The first model presented by Sasse [4] consisted entirely of concrete standing and hanging walls for 3 to 6 baffles.

A primary treatment in a two-chamber-settler was included in the construction. HRT was at least of 1.5 to 3 days. The calculations were proposed to evaluate the performances and to size all the compartments. Based on this model, AFs were built in different developing countries, mainly in Asia.

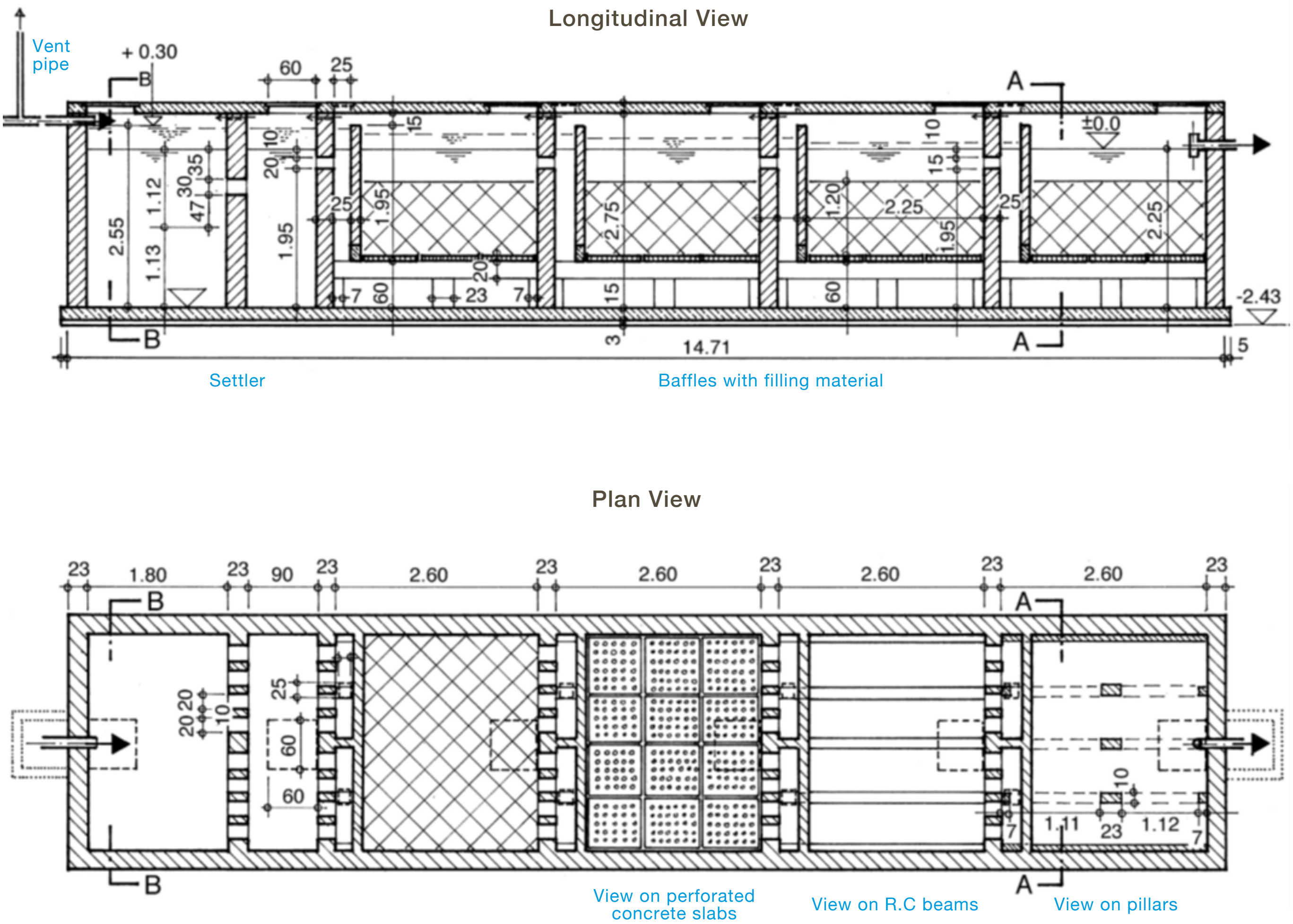


FIGURE 4: Longitudinal section and plan view of an AF. [5]

[4] Source: BORDA, 1998 & BORDA/WEDC, 2009.
[5] Source: BORDA, 1999.

After some years, the “hanging” walls, forming the down-flow shafts, have been replaced by vertical PVC pipes and Tee-pieces.

