Organic matters removal from hospital wastewater by EGSB: Influences of seeding sludge and up-flow velocity

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Abstract: ***Wastewater from Binh An hospital was treated by EGSB lab-scale model. It is found that both EGSB started up with granular sludge and septic sludge operated at organic loading rate of 0.2-1.8 kg COD/m^3.day, with upward-flow velocity of 1.3 m/h can achieve greater than 65% COD removal efficiency and meet the current Vietnamese discharged standard for effluent from hospital wastewater (QCVN 28:2008/BTNMT). COD decreased from 148 ± 18 mg/L of the influent to 50 ± 18 mg/L of the effluent and BOD$_5$ of the effluent bellowed 35 ± 12 mg/L. When the organic loading rate increased from 1.8 kg COD/m^3.day to 2.3 kg COD/m^3.day, corresponding to the up-flow velocity increased from 2.4 m/h to 2.8 m/h, COD removal efficiency reduced significantly. The up-flow velocity of 2.8 m/h leaded small and low density suspended solids and granular sludge flowing with effluent. With COD of the influent < 200 mg/L, EGSB can remove > 65% of COD if the up-flow velocity and the organic loading rate was controlled ≤ 2.4 m/h and about 1.8 kg COD/m^3.day, respectively. EGSB with media F25 gave higher COD removal efficiency compared to that without media addition.***

Keywords: EGSB, wastewater treatment technology, anaerobic biological process**,** hospital wastewater**.**

1. Introduction

Ho Chi Minh City is considered to be one of the most dynamic areas of Vietnam. Ho Chi Minh City (HCMC) is a social, cultural and economic center of the South of Vietnam. Beside industrial - economic development, public health has been paid more and more attention. Several hospitals, clinics, health care centers have been invested in HCMC to satisfy public demand on health care service. At present, HCMC has 185 hospitals, over 400 health care centers, clinics and approximately 12,000 private clinics are operating [1]. Its development creates good condiction for public health care on the one hand and causes more environmental problem on the other hand if wastes generated from its operation are not well managed. About 20,000-26,000 m^3/day of wastewater are generated from hospitals, health care centers, clinics in HCMC [2]. Proper treatment of this kind of wastewater to meet Vietnamese standard before discharged to the common sewer system of the city are still limitted. In addition, population increases leading to an increase in health care demand as well as wastewater generation from this activity.

So far, several technologies have been applied to treat hospital wastewater. Each technology has specific advantages and disadvantages. Aerobic biological technologies are able to remove biodegradable organic matters in the wastewater without creating hazard by-products or wastes, but it consumes a lot of energy for aeration, requires larger land areas, to be able to receive low organic loading and low microorganism (sludge) concentration, only in the range of 2-5 g VSS/L [3]. Meanwhile, anaerobic biological processes are able to remove organic matters with high organic loading rate, lower energy consumption, less excess sludge generation and lower land area requirement [4], [5], [6]. Organic loading rate in anaerobic bioreactors can be controlled in the range of 3.2-32 kg COD/m^3.day compared to those of aerobic bioreactors can be only in the range of 0.5-3.2 kg COD/m^3.day [7], [8], [3]. This show how high organic loading rate the anaerobic bioreactors to be able to handled compared to those of the aerobic bioreactors. Besides, greater amount of excess sludge generates from aerobic bioreactors needed to be handled compared to those of the anaerobic bioreactors. Because of these specific advantages of anaerobic technology, it seems to be a possible solution to apply where land is limited, and low energy consumption as well as less by-products or waste generation from treatment process is paid attention. Expanded granular sludge bed - EGSB is one of anaerobic bioreactors to be able to meet these requirements and was selected to evaluate its performance in removing organic matters of hospital wastwater.

The study was carried out to evaluate influences of types of seeding sludge to acclimatization time, up-flow velocities, and addition media to organic removal efficiency of hospital wastewater using EGSB.

