BASTAF - NEW TECHNOLOGY IN DECENTRALIZED WASTEWATER MANAGEMENT FOR VIETNAMESE CONDITIONS

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Abstract

The decentralized approach is a new means of addressing wastewater management needs of sewered and unsewered areas in a comprehensive fashion. The basic idea of that is to treat the wastewater (possibly together with refuses) on-site by means of low-cost treatment systems, and make direct use the treatment products (water, compost, and biogas). This alternative can meet a sustainable wastewater management requirement and has a promising future, especially for developing country of Vietnam, where the water and sanitation issues are becoming a more and more important issue and are under new period of infrastructure development. Further, the authors describe results from experiment on treatment of real domestic wastewater by baffled septic tank with anaerobic filter (BASTAF) that could be most feasible option for on-site wastewater treatment in urban residential areas of Vietnam. The data show that baffled septic tank with anaerobic filter could effectively treat black wastewater from toilets, with removal efficiency by COD in average 73.6%, by BOD5 71.1%, by SS 75.4%. The decentralized schemes of wastewater management are also proposed for medium and small cities of Vietnam.

Key words: Anaerobic digestion, anaerobic filter, baffled septic tank, decentralized wastewater treatment

Introduction

Nowadays there are 620 cities and towns in 76-mio. population Vietnam. The country is under rapid urbanization and industrialization process, with positive indicators in socio-economic development. However, there is an increasing problem of water pollution. The water supply capacity has increased from 1.95 mio. cmpd. in 1990 to nearly 3 mio. cmpd. in late 2001. In the same period, the urban population has raised from 12 mio. in late 1980 to nearly 18 mio. in late 1999, accounting for 23.5% of the country's population. There is very low ratio of population, especially in rural, peri-urban and low-income urban areas, served by adequate sanitation. Urban sewerage and drainage systems are still poor and under degradation. In most of cities and towns, flood and inundation often occur in rainy season. Existing sewer networks (if any) in cities have been built for surface water drainage only. Mainly domestic wastewater from houses is directly discharged to the combined sewerage network and then flows to the canals, lakes and ponds without any treatment. In consequence, it exceeds self-purification capacity of receiving water bodies and causes surface and ground water pollution, impacting directly to public health and reducing the environment value. More than ever, development of urban sewerage and drainage systems in Vietnam has become an urgent need.

In Vietnam, septic tank is the most common on-site treatment facility in urban and peri-urban areas (See Table 1). In urban centers the ratio of households equipped with septic tanks is nearly 50-80%. In the rest parts of the city the ratio is 20-30% (Department of Statistics, 2002). Desludging of septic tanks is not often followed. Study carried out by CEETIA in the period 1998 - 2002 shows that most of septic tanks are often extremely outdated and damaged. They are not repaired and regularly overloaded, while sludge is not emptied regularly. Household septic tanks often consist of 2 chambers and they are placed underground in the house basement. All of investigated septic tanks are working without filtration chambers. Number of those was under designed and operated with rather low treatment efficiency. The characteristics of effluent from surveyed septic tanks in 4 selected cities: Hanoi, Hai Duong, Vinh Yen and Thai Nguyen in northern part of Vietnam were: BOD_5 240 ~ 720 mg/l; COD 320 ~ 1,200 mg/l; TSS 440 ~ 2640 mg/l (CEETIA, 2001). In some cases suspended solids content in effluent eventually higher than in influent due to floating substances in not-emptied septic tanks are washed out.

Table 1. Types of toilets in Vietnam

Type of toilet	Number	% of total	In urban areas	% of type	In rural areas	% of type
Septic tank	2,734,270	16.42	2,183,798	79.87	550,472	20.13
Suilabh	196,381	1.18	90,007	45.83	106,374	54.17
Pit latrine/Double vault	11,058,755	66.42	1,384,509	12.52	9,674,246	87.48
No toilet	2,650,814	15.92	362,001	13.66	2,288,813	86.34
Not stated	9,769	0.06	2,156	22.07	7,613	77.93
Total	16,649,989	100	4,022,471		12,627,518	

(Nguyen Viet Anh, CEETIA, adap. from Department of Statistics, 2001).