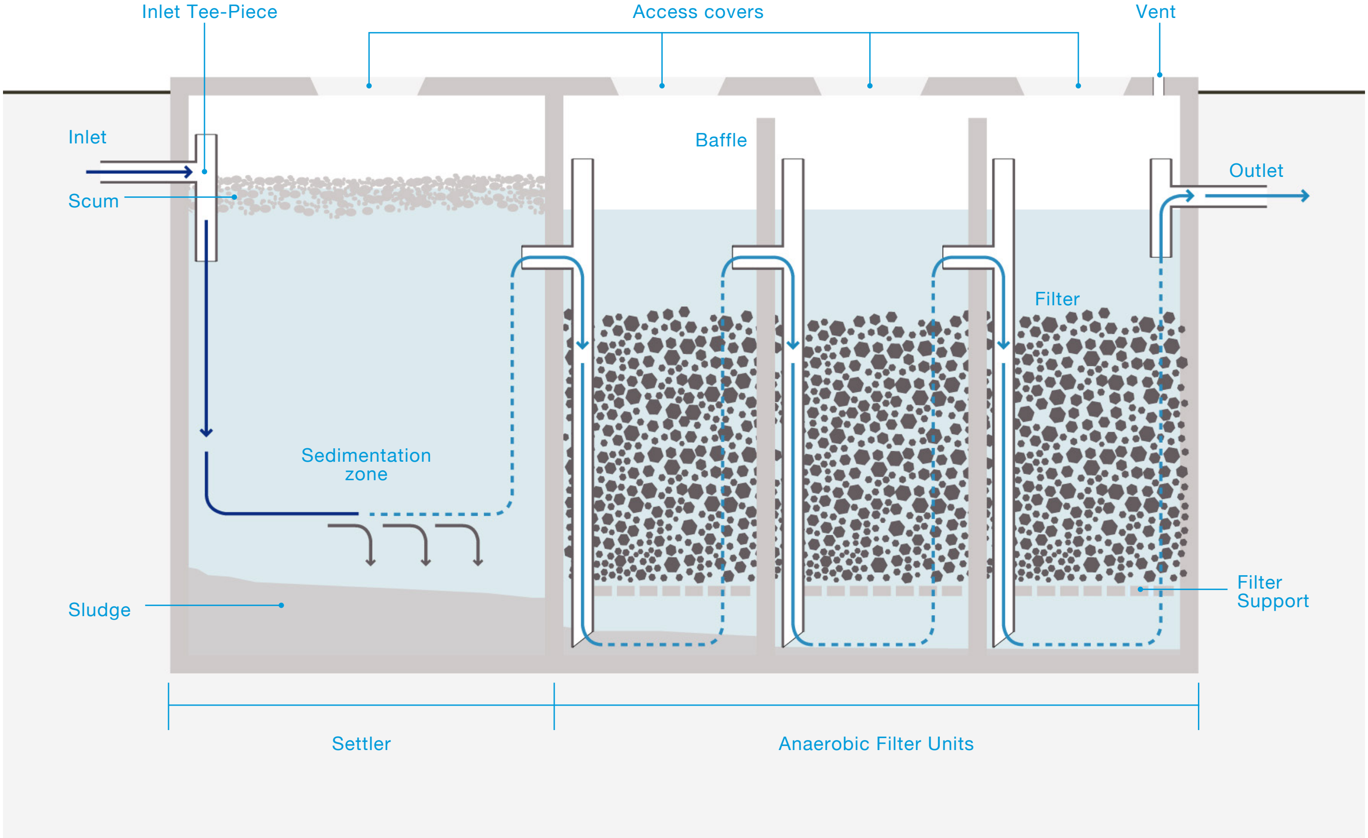


FIGURE 5: Schematic of an anaerobic filter. Gas is evacuated by the venting opening at the upper right. [6]

FIGURE 6: During construction: view of an AF (left) and slabs to support the filling media with a central concrete nozzle for desludging (right). [7]

[6] Source: Tilley et al., EAWAG, 2014.
[7] Source: BORDA India.

FIGURE 7: AF baffles with inlet and outlet pipes (left); up- and down-flow pipes. [8]

In India, the Anaerobic Filter is called Fixed Film Reactor FFR.

Access cover must be provided for each baffle, including the settler. Access to the top of the PVC Tee-pieces should be possible trough covers to desludge the pipes and Tee-pieces with diameter more than 25 cm. When biogas is collected for use, covers must be gastight and fitted with a gas pipe.

The void space of the filter medium influences the digester volume required to provide sufficient HRT. Gravel has approximately 35% void space, while specially manufactured plastic pieces may have over 90%. [9] Prefabricated plastic or glass fiber models of AF are now available, and sometimes directly replaced by platsic tanks.

FIGURE 8: ABR and AF in rainwater harvesting plastic tanks installed Rohingya Refugee Camp 23, Bangladesh. [10]

[8] Source: BORDA India.
[9] Source: Sasse, 2009.
[10] Photo: M. Wauthelet, Epuval NPO.

The filling media can be made of plastic balls, cuttings from PVC tubes with a diameter of 10–25 mm, plastic rings, gravels, pumices (10–30 mm), bricks, coconut shells, brushes, or fabrics. They could vary in sizes from largest to finest from the first to the last baffle.

It is recommended to use plastic rings or tubes or recovered material such as electrical conduits and bottles. In order to take out and clean this material, fishing nets could be used. Their diameter should be smaller than the manholes on the baffles.