2. Materials and Methods

2.1 Experimental set up

Lab-scale EGSB reactor consists of two parts: anaerobic degradation part and gas sepration part. The anaerobic degradation part of the reactor is made of PVC pipe with a height of 1900 mm, an inner diameter of 100 mm, and its effective volume of 14.9 L. The gas separation part is made of acrylic pipe with a height of 100 mm and a volume of 0.8 L and 2 fan-shaped baffle plates installed in this part for gas-solid-liquid separation. Effluent is collected through as a plastic funnel on the top of the reactor. Three valves with diameter of 12 mm are installed along the reactor height to take sludge samples during operation: (1) the first valve is 400 mm from the reactor' bottom; (2) the second valve is 600 mm from the first valve; and (3) the third valve is 400 mm from the reactor' top. The basement of the reactor is made of a PVC pipe with a diameter of 90 mm and a height of 300 mm and connected to the reactor of another connector with a diameter of 114 mm. Total height of the reactor is 2400 mm.

The reactors were placed at the wastewater treatment plants of Binh An Hospital, HCMC, Vietnam. Wastewater was collected from an existing pit hole of the hospital and pumped into a storage tank of 800 L. Prominent dosing pump with a flow rate of 120 ml/minute and a pressure of 0.1 Mpa to feed wastewater into the reactors from the reactors' bottoms. N-FEEDER pumps were used to circulate wastewater back to the reactors. N-FEEDER pumps worked at flow rate of 540 ml/minute and a pressure of 0.2 Mpa. Influent and effluent pipes are made of soft plastic pipe with diameter of 10 mm. The circulated pipe has a diameter of 21 mm and length of 3000 mm and is connected to intermediated tank with a dimension if 200 mm x 150 mm x 150 mm. At the bottom of the intermediated tank, a valve with a diameter of 16 mm was installed in order to release wastewater if necessary. A photo and a design of the reactor is presented in Figure 1 and Figure 2.

Figure 1: Photo of the reactors

Concentration of sludge in anaerobic bioreactors is usually controlled in the range of 10-20 g VSS/L [8], [3]. In this study, septic sludge and granular sludge were used with concentration of about 12 g VSS/L.

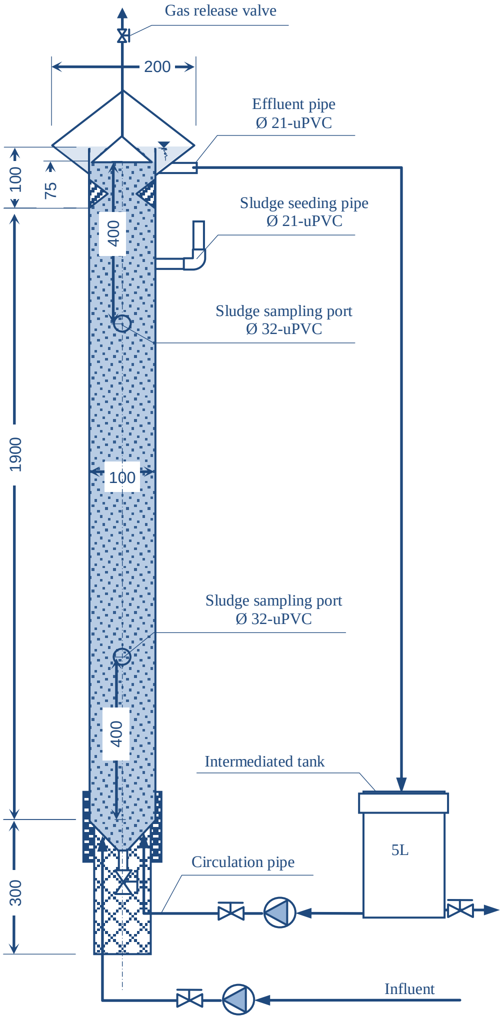

Figure 2: Design of the reactor

2.2 Influence of types of seeding sludge to acclimatization time of EGSB

Each type of sludge feeding into the EGSB needs a certain time for microorganism to acclimatize to the new environment. In order to determine influence of seeding sludge to the acclimatization time, experiments were carried out with the following conditions:

- Operating two EGSB parrallelly with the same operational conditions but using different types of seeding sludge. The reactor A (MH A) was operated with only granular sludge, while the reactor B (MH B) was operated with septic sludge in combination with media.
- Two reactors were started up at the organic loading rate of 0.2 kg COD/m^3.day. When the system reached steady state, organic loading rate was increased by increasing the influent flow rate. The up-flow velocity was controlled at about 1.3 m/h. It is maintained by adjusting flow rate of recirculation pumps.
- Media F25 was added into the reactor 1. It is made of systhetic plastic with white color. The media has surface area of 620 m^2/m^3 with a diameter of 25 mm and a height of 10 mm. As introduction of the producer, it is better to add about 20-60% of the reactor volume with this type of

media. In this study, 25% of the effective volume of the reactor B was added by this media (Figure 3). Average concentration of wastewater from Binh An hospital used in this study is described in Table 1. Operational conditions are summarized in Table 2. Everyday, influents and effluents were analyzed pH, SS, COD_{total}.