As a part of the Swiss Government funded project of Capacity building in environmental science and technology at Center for Environmental Engineering of Towns and Industrial Areas (CEETIA), Hanoi University of Civil Engineering, in co-operation with Swiss Federal Institute for Environmental Science and Technology (EAWAG), the decentralization concepts and technologies in wastewater management are being systematically investigated, with focus on its development and practical implementation in Vietnam. Looking for appropriate technical solutions for improvement of septic tank performance in urban areas in Vietnam is one from major interests of CEETIA-EAWAG research team.

Experiment on treatment of real domestic (black) wastewater by baffled septic tank with anaerobic filtration chambers (BASTAF)

Why BASTAF among various alternatives?

Around the same time as Lettinga developed the UASB, McCarty and co-workers at Stanford developed the Anaerobic Baffled Reactor (ABR) (McCarty, 1981).

Probably the most significant advantage of the ABR is its ability to separate acidogenesis and methanogenesis longitudinally down the reactor, allowing the reactor to behave as a two-phase system without the associated control problems and high costs (Weiland and Rozzi, 1991). Two-phase operation can increase acidogenic and methanogenic activity by a factor of up to four as acidogenic bacteria accumulate within the first stage (Cohen *et al.*, 1980, 1981), and different bacterial groups can develop under more favorable conditions.

Long retention time requirement is one of the main drawbacks of anaerobic wastewater treatment processes. The capital cost of such a process is most sensitive to the size of the reactor. Compared to several other anaerobic wastewater treatment processes, ABR by retaining the biomass within the reactor for long periods requires a smaller volume. In addition, ABR is simple and inexpensive to construct, because there are no moving parts or mechanical mixing devices. It consists of a series of vertical baffles to force wastewater to flow under and over them.

The other advantage of facility combining baffled reactor and up-flow anaerobic filter is it could be by modifying conventional septic tank, constructed underground in the basement of houses where septic tank used to be, especially in high-dense areas of the cities, and it is very simple in operation and maintenance. Hence, it is very attractive research called in order to evaluate the performance of anaerobic baffled reactor (with or without anaerobic filter) in treating domestic (black) wastewaters.