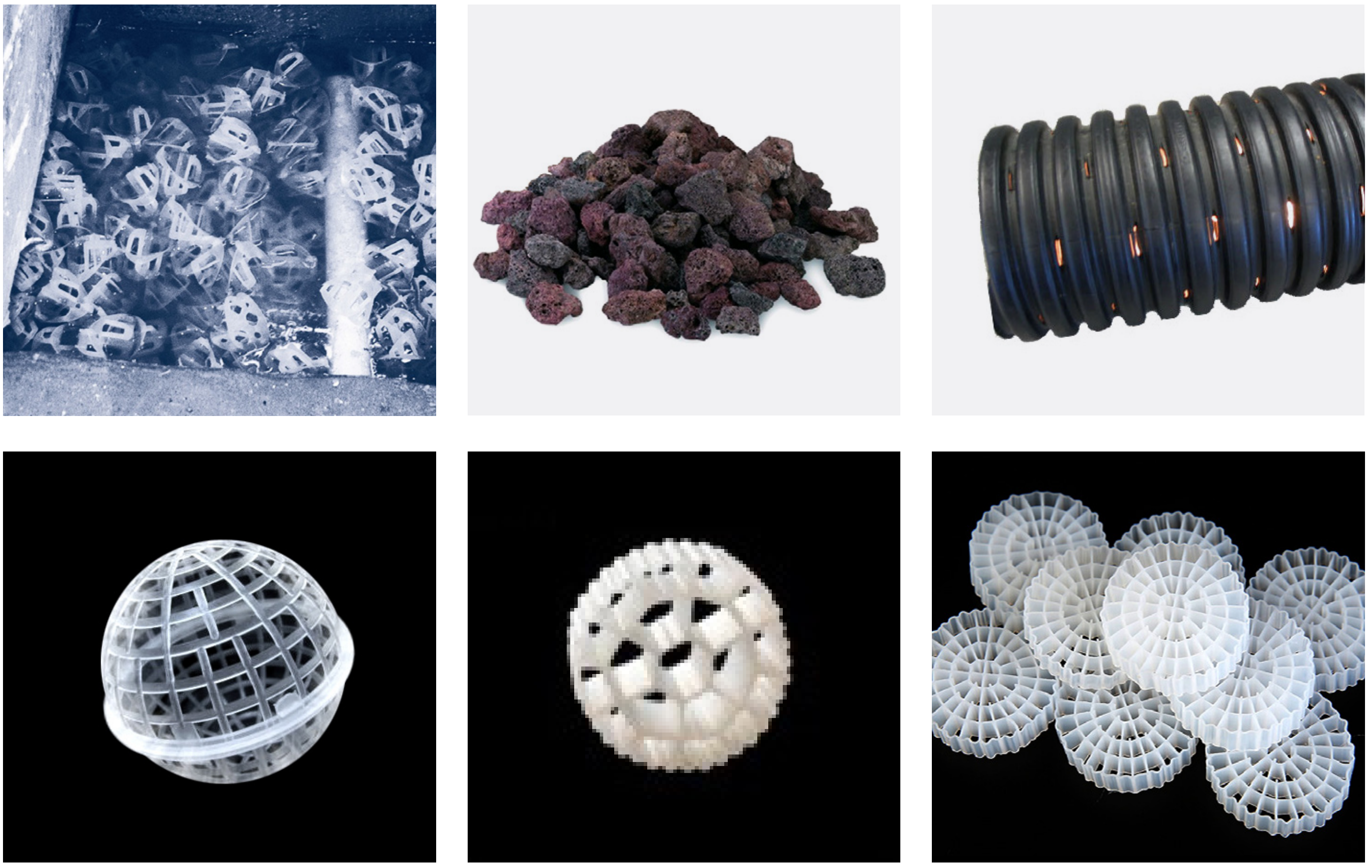


FIGURE 9: Selection of filling media for AF. [11]

[11] Source: Sasse, 2009.

Basics of sizing

Baffles:

The task of baffles is to increase the contact time between organic fresh matter and the active biomass (bacteria) maintained on the supporting filling media. On the bottom, the bacterial granules form a fluidized biofilm or sludge blanket. The wastewater that enters a tank should be distributed over the floor area as evenly as possible. This is facilitated by relatively short compartments of a maximum length equal to 100% of the height. In the case of down-pipes, a distance of less than 75cm-width should be kept between the pipes.

Maximum width and flow distribution:

It is necessary to distribute the liquid to be treated across the entire width of the tanks.

Provision of parallel treatment streams:

To ensure flexibility of operation during maintenance events, the design should include at least two baffled reactor streams in parallel. To ensure good mixing and avoid high structural costs, individual streams should not be more than 2.5–3 m wide.

Numbers of chambers:

Minimum 3, maximum 6; if calculation results in more than 6 chambers it is recommended to place two or more AFs in parallel.

Baffle outlets:

Placed 30 cm under the liquid level in order to retain floating materials.

Parameters to be considered:

HRT minimum 1.5d; Depth minimum 1m; Up-flow baffles in series filled with filling material decreasing in size to increase the performances; Settler needed for raw wastewater; Organic load limits 4 to 5kg COD/m^3.d [12], but it can work also at higher organic loads of up to 15kg COD/m^3.d; Gross volume 0.5m^3/person [13]; small units up to 1m^3/person.

[12] [13] Source: Sasse, 2009.

Factors to be respected in order to optimize the anaerobic digestion:

- Temperature: Most AF operate in tropical countries, but a wide range of temperatures is observed. Best performances are achieved at fluid temperatures ranges of 25–30°C. The Temperature must be as constant as possible.
- Oxygen: an AF needs strict anaerobic conditions.
- pH must be stable between 6 and 8; no toxics are tolerated in the wastewater; C/N ratio should be between 15 and 30.
- Because of high hydraulic head losses, in combination with an ABR, an AF could be a hydraulic buffer. An AF accepts more shocks than an ABR.

Hydraulic Retention Time (HRT):

= Vh/Q (Vh is the effective capacity in m^3, Q is the daily flow in m^3/d).

Solid Retention Time (SRT):

of more than 100 days is required for an effective digestion of the complex molecules (in organic matter or bacteria).

Desludging / effective capacity:

accumulation of sludge reduces the effective capacity of the baffles and the HRT.

The ratio Settleable Solids (SS) / COD (in mg/l / mg/l) of fresh domestic wastewater or sludge is about 0.35 to 0.45. This ratio can strongly decrease after the settler.

Sludge-storage: up to 5 l sludge volume are produced in the settler per kg of COD influent. This volume will be reduced (40%) by digestion in 2 years (in case of 2-years desludging period).

About 1.5 l sludge volume per kg COD are produced in the baffles and decreased from the 1st to the next ones. These volumes should be linked to the temperatures (digestion rate), the WW characteristics, the HRT's, loads and velocity.

Desludging every year or 2 years maximum. If the AF is fitted with lateral pipes to collect and drain the sludge, weekly or monthly desludgings are possible.

Manual emptying and sludge handling are very dangerous because of presence of gases and pathogens. Never enter an ABR even after complete emptying. It is only after several days of ventilation that a test can be carried out with an animal.

Personal protective equipment:

is necessary, such as rubber boots, masks, glasses, waterproof clothing and gloves.

Up-flow velocity:

The velocity is conditioned by the porosity of the filling material. The peak upflow velocity cannot exceed 2 m / h: Vmax= Qmax / (S up-flow baffle * porosity).

BOD/COD load:

Max. 4.5 kg COD / day per m^3 of AF. [14]
Loads up to 15 kg COD / m^3.d can be accepted.

Biogas production:

Collecting biogas requires tight lids and piping system. Calculated biogas production: Feces + urine: 1 person produces about 15–27 l biogas / d.; or COD produced per person: 38 g (feces) + 9 g (urine) / d * 0.35 l methane / COD removed.

Experiences shows that max 16 l methane / p.d. is captured, if 100 % COD is removed in the ABR, in case of biogas with 70% methane content this will be:

→ 16 l CH_4/p.d. / 70% methane content in the biogas → 23 l biogas / p.d.

Performances[15]

Performances are directly linked to the composition of wastewater: carbohydrates are easy to digest; fibers are more resistant.

Relative performances are higher for raw wastewater compared to wastewater pumped from a septic tank. The AF is fully functional after a starting period of 2–6 months, but inoculation and low starting flows are recommended to shorten this period.

→ Biogas could be recovered and used if BOD > 1,000 mg/l.