Figure 3: Media added into the reactor 1

Table 1: Composition of wastewater from Binh An hospital

Parameters	Unit	Average concetration
pH	-	7.5
SS	mg/l	235
BOD_5	mg/l	250
COD	mg/l	400
N_{total}	mg/l	40
Oil and grease	mg/l	75
Coliform	MNP/100 ml	$10^4 – 10^5$

Table 2: Operational conditions to evaluate influence of type of seeding sludge

Parameters	Unit	Exp. 1	Exp. 2	Exp. 3
Organic loading rate	kg COD/m^3.day	0.2	0.6	1.8
Flow rate	L/day	21.8	43.2	245.3
HRT	h	17.3	8.7	1.5
Up-flow velocity	m/h	1.3	1.3	1.3
Recirculation flow	L/day	223.2	201.9	0
Recirculation ratio	%	91	82	0

Exp. = Experiment

2.3 Influence of up-flow velocity to organic matter removal efficiency of EGSB

Control of up-flow velocity plays an important role in increaseing contact between microorganism and substracts. However, very high up-flow velocity may carry the sludge out of the reactor and reduce its efficiency. Kato et al. (2003) found that it is possible to achieve organic removal efficiency of 70% by using EGSB to treat domestic wastewater containing low COD concentration of 126 ± 53 mg/L with organic loading rate of 0.1-1.4 g COD/L.day, HRT of 4 hours, sludge concentration of 12 g VSS/L and up-flow velocity of 1.23-3.83 m/h. While a researched results of Yoochatchaval et al. (2008) ([9]) showed that if COD concentration of wastewater as low as 0.6-0.8 g/L, EGSB has to operate 51 days in the conditions of up-flow velocity of 5 m/h, HRT of 2.5 hours, organic loading rate of 6.5 kg COD/m^3.day to reach COD removal efficiency of 82.3%. In this study, as COD concentration of hospital wasetwater as low as only about 0.4 g/L, organic loading rate was increased from 1.4 kg COD/m^3.day to 2.3 kg COD/m^3.day by increasing up-flow velocity from 2.0 m/h to 2.8 m/h. The reactor B was operated at different up-flow velocities as summarized in Table 3 in order to evaluate influence of up-flow velocities to COD removal efficiency of the EGSB.

Table 3: Operational conditions to evaluate influence of up-flow velocity to EGSB performance

Up-flow velocity (m/h)	Flow rate (L/day)	Organic loading rate (kg COD/m^3.day)	HRT (h)	Recirculation ratio (%)
2.0	288.0	1.4	1.0	23
2.4	360.0	1.8	0.8	19
2.8	446.4	2.3	0.7	16

2.4 Influence of addition media to organic matter removal efficiency of EGSB

In order to evaluate influence of adding media F25, the EGSB reactors with and without media F25 were operated at the same conditions as summarized in Table 4.

Table 4: Operational conditions to evaluate influence of adding media F25 to EGSB performance

Parameters	Unit	Exp. 1	Exp. 2
Organic loading rate	kg COD/m^3.day	1.2	1.8
Flow rate	L/day	172.8	245.0
HRT	h	2.2	1.5
Up-flow velocity	m/h	1.3	1.3
Recirculation flow	L/day	72	0
Recirculation ratio	%	42	0