Materials and methods

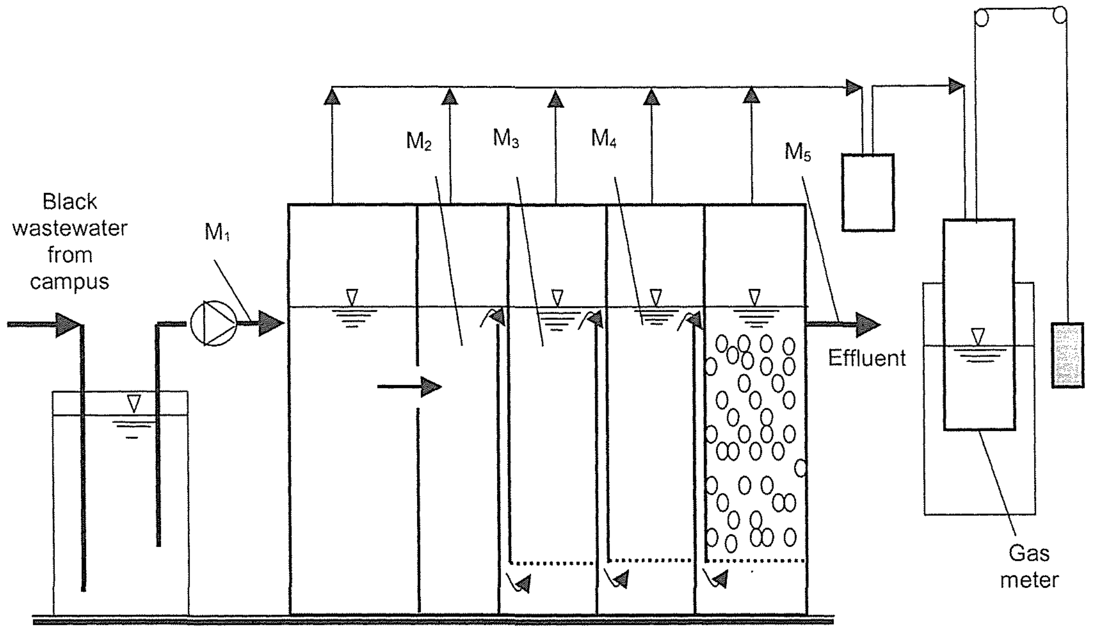

Figure 1. Baffled septic tank with anaerobic filter (BASTAF)
M1, M2, M3, M4, M5: Sampling points

BASTAF model at CEETIA's Laboratory

From 2000, CEETIA has installed two models of baffled septic tank, small and big, made from Plexiglas. The scheme of arrangement of models is shown in Figure 1. Total liquid volume was 46 l of small model and 215 l in big model, respectively. The first chamber in both models is separated in the middle through a wall (height 55 cm) with a window (2 cm wide) in the middle to play a role of primary settling-digestion chamber, as in conventional septic tank. This structure can reduce suspended solids coming into next chambers that could be barrier for removal of organic matters by microorganism in sludge, as well as gives the reactor more stability to hydraulic and organic shocks. Operation of those two septic tank models started since July 2001.

Wastewater source

Peristalic pumps were used to feed the reactors with a real wastewater from toilets in building of classes at the University's campus near Laboratory.

Seed sludge

At the beginning no sludge is added in order to study on the acclimatization and growth of the sludge in the reactor.

Operational regimes

Summary of the reactor operation regimes is given in Table 2.

Table 2. Operational conditions of BASTAF models

Stage	Period, days of operation	Flow, l/h	Up-flow velocity v, m/h	HRT	Influent SS, mg/l	Influent COD, mg/l	OLR, gCOD/l.d
Stage 1. 2 models worked in parallel, continuous feeding. Last chamber of both was Anaerobic filter (AF), with 30 ~ 40 mm-diameter Clinker in big and 20 ~ 40 mm-length, 15-mm-diameter PVC pipe pcs. in small model.							
Small	July 2001 ~ June 2002, 339 days	5.3 ~ 6	0.3	7.8 ~ 8.7	9 ~ 235	79 ~ 667.2	0.25 ~ 3.04
Big	December 2001 ~ June 2002, 232 days	20	0.3	10.8	81 ~ 1591	214 ~ 1031.2	0.27 ~ 2.3
Stage 2. 2 models worked in parallel, discontinuous feeding. AF was not in big model, and was with Clinker in last chamber of small one.							
Small	June 2002 ~ August 2002, 54 days	2.3	0.13	471.8	63 ~ 1065	121 ~ 971	0.006 ~ 0.05
Big	June 2002 ~ August 2002, 54 days	18.5	0.3	83.7	63 ~ 1065	121 ~ 971	0.04 ~ 0.28
Stage 3. 2 models worked in series, continuous feeding, big model (without AF) followed by small model, with Clinker AF in 2 last chambers.							
Small	September 2002 - February 2003, 167 days	4.74 2.34 3.54	0.13 0.06 0.1	25.9 52.4 34.7	24 ~ 234	98 ~ 605	0.35 ~ 0.92
Big	September 2002 - February 2003, 167 days	12.41 6	0.3 0.15	46.2 95.6	80 ~ 622	207 ~ 930	

Results and discussion

BASTAF reactor performance

pH value had trend to increase longitudinally down the reactor, showing that the methanogenesis phase occurred in the last chambers. Two-phase operation can increase acidogenic and methanogenic activity as acidogenic bacteria accumulate within the first stage and different bacterial groups can develop under more favorable conditions.

Sludge formation in chambers of reactor was not event along the experiment period. It was very slow in the first and second month after operation started, and was accelerated in next months. After 6 months of operation the sludge layer depth in the reactor was increasing very slowly. Steady removal efficiency of the reactor was recorded after 4 months of operation, when the sludge layer reached 7.5 cm depth in the bottom of reactor. Desludging was not carried out during experimental period, July 2001 ~ January 2003.