→ Suspended solids and BOD removal can be as high as 90% but is typically between 50% and 80%.

→ Total Coliform reduction is 1 to 2 log units. [16] AF effluents have to be post-treated before irrigation or discharge.

→ Hydraulic retention time (HRT): 1.5–2d for pre-settled blackwater; [17] 0.7–1.5d for greywater. [18]

[14] Source: Sasse, 2009.
[15] Source: The following information is extracted from Sustainable Sanitation and Water Management (www.sswm.info).
[16] [18] Source: Morel & Diener, 2006.
[17] Source: Sasse, 1998.

The best results are observed when the filling material has high specific area of 90 to 300 m^2 surface area per m^3 of reactor volume. [19] A rough surface provides a larger area, at least in the starting phase. Later on, the biofilm that grows on the filter media quickly closes the smaller groves and holes. [20] It is also observed that the biofilm can peel off from smooth plastic surfaces (smooth plastic pipes or rings as filling material), the performances can be reduced in consequence.

There is an increased risk of clogging due to sludge and mineral matter. Clogging leads to a reduction of the active volume and ensuing decrease of the performances within 2 to 6 months, because the biofilm is washed out by the wastewater which passes the AF on a short cut or preferential way.

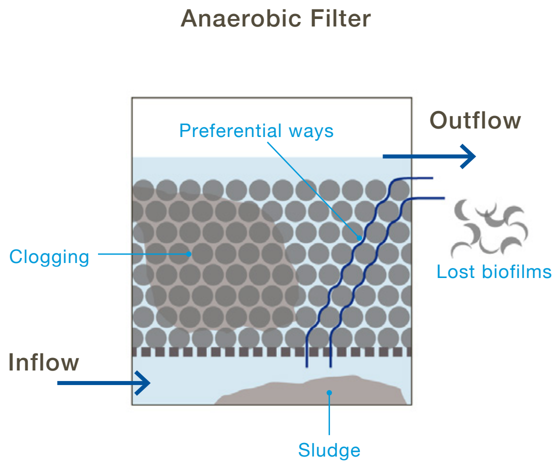


FIGURE 10: Clogging of AF leads to biofilm losses and decrease of performance. [21]

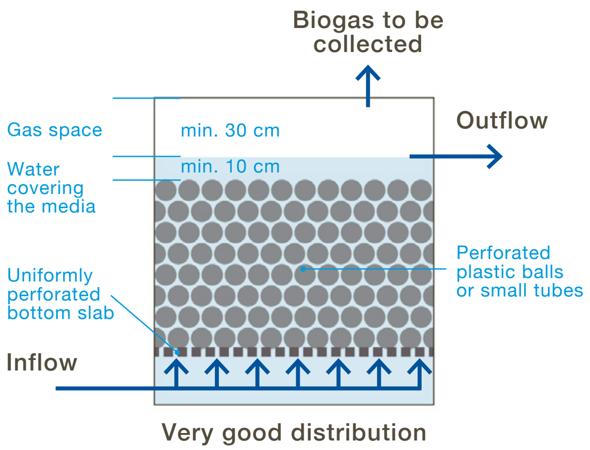


FIGURE 11: Interior design of AF layers for best performance. [22]

Recommendations to achieve and maintain best performances:

- → Good contact between the media (filling material) and wastewater.
- → Uniform wastewater distribution.
- → Uniformly perforated bottom slabs.
- → Balls or tubes with a lot of perforations are offering large contact area and wide passages for wastewater.
- → Preferential way or shortcut are reduced through equalization of the flow and wastewater covering the media.
- → No odor; energy valorization if biogas is collected and used.
- → Foam may appear at the top of the wastewater surface; this indicates that a space for gas collection is needed.

[19] Source: Sasse, 1998 & Morel, 2006.
[20] Source: Sasse, 1998.
[21] [22] Source: Epuval NPO.

Calculations

Calculations of “factors of performances” based on the curves obtained in laboratories.[23]

FIGURE 12: COD Removal relative to wastewater strength in anaerobic filters.

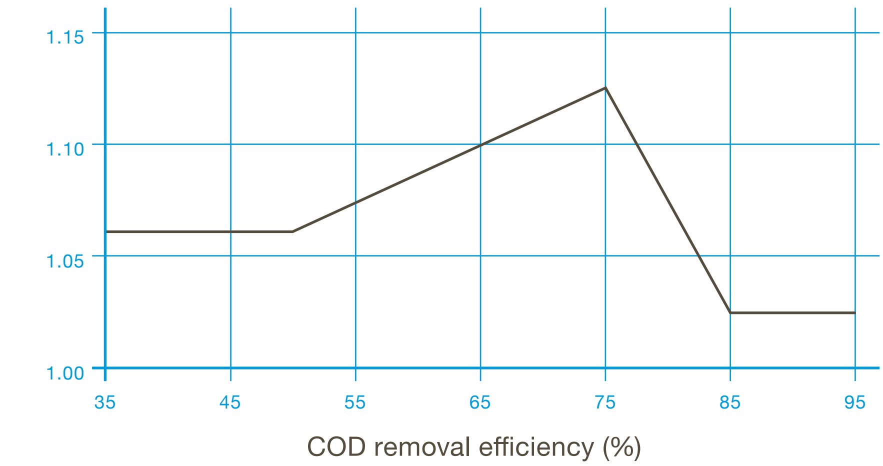


FIGURE 13: Reduction of sludge volume during storage.