3. Results and Discussions

3.1 Influence of types of seeding sludge to acclimatization time of EGSB

3.1.1 At organic loading rate of 0.2 kg COD/m^3.day

The reactor A was operated with granular sludge from UASB of VEDAN Wastewater Treatment Plant, while the reactor B was operated with septic sludge from Hoa Binh Fertilizer Factory in combination with meadia F25. Both reactors were controlled at organic loading rate of 0.2 kg COD/m^3.day. The experimental results show that COD removal efficiency of the reactor A reached 72% in average as COD reduced from 148±18 mg/L in the influent to 41±15 mg/L in the effluent. The highest COD removal efficiency of the reactor A reached 82%, equivalent to COD reduction from 118 mg/L in the influent to 21 mg/L in the effluent. Average COD removal efficiency of the reactor B using septic sludge in combination with media F25 reached only 66% as COD reduced from 148±18 mg/L in the influent to 50±18 mg/L in the effluent. The highest COD removal efficiency of the reactor B reached 80%, equivalent to COD reduction from 160 mg/L in the influent to 32 mg/L in the effluent. Both reactors reached steady state at day 14 after operation. Kato et al. (2003) ([10]) also reported that at organic loading rate of 0.1-1.4 kg COD/m^3.day and up-flow velocity of 1.25-3.75 m/h, it is possible to reach COD removal efficiency of 62-74% by EGSB.

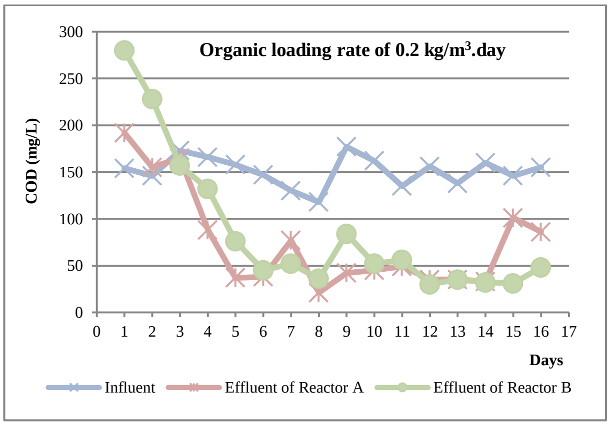

Figure 3: Varying of COD in the influent and effluents from the reactor A and reactor B at organic loading rate of 0.2 kg COD/m^3.day

pH of the influent was about 7,0±0,11. pH of the effluent from the reactor A and the reactor B was 7,1±0,16 and 7,0±0,16, respectively. Concentration of the influent's SS was very low, only about 11±3 mg/L. Concentration of SS in the effluents of both reactors increased within the first 6 days of operation and then decreased gradually. However, SS in the effluents were still higher than that of the influent. It is attributed to unacclamization of sludge. Composition of influent and effluents from the reactor A and the reactor B operated at organic loading rate of 0.2 kg COD/m^3.day at steady state is summarized in Table 5.

Table 5: Composition of influent and effluents from the reactor A and the reactor B operated at organic loading rate of 0.2 kg COD/m^3.day

Parameters	Influent	Effluent of the reactor A	Effluent of the reactor B
pH	7.0 ± 0.11	7.1±0.16	7.0 ±0.16
SS (mg/l)	11±3	18±7	19±13
Alkalinity (mg $CaCO_3$/l)	95±15	72±31	56±21
COD_{total} (mg/l)	148±18	41±15	50±18
N-ammonia (mg N/l)	18±1	19 ± 3	21±3

3.1.2 At organic loading rate of 0.6 kg COD/m^3.day

After the reactors reached steady state at organic loading rate of 0.2 kg COD/m^3.day, the organic loading rate of both reactors were increased to 0.6 kg COD/m^3.day by increasing influent flow rate and reducing recirculation flow rate. The systems were operated for 24 days to reach steady state. The experimental results showed that average COD removal efficiency of the reactor A using granular sludge reached 81% as COD reduced from 213 ± 140 mg/L in the influent to 41 ± 26 mg/L in the effluent. The highest COD removal efficiency of the reactor A achieved 93% as COD reduced from 100 mg/L in the influent to 7 mg/L in the effluent. In the case of the reactor B using septic sludge in combination with media F25, the highest COD removal efficiency was only 80% as COD reduced from 402 mg/L in the influent to 32 mg/l in the effluent. It is important to remark that during operation at this organic loading rate, COD of the influent sometime increased significantly from 98 mg/l up to 426 mg/L, but COD removal efficiencies of both reactors remained greater than 65%. Variation of COD in the influent and effluents of both reactors operated at organic loading rate of 0.6 kg COD/m^3.day is described in Figure 4.