Suspended solids removal

SS concentration was decreasing along the chambers. Most of solids were removed from the settling chamber. That could give better removal of organic matters in the next chambers.

Summary of removal efficiency of SS and COD are given in Table 3. Time courses of SS and COD removal efficiencies from stage 3 are shown in Fig. 2 ~ 3.

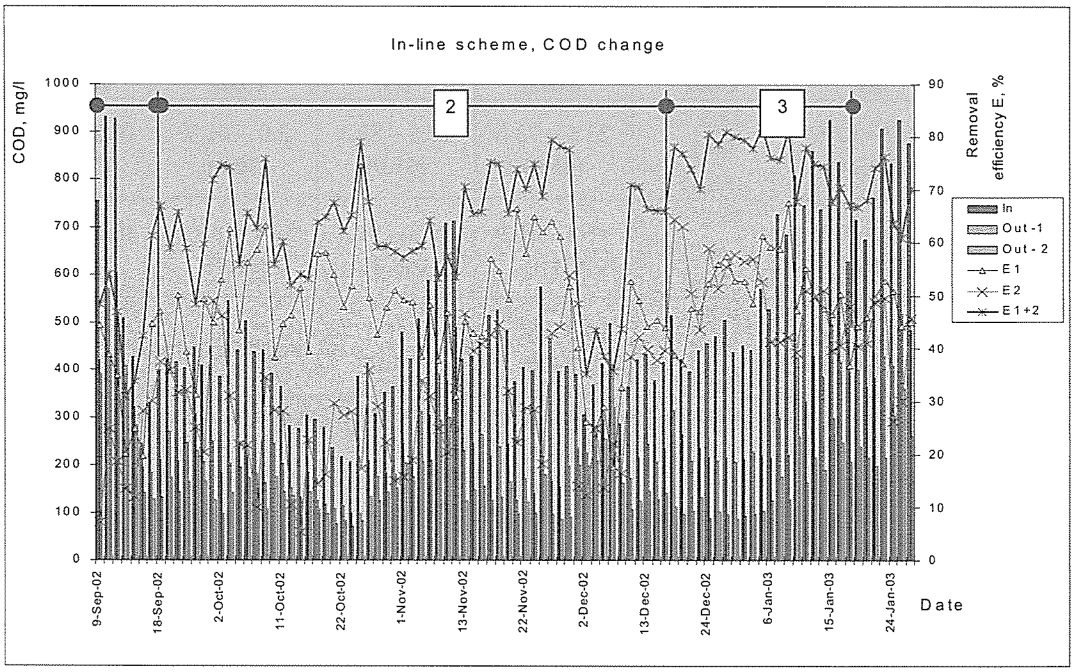

Figure 2. SS removal efficiency in 2 BASTAFs in series (stage 3, Sep. 2002 - Jan. 2003).