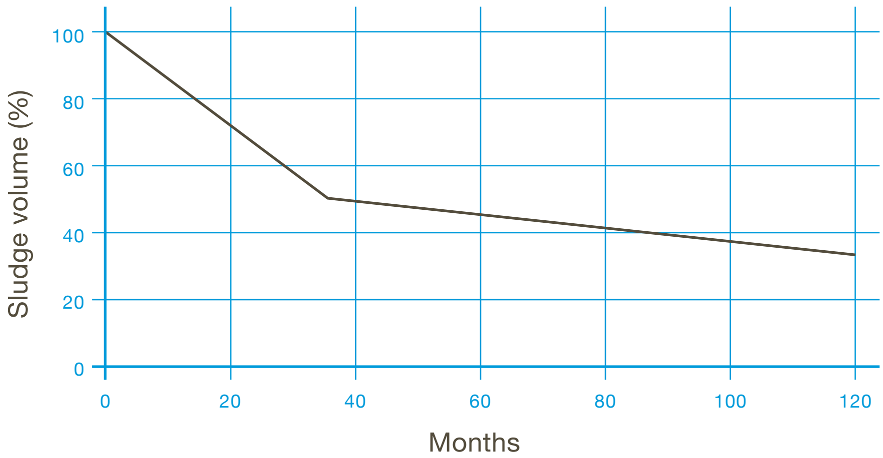
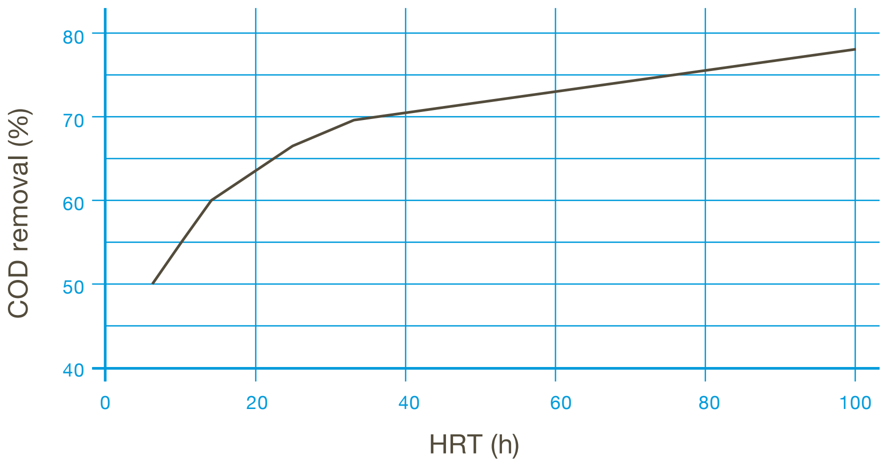


FIGURE 14: COD removal in relation to HRT in anaerobic filters.



[23] Source: Sasse, 2009.

FIGURE 15: COD removal relative to wastewater stength in anaerobic filters.

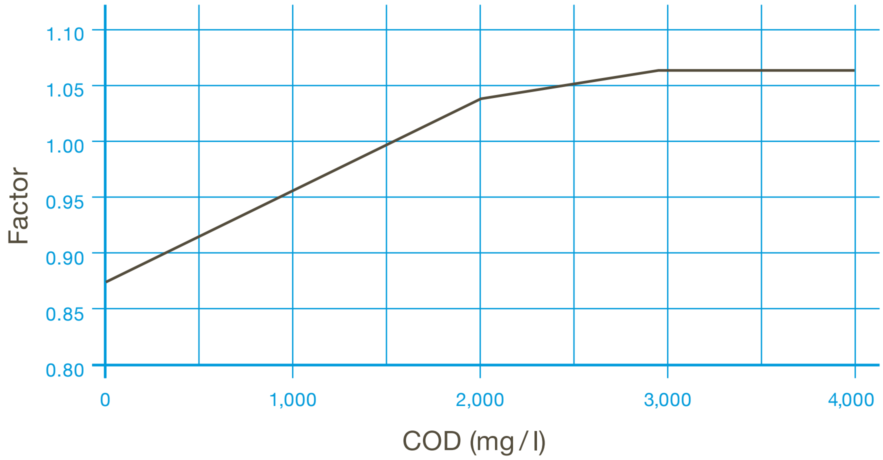


FIGURE 16: Spreadsheet for calculating anaerobic filter dimensions.

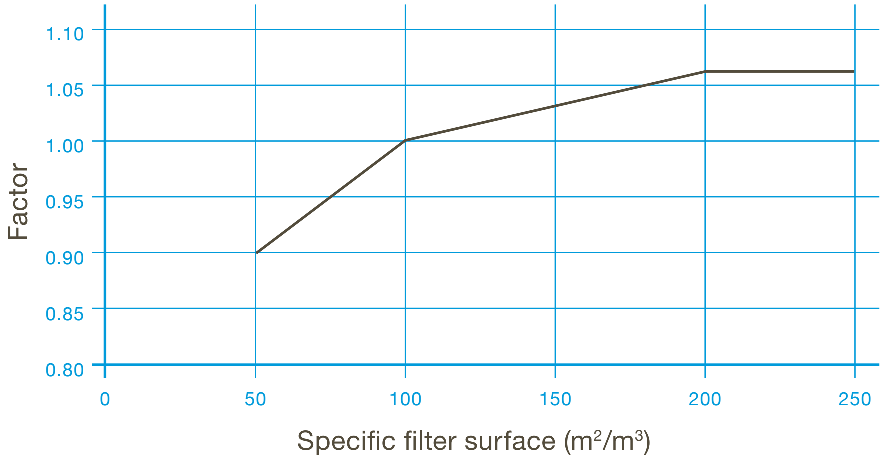


FIGURE 17: COD removal in settlers.