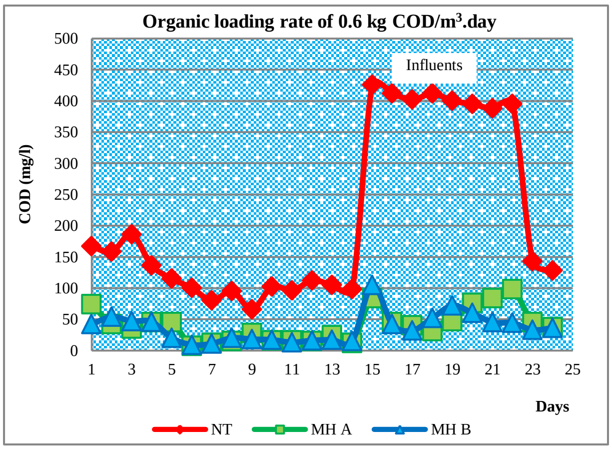

Figure 4: Varying of COD in the influent and effluents from the reactor A (MH A) and reactor B (MH B) at organic loading rate of 0.6 kg COD/m^3.day

pH of effluents of both reactors increased. pH of the influent was 6,8±0,55, while pH of effluents of the reactor A and the reactor B were 7,1±0,19 and 7,1 ±0,23, respectively. Though SS concentration of the influent varied in the range of 4 – 140 mg/l, SS concentrations of effluents of the reactor A and the reactor B were as low as 7±9 mg/l and 10±10 mg/l, respectively. Composition of influent and effluents from the reactor A and the reactor B operated at organic loading rate of 0.6 kg COD/m^3.day at steady state is summarized in Table 6.

Table 6: Composition of influent and effluents from the reactor A and the reactor B operated at organic loading rate of 0.6 kg COD/m^3.day

Parameters	Influent	Effluent of the reactor A	Effluent of the reactor B
pH	6,8 ±0,55	7,1±0,19	7,1 ±0,23
SS (mg/l)	40±48	7±9	10±10
Alkalinity (mg $CaCO_3$/l)	105±17	78±29	73±28
COD_{total} (mg/l)	213 ±140	41±26	36±23
N-ammonia (mg N/l)	15±4	17± 3	17±3

3.1.3 At organic loading rate of 1.8 kg COD/m^3.day

After reached steady state at the organic loading rate of 0.6 kg COD/m^3.day, both reactors were increased organic loading rate to 1.8 kg COD/m^3.day by increasing influent flow rate and reducing recirculation flow rate. At this organic loading rate, pH of effluents were stable at 7,3±0,17 và 7,3 ±0,08 for the reactor A and the reactor B, respectively, while pH of the influent was 7,2 ±0,13. After 13 days of operation, COD concentration of the influent decreased significantly. COD removal efficiency of the reactor A achieved 77% as COD reduced from 112±34 mg/L in the influent to 26±9 mg/l in the effluent. In the case of the reactor B, COD reduced from from 112±34 mg/L in the influent to 28±16 mg/l in the effluent, equivalent to COD removal efficiency of 75%. Concentration of SS in the influent was 51±38 mg/l, while in the effluents, it was in the range of 5 -10 mg/l for the case of the reactor A and 3 -13 mg/l for the case of the reactor B. Variation of COD in the influent and effluents of both reactors operated at organic loading rate of 1.8 kg COD/m^3.day is described in Figure 5. Composition of influent and effluents from the reactor A and the reactor B operated at organic loading rate of 1.8 kg COD/m^3.day at steady state is summarized in Table 7.

Table 7: Composition of influent and effluents from the reactor A and the reactor B operated at organic loading rate of 1.8 kg COD/m^3.day

Parameters	Influent	Effluent of the reactor A	Effluent of the reactor B
pH	7,2±0,1	7,3±0,1	7,3±0,1
SS (mg/l)	51±38	5±2	7±2
Alkalinity (mg $CaCO_3$/l)	99±23	87±21	92± 26
COD_{toal} (mg/l)	112±34	26±9	28±16
N-ammonia (mg N/l)	23±5	23±4	23± 3