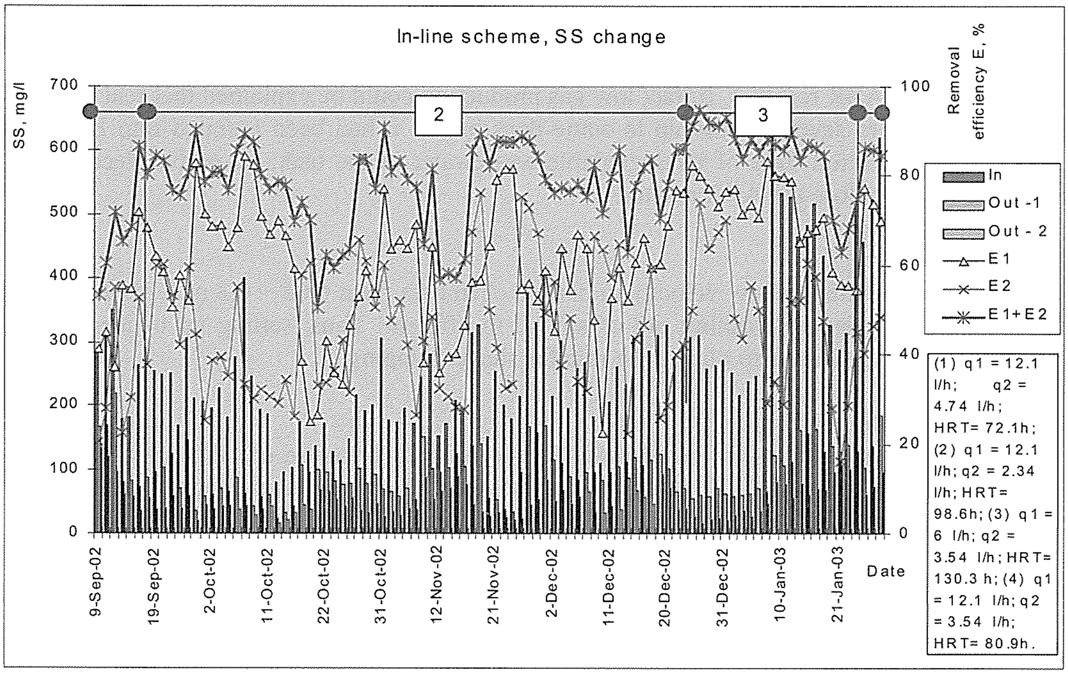

Figure 3. COD removal efficiency in 2 BASTAFs in series (stage 3, Sep. 2002 - Jan. 2003).

Table 3. SS, COD, BOD_5 removal efficiencies, %

Stages	*Small model*			*Big model*		
	SS	*COD*	*BOD_5*	*SS*	*COD*	*BOD_5*
1	16.7 ~ 87.5 **(59.1)**	28.3 ~ 90.2 **(50.1)**	23.5 ~ 73.6 **(46.0)**	12.8 ~ 83.3 **(51.0)**	2.0 ~ 61.9 **(30.6)**	19.2 ~ 61.5 **(37.6)**
2	47.6 ~ 97.2 **(75.4)**	43.2 ~ 94.9 **(73.6)**	45.3 ~ 90.9 **(71.1)**	35.9 ~ 91.3 **(68.7)**	28.4 ~ 83.8 **(59.9)**	36.4 ~ 91.2 **(60.7)**
3	50.7 ~ 94.9 **(78.8)**	30.8 ~ 81.8 **(64.7)**	24.5 ~ 81.6 **(64.4)**	(2 models in series)		

(Note: figures given in table: minimum ~ maximum (**average value**)).

In the first stage comparison of removal efficiencies of total and dissolved COD and BOD_5 was conducted. It shown that soluble and colloidal matters were removed more effectively than insoluble matters. Hence, the reactor equipped with primary settling chamber before baffled chambers would have better treatment efficiency. Good contact between bacteria in sludge layer and soluble and colloidal organics in solids free substrate could be provided for effective metabolism process. Further more, settling chamber at the beginning could give reactor stability to hydraulic and organic shocks.

Organic loading rate

During the stage 3 (in-line scheme) the F/M (food/microorganisms) ratio was calculated as 0.24 ~ 0.31 g COD_{in}/g VSS.d, with OLR 0.35 ~ 0.92 gCOD/l.d, and gas production rate (GPR) 0.033 ml CH_4/mg VSS. From different studies the ABR can treat wastewater under ranges of F/M 0.064 ~ 0.587 gCOD_{in}/gVSS.d, with OLR 0.1 ~ 20 g COD/l.d, GPR 0.11 ~ 1.28 ml CH_4/mgVSS. That means the current study got results in a range of studied ABR reactors. In fact low gas production could be explained that real wastewater kept in collection tank from several hours up to some days before it had been pumped into Laboratory. That could create long retention time of biodegradable wastewater in the tank, its partial decomposition with production of biogas before the ABR reactor.

Up-flow velocity

The models were run with up-flow velocity in baffled chambers from 0,06 ~ 0,3 m/h. Higher velocity, as it was tested in stage 1, led to washing out of sludge in effluent. Thus, setting up of anaerobic filtration chamber at the rear of reactor also played the role for sludge trapping.