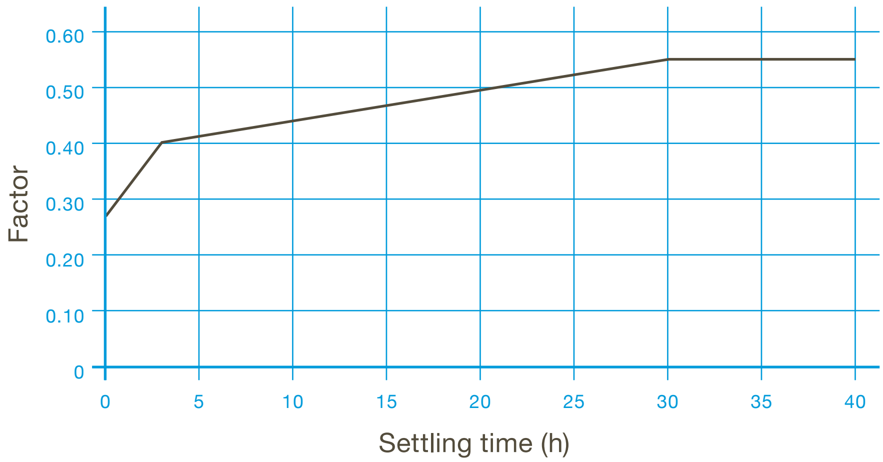
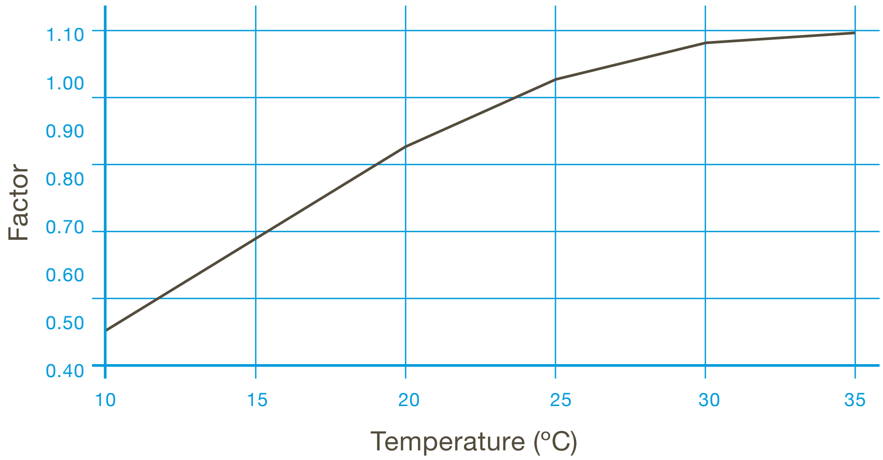


FIGURE 18: COD removal in relation to temperature in anaerobic reactors.



The spreadsheet in Figure 19 uses the curves and the basics of sizing for calculation. The performances are based on laboratory tests and extrapolated. It must be considered as theoretical. Some factors are above 1 and can result in a performance value higher than 100% —refer to J11 in the spreadsheet. The same cell J11 limits it theoretically at 98%.

Nevertheless, the spreadsheet allows to optimize the amount and dimensions of the different elements of the AF system and to analyze the different impacts of the parameters (peak flow, COD, BOD, etc.). Also, it will make it possible to check whether the conditions for proper operation are met.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**General spread sheet for anaerobic filter (AF) with integrated septic tank (ST)**											
2	Daily waste water flow	time of most waste water flow	max peak flow per hour	COD inflow	BOD5 inflow	SSsettl,/COD ratio	***lowest*** digester temp	**HRT in septic tank**	desludging interval	COD removal septic tank	BOD5 removal septic tank	BOD/COD remov, Factor
3	given	given	calcul,	given	given	given	given	chosen	chosen	calcul,	calcul	calc,
4	m3/day	h	m3/h	mg/l	mg/l	ratio	°C	HRT in septic tank	months	%	%	ratio
5	10	16	0,63	1500	900	0,42	25	2,5	12	26%	28%	1,06
6			COD/BOD5==>	1,67		Domestic 0,35<x<0,45		1,5 - 2,5 h	max, 24 months			
7	**treatment data**											
8	COD inflow in AF	BOD5 inflow into AF	specific surface of filter medium	voids in filter mass	**HRT inside AF reactor**	factors to calcultate BOD removal rate of anaerobic filter				COD removal rate (AF only)	COD outflow of AF	COD removal rate of total system
9	calcul	calcul.	given	given	chosen	Calculated according to graphs				calcul	calcul	calcul
10	mg/l	mg/l	m^2/m^3	%	h	f-temp	f-strenght	f-surface	f-HRT	%	mg/l	%
11	1106,25	649,58	100	35%	**30**	1,00	0,96	1,00	0,69	75%	282,09	81%
12	1,03		*80-120*	*35-45%*	*24-48h*							
13				**dimensions of septic tank**								
14	BOD/COD rem. Factor	BOD5 rem rate of total system	**BOD5 outflow of AF**	inner width of septic tank	minimum water depth at inlet point	Inner length of first chamber		length of second chamber		sludge accum.	volume incl. Sludge	**actual volume of septic tank**
15	calcul	calcul	calcul	chosen	chosen	calcul	chosen	calcul.	chosen	calcul.	requir.	calcul.
16	ratio	%	mg/l	m	m	m	m	m	m	l/gBOD	m^3	m^3
17	1,06	86%	123,17	1	2,5	1,42	1,7	0,71	0,85	0,00416	5,31	6,38
18				*sludge l/g BOD rem.*								
19	**Dimensions of anaerobic filter**							**biogas production**			**Checks**	
20	**Volume of filter tank**	**depth of filter tank**	**length of each tank**	**number of filter tank**	**width of filter tanks**	space below perforated slabs	filter height (top 40 cm below water level)	out of septic tank	out of anaerobic tank	**total**	org. Load on filter volume COD	max. upflow velocity inside filter voids
21	calcul	chosen	calcul	chosen	requir.	chosen	calcul.	*assump.: 70%CH4; 50% dissolved*			calcul	calcul
22	m^3	m	m	No.	m	m	m	m3/d	m3/d	m3/d	kg/(m3*day)	m/h
23	12,50	2,5	2,50	3	0,92	0,6	1,45	0,98	2,06	3,04	3,15	0,77
24											<4,5 (up to 15	<2,0

FIGURE 19: Spreadsheet for calculations.

Due to mismatches with the curves,
some formula have been modified for the present manual:

C5 = A5 / B5
J5 = F5 / 0.6 x IF (H5 < 1;H5 x 0.3; IF (H5 < 3; (H5 - 1) x 0.1 / 2 + 0.3;IF(H5 < 30; (H5 - 3) x 0.15 / 27 + 0.4; 0.55)))
The formula relates to Figure 17.
The number 0.6 is a correction factor based on practical experience.