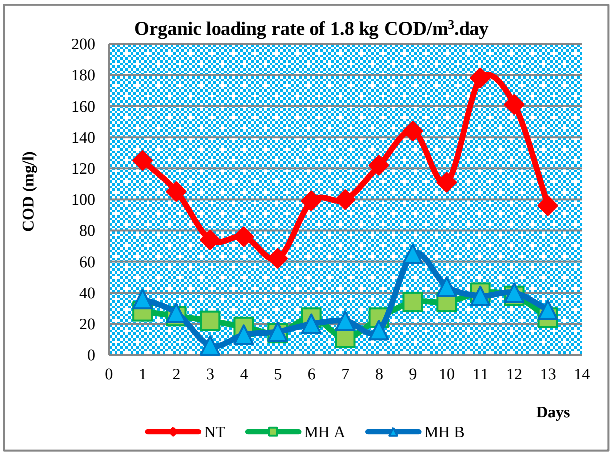

Figure 5: Varying of COD in the influent and effluents from the reactor A (MH A) and reactor B (MHB) at organic loading rate of 1.8 kg COD/m^3.day

As summarized in Figure 6, there is insignificant different in COD removal efficiencies of both EGSB at different organic loading rates.

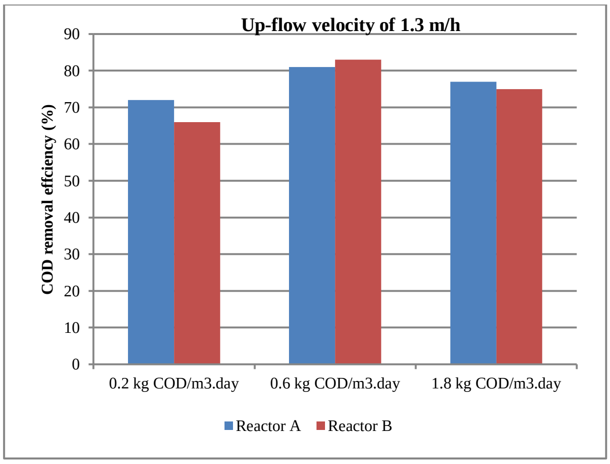

Figure 6: COD removal efficiency of the reactor A (MH A) and reactor B (MHB) at different organic loading rate and the same velocity of 1.3 m/h

3.2 Influence of up-flow velocity to organic matter removal efficiency of EGSB

The experimental results as discussed above indicate that it is possible to use EGSB seeding with septic sludge to remove organic matters in the hospital wastewater. Therefore, in this study, only reactor B was operated to evaluate influence of up-flow velocities to COD removal efficiency. The reactor was operated at up-flow velocities of 2.0 m/h; 2.4 m/h and 2.8 m/h in sequence. The experimental results are summarized in Table 8. When controlled up-flow velocity at 2.0 m/h, COD removal efficieny reached 66% in corresponding to COD reduction from 110±11 mg/l in the influent to 37±7 mg/l in the effluent. When the up-flow velocity was increased to 2.4 m/h, COD removal efficiency of the reactor still remained at 71%, and COD reduced from 115±13 mg/l to 33±5 mg/l. However, when increase the up-flow velocity upto 2.8 m/h with organic loading rate of 2.3 kgCOD/m³.day, COD removal efficiency reduced significantly. In this condition, COD removal efficiency was only 40% in corresponding to COD reduction from 114±27 mg/l to 68±26 mg/l.

Table 8: Composition of influent and effluents from the reactor A and the reactor B operated at different up-flow velocities

Parameters	**Up-flow velocity of 2.0 m/h**	
	Influent	Effluent
pH	7.10±0.11	7.20±0.09
SS (mg/l)	39±12	7±2
Alkalinity (mg $CaCO_3$/l)	110±11	125±9
COD_{total} (mg/l)	110±18	37±7
N-ammonia (mg N/l)	18±1	21±4
Parameters	**Up-flow velocity of 2.4 m/h**	
	Influent	Effluent
pH	7.10±0.07	7.30±0.11
SS (mg/l)	32±12	5±2
Alkalinity (mg $CaCO_3$/l)	122±12	130±6
COD_{total} (mg/l)	115±13	33±5
N-ammonia (mg N/l)	18±3	24±3
Parameters	**Up-flow velocity of 2.8 m/h**	
	Influent	Effluent
pH	6.90±0.34	7.10±0.11
SS (mg/l)	38±11	59±41
Alkalinity (mg $CaCO_3$/l)	99±20	99±15
COD_{total} (mg/l)	114±27	68±26
N-ammonia (mg N/l)	18±5	17±3

When the up-flow velocity increased to 2.8 m/h, SS concentration of the effluent increased significantly to 59±41 mg/L compared to less than 10 mg/L if the up-flow velocity was in the range of 2.0 - 2.4 m/h.