Hydraulic retention time (HRT)

One from important parameters for ABR performance is HRT. Increase of HRT in stage 2 up to 471.8 hours for the small model and 83.7 hours for the big model significantly improved removal efficiency in compared with 8.7 hours and 10.8 hours respectively in the stage 1. Similar picture was observed in stage 3, while HRT was reduced, and that could demonstrate less removal efficiency of the reactor, despite of in-line scheme was set with more number of baffled chambers and already stabilized biomass.

Results from stage 2 shown that discontinued operation regime did not have negative effect on the reactor performance. Stops of reactors during night time (in stage 3) and holidays also did not have any impact on their performance while re-started. This could be one from important advantages of the ABR

Ambient temperature

Temperature has important impact to treatment efficiency of anaerobic reactors. Results from experiments in stage 2 and 3 shown that removal efficiency for BOD, COD, SS, as well as gas produced volume in lower temperature days was less than in others. However, it was noted that there is no big difference in reactor performance when temperature varied in a range over 20°C. It was contrary to cases while ambient temperature was bellow 20°C. Very low treatment efficiencies ware recorded during coldest winter days in Hanoi, with temperature varied from 8 to 15°C.

It shows that change of produced gas volume is very identical to organic loading rate changes. During January 2003 period, organic load on the big model was COD_{in} 528 ~ 926 mg/l, OLR 0.35 ~ 0.62 g COD/l.d, then gas production rate GPR was 23 ~ 199 ml/g COD_{in}. Similarly, in small model, following big model in line, COD_{in} (eq. COD effluent from big BASTAF) was 215 ~ 496 mg/l, OLR 0.4 ~ 0.92 g COD/l.d. then GPR was 0 ~ 0.18 ml/g COD_{in}. Gas production almost was not observed during coldest days of late December 2002 ~ early January 2003 with temperature bellow 8°C, what was very identical with low removal efficiency of the reactors.

Anaerobic filter
Clinker was suitable material for anaerobic filtration media, having high porosity, large and rough surface for attachment and growth of microorganisms. This cheap local material is available around the country, what makes its use simple and feasible.
Anaerobic filter could enhance the treatment efficiency and prevent from washing out of sludge in effluent. Results from stage 2 shown COD and BOD removal could be increased up to 10 ~ 27% by additional anaerobic filter at the rear, after baffled chambers.

Number of baffled chambers
It is confirmed that more number of compartments in the reactor gives better treatment performance and the reactor would be far more resistance to hydraulic and organic shocks, since they will protect against the shift in acid production towards to rear. Despite, more baffles leads to more construction expenses and land required. There fore a compromise should exist between optimal (required) compartment number, ''safe'' compartment number, and also up-flow liquid velocity. Number and size of compartment should be calculated based on required (given) treatment efficiency. For a case of BASTAF replacing role of septic tank in households in Vietnamese cities where effluent from mentioned reactors goes to the combined sewers, adequate COD and SS removal could be reached in reactor with 3 ~ 4 baffled chambers. It is suggested that a settling chamber should be installed in front of baffled chambers for flow balancing and settling of suspended solids, and, 1 ~ 2 anaerobic filters after baffled series.

Conclusions

Baffled septic tank with or without up-flow anaerobic filter has shown positive results for real domestic (black) wastewater treatment in Vietnamese condition. It could be developed further for practical implementation. Results from this study could be adapted for revision of existing septic tank design standards in the country.

For BASTAF replacing role of conventional septic tank in on-site/decentralized wastewater treatment schemes for a group of houses in Vietnamese cities, adequate COD, BOD and SS removal could be reached by a facility comprising a settling chamber, 3 ~ 4 up-flow anaerobic baffled chambers followed by 2 anaerobic filtration chambers in series. Effluent from BASTAF goes to combined sewers, or to the stabilization ponds or infiltration facilities such as soak-away chamber, infiltration field, etc., after that the effluent could meet the requirement for secondary treatment before it is infiltrated into the soil or discharged to receiving water bodies or reused in irrigation.

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