K5 = L5 x J5
L5 = IF (J5 < 0.5; 1.06; IF (J5 < 0.75; (J5 - 0.5) x 0.065 / 0.25 + 1.06;IF (J5 < 0.85; 1.125 - (J5 - 0.75) x 0.1/0.1; 1.025)))
D6 = D5 / E5
A11 = D5 x (1 - J5)
B11 = E5 x (1 - K5)
F11 = IF (G5 < 20; (G5 - 10) x 0.39 /(20-10) + 0.47; IF(G5<25; (G5 - 20) x 0.14 / 5 + 0.86;’IF (G5 < 30; (G5 - 25) x 0.08 / 5 + 1;1.1)))
G11 = IF (A11 < 2000; A11 x 0.17 / 2000 + 0.87;IF (A11 < 3000; (A11 - 2000) x 0.02 / 1000 + 1.04; 1.06))
H11 = IF (C11 < 100; (C11 - 50) x 0.1 / 50 + 0.9; IF (C11 < 200; (C11 - 100) x 0.06 / 100 + 1; 1.06))
I11 = IF(E11<12;(E11-7)x0.1/(12-7)+0.5;IF(E11<24;(E11-12)x0.07/12+0.6;IF(E11<33;(E11-24) x0.03/9+0.67;IF(E11<100;(E11-33)x0.09/67+0.7;0.78))))
J11 = IF (F11 x G11 x H11 x I11 x (1 + (D23 x 0.04)) < 0.98;F11 x G11 x H11 x I11 x (1 + (D23 x 0.04)); 0.95)
The formula considers improved treatment by increasing the number of chambers and limiting the treatment efficiency to 98%.

K11 = A11 x (1 - J11)
L11 = (1 - K11 / D5)
A17 = IF (L11 < 0.5; 1.06 ; IF (L11 < 0.75; (L11 - 0.5) x 0.065 / 0.25 + 1.06;IF(L11 < 0.85; 1.125 - (L11 - 0.75) x 0.1 / 0.1; 1.025)))
B17 = L11 x A17
C17 = (1 - B17) x E5
F17 = 2/3 x K17 / D17 / E17
H17 = F17 / 2
J17 = 0.005 x IF (I5 < 36;1 - I5 x 0.014; IF (I5 < 120; 0.5 - (I5 - 36) x 0.002; 1/3))
K17 = IF (OR (K5 > 0;J5 > 0); IF(J17 x (E5 - B11) / 1000 x I5 x 30 x A5 + H5 x C5 < 2 x H5 x C5;2 x H5 x C5; J17 x (E5 - B11) / 1000 x I5 x 30 x A5 + H5 x C5); 0)
L17 = (G17 + I17) x E17 x D17
A23 = E11 x A5 / 24
C23 = B23
E23 = A23 / D23 / ((B23 x 0.25) + (C23 x (B23 - G23 x (1 - D11))))
G23 = B23 - F23 - 0.4 - 0.05
H23 = (D5 - A11) x A5 x 0.35 / 1000 / 0.7 x0.5
I23 = (A11 - K11) x A5 x 0.35 / 1000 / 0.7 x 0.5
J23 = SUM (H23 : I23)
K23 = A11 x A5 / 1000 / (G23 x E23 x C23 x D11 x D23)
L23 = C5 / (E23 x C23 x D11)

Operation & Maintenance for AF

Height of sludge accumulation must be controlled at least each 2 months. Pipes and Tee-pieces must be cleaned with a brush.

Like an ABR, an AF should be desludged every year or latest after 2 years of operation. If the accumulation of sludge is fast, emptying must be done more frequently. The emptying companies must be equipped with appropriate vehicles and strong pumps. Manual emptying is not recommended.

FIGURE 20: Liquid level can be monitored by observing level in sampling pipes. [24]

FIGURE 21: Cleaning the pipes with a brush (left) and desludging by vacuum truck (right). [25]

[24] [25] Source: SNV.

Settler (Septic Tanks)

Desludging intervals depend on number of users and their behavior. In refugee camps, desludging and removal of coarse material and garbage such as stones, plastics, greases, and wood should be done at least monthly. Desludging must be possible through the manholes.

FIGURE 22: Desludging with vacuum pump and truck. [26]

Anaerobic Filter

Cleaning should be carried out when the flow is reduced and/or the performances decrease. Backwashing could be done by running the system in reverse mode or by removing and cleaning the filter material.[27] Light filling material, such as plastics or balls in small baskets made of fishing nets, are easier to remove than rocks. Desludging and cleaning of the filter material could both pose health-hazards; therefore, appropriate safety measures should be taken.[28]

Desludging methods of an AF can be done in different ways; they are more difficult than those applied for an ABR.

Gravitational desludging (See Figure 23) via a lateral pipe (fixed on the AF bottom) could be done every month, before problems, such as clogging or excessive accumulation and packing of sludge, occur. This can avoid the use of emptying trucks and would allow the drying of the sludge. As a remark: desludging in an ABR is different as in an ABR desludging flow has to be stopped before the outflow becomes clear (visible granules), to keep some sludge granules as inoculant in the system.

[26] Source:
[27] Source: Sasse 1998; Morel & Diener 2006.
[28] Source: Tilley et al., 2008.