3.3 Influence of adding media to organic matter removal efficiency of EGSB

In order to evaluate influence of presence of media F25, a EGSB without media was operated at the same conditions as that of EGSB with adding media. Septic sludge was used as seeding. At organic loading rate of 1.2 kg COD/m^3.day, up-flow velocity of 1.3 m/h, average COD removal efficiency reached 64% in corresponding to COD reduction form 105 ± 15 mg/l to 38 ± 12 mg/l after 12 days of operation. The highest COD removal efficiency achieved was 80%, and COD of effluent as low as 18 mg/L. After reached steady state, the EGSB was increased organic loading rate to 1.8 kg COD/m^3.day at the same up-flow velocity of 1.3 m/h by increasing influent flow rate to 244.8 L/day and reducing recirculation flow rate to 0. At this operational condition, COD removal efficiency of EGSB reduced significantly. Average COD removal achieved was only 45%, and COD could only reduce from 115 ± 17 mg/l to 63 ± 13 mg/l, while the EGSB with media F25 was able to remove 75% COD in average. COD removal efficiency of EGSB with and without media F25 at the organic loading rate of 1.8 kg COD/m^3.day and up-flow velocity of 1.3 m/h is described in Figure 7.

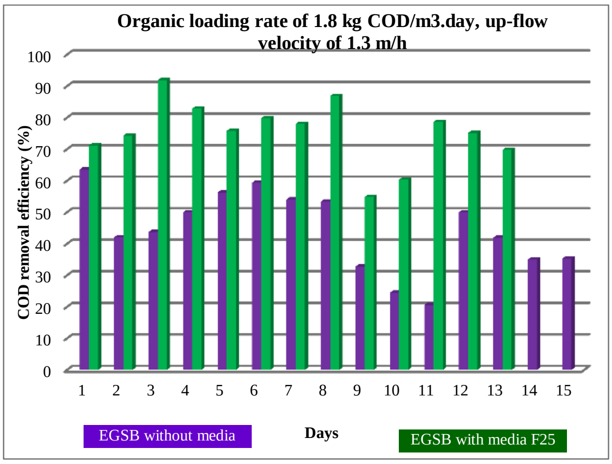

Figure 7: COD removal efficiency of the EGSG with and without media F25 at the organic loading rate of 1.8 kg COD/m^3.day and the up-flow velocity of 1.3 m/h

4. Conclusions and Recommendations

The experimental results allow to draw the following conclusions:

- When operating at the up-flow velocity of 1.3 m/h, both EGSB reactors seeding with granular sludge and septic sludge in combination with media F25 are able to remove organic matters from hospital wastewater. When increasing organic loading rate from 0.2 kg COD/m^3.day to 1.8 kg COD/m^3.day, COD removal efficiency of both reactors maintained above 65% in corresponding to COD reduction from 148±18 mg/L to 50±18 mg/L, and BOD_5 of the effluents lower than 35±12 mg/L, meet Vietnamese standard of QCVN 14:2008/BTNMT class B for discharging into sewer network. Both reactors were operated without adding chemicals for pH and alkalinity controlling.
- No significant different in acclimatization time found in the EGSB reactor seeding with granular sludge compared to septic sludge in combination with media F25.
- For COD concentration of wastwater lower than 200 mg/L, COD removal efficiency of EGSB can reach > 65% if it is operated at velocity not more than 2.4 m/h and organic loading rate upto 1.8 kg COD/m^3.day. When increased up-flow velocity from 2.4 m/h to 2.8 m/h in corresponding to organic loading rate increased from 1.8 kg COD/m^3.day to 2.3 kg COD/m^3.day, COD removal effiency of EGSB reduced significantly. Small and low density particulate matters were carried along with effluents.
- EGSB with media addition gave higher COD removal efficiency. It is necessary to recheck this conclusion by operating EGSB with and without media addition to treat wastewater containing higher COD concentration.

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Author Profile


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