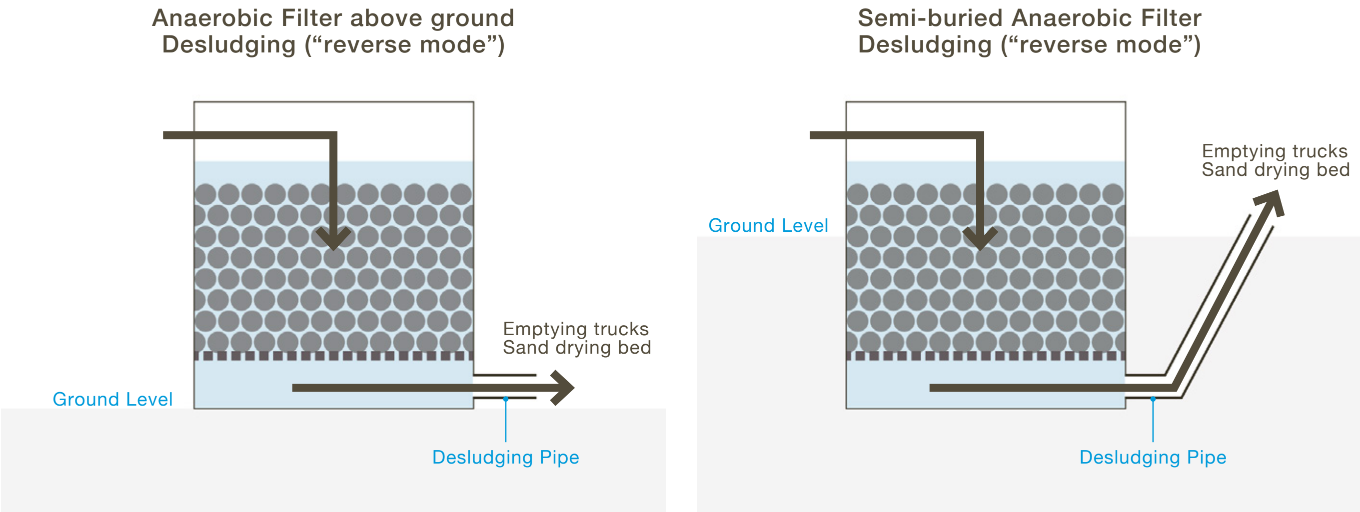


FIGURE 23: Gravitational Desludging of AF by reverse mode through a desludging pipe on the bottom. [29]

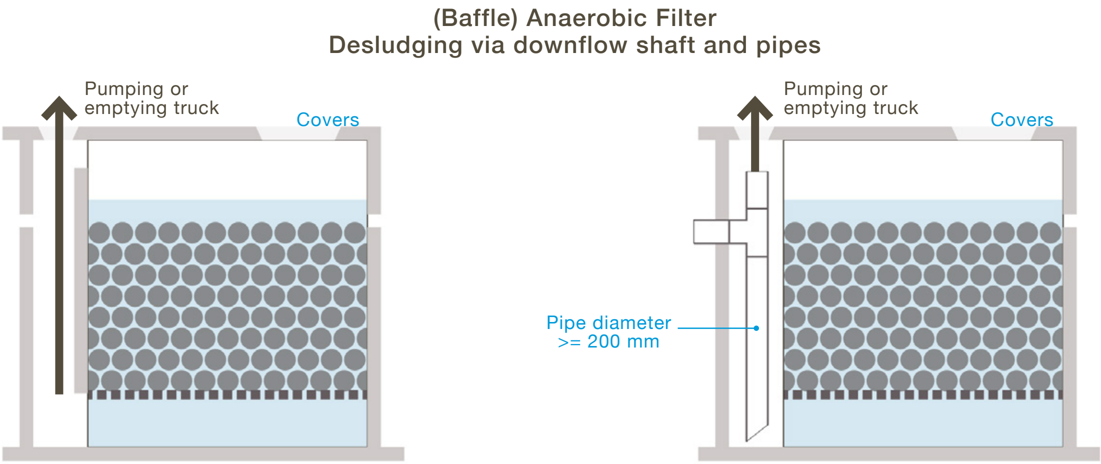


FIGURE 24: Desludging of AF by truck or pumps. [30]

The sludge must be treated by dewatering followed by drying, composting, incineration, liming, or soilisation, to eliminate hygienic risks and reduce the pollution. After treatment — mainly to eliminate the pathogens, the sludge can be valorized in agriculture. Fresh sludge cannot be directly used or discharged.

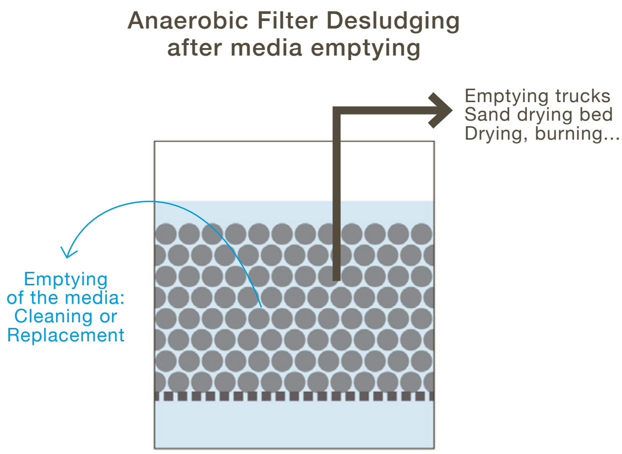


FIGURE 25: An AF could be totally cleaned if the filling media is completely removed. [31]

[29] [30] [31] Source: M. Wauthelet, Epuval NPO.

Effluent Quality Monitoring

The effluent outflow is collected and tested for the following parameters:

1. BOD < 30 mg/l
2. COD < 250 mg/l
3. TSS < 100 mg/l
4. TDS < 2,100 mg/l
5. Oil and grease < 10 mg/l
6. pH – 6-8.5
7. Total Residual chlorine < 1.0 mg/l
8. Ammoniacal Nitrogen (as N) < 50 mg/l
9. Sulphate as SO_4 < 1000 mg/l
10. Chloride < 600 mg/l

It is advisable to sample the inlet values of all streams to reach better interpretation of treatment results. Weekly controls of the sewerage system are recommended by BORDA (See Figure 26).

FIGURE 26: SANIMAS Operation and Maintenance Guideline for Operator.

Maintenance

To be carried out by personnel, which should be trained during the construction process. Trained personnel should check all control openings weekly and remove any obstructions to the regular flow:

- → Replacement of broken pipes, elbows, valves, Tee-pieces.
- → Installation of new filter media if necessary due to losses during removing, if not washable.
- → Installation of new gas pipes or vents due to corrosion or breakage.
- → Replacements of walls, covers or slabs.
- → Repair of cracks in walls or slabs.
- → Toilet users must be advised not to apply chemical detergents for toilet bowl cleaning, as their application kills the active bacteria in the wastewater treatment system, disabling the treatment process and resulting in fast sludge accumulation with ensuing increased maintenance work and operational cost.
- → If biogas is utilized, storage, pipelines and appliances must be also monitored regularly by trained personnel.

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Bangladesh Agricultural University was established as the only university of its kind in Bangladesh in 1961. It started functioning with the College of Animal Husbandry and Veterinary Science at Mymensingh as its nucleus. The university has six faculties and 43 departments covering all aspects of agricultural education and research. BAU was the second highest budgeted public university in Bangladesh for the year 2013–2014. It is ranked number four from 166 universities of Bangladesh according to the webometrics university ranking 2020.

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