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Influence of Different Hydraulic Retention Time on Modified Septic Tank System for Faecal Sludge Treatment

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ABSTRACT

The objectives of the study were to design and fabricate an modifiied septic tank and monitoring the performance of developed purification tank. This system was implemented and tested as part of a research project focused on innovative decentralized wastewater treatment solutions. This system consist of four chambers in series with different filter media. First two chambers were anaerobic and third was aerobic and last chamber was sedimentation tank. Moving bed biofilm media and plastic bio cube ball were used as filter media. The reactor was made with 5mm acrylic sheet. The catalyst behind the system was the bacteria that helps to digest all the inputs. The output is reusable and can be released to a common water body. The structure of this system was designed fully demonstrate the purification function of microorganism attached growth system. High removal of organic load was achieved under all loading criteria in this system. The system was observed to remarkably efficient in removing pollutants with the average removal efficiency of 79% for BOD, 70% for COD, 82% for TS, 84% for TDS, 78% for TSS, 56% for VSS, 80% for NH3-N, 72% for NO3-N, 92% for PO4. This anaerobic-aerobic system is a feasible option of onsite domestic wastewater treatment for the people of the developing country like Bangladesh.

1. Introduction

Faecal Sludge Management (FSM) is one of the complex and difficult job in the world. FSM is important as over a billion people in urban and peri-urban areas of Africa, Asia, and Latin-America are served by on-site sanitation technologies, Faecal Sludge (FS) is not well managed in many cities (Murungi and Peter 2014) of the above continents. This trend particularly intense in developing country, where an additional 2.1 billion people are expected to be living in cities by 2030. These cities produce billions of tons of waste every year, including faecal sludge. The disposal of sludge become a problem with the application of the more intensive methods of treatment, which resulted in the production of large volumes of sludge (Metcalf and Edddy 1995). FS may be treated in separate treatment works or co-treated with sludge produced in wastewater treatment plants. (Strauss *et al* 2002). Waste generation of the world is increasing along with the population and development of the region. Management of this produced waste is one of the prime concerns of the countries. Sludge Management is a major Challenge in Bangladesh. Bangladesh has shown remarkable progress in liminating open defecation, but there is urgent need for Faecal Sludge Management (FSM) in Bangladesh mainly in urban areas (Islam 2016), where most human waste is dumped untreated into waterways or onto marginal land, harming the environment and health, especially of the country's poorest (Opel 2011). Only 20% of the population of Dhaka is served by a highly expensive sewerage network; the rest use septic tanks, pit latrines, unhygienic latrines (Hasan et al 2014) and other major cities of Bangladesh do not use sewer network. Only a small percentage of faecal sludge is managed and treated appropriately (Hasin and Abdullah 2015). The outlet of most of the septic tank is connected with rain water sewer. Consequently, untreated wastewater is directly discharged

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into the rain water sewer. The proper emptying mechanism for pits or septic tanks are almost absent. Most of the containment emptied manually where the percentage of mechanical emptying is very low and private sweepers are dominantly doing the emptying job. (M. Sabok et al 2018). Khulna is the third largest city of Bangladesh situated in the south-western part of the county and lies in the delta of the river Ganges (Hasan et al 2004), The city has an estimated population of 1.6 million and total number of household is 66257 Toilet with septic tank is rising in Khulna city. There are 94% septic tank is connected with surface or gray water drain and maximum drain outlet is connected with river and this is very harmful for our environment ecosystem. Maximum septic tank have not been emptied for a long time. More than 85% of households practice unsafe faecal sludge (FS) emptying and conveyance. Collected sludge from septic tank is directly or indirectly disposed into waterbodies. Septic sewage is also considerably more offensive to the olfactory nerves (Davis & Conwell., 2006). So, the disposal of human excreta required treatment before its discharge into the natural environment. If the wastewater do not treated well enough this will pollute recipient with phosphorus and nitrogen, organic matter and bacteria that can lead to eutrophication and potential health problems. The Mayur is the example of that is almost dead due to siltation and waste disposal in Khulna city. Application of a proper on site decentralized technology needed for faecal sludge treatment.

Presence of organic micropollutants in municipal wastewater is well documented (Reemtsma *et al.,* 2006; Lishman *et al.,* 2006; Vieno *et al.,* 2007) and a potential threat to the receiving water (Parrott and Blunt, 2005; Zeilinger *et al.,* 2009). Removal efficiency of these compounds at wastewater treat-ment plants, WWTPs, is often highly dependent on the bio-logical treatment (Carballa *et al.,* 2004; Zorita *et al.,* 2009); moreover, it has been shown that the biological treatment design can influence the overall micro pollutant removal (Stumpf *et al.,* 1999). Biological wastewater treatment techniques can normally be classified as either suspended or attached growth pro-cesses. The suspended activated sludge process is the most frequently used biological treatment at municipal WWTPs, thus, technical and operational solutions that can improve micro pollutant removal in this process are highly desirable. Previously, it has been reported that upgrading of high loaded activated sludge processes to nitrogen removal through enlargement of the treatment basin enhances removal of some micro pollutants (Andersen *et al.,* 2003; Schaar *et al.,* 2010). Despite this improvement, numerous micro pollutants are rather stable in activated sludge treatment (Mie`ge *et al.,* 2009). However, for some of these compounds considerably higher removal rates have been observed for biofilm carriers than activated sludge (Fala˚s *et al.,* 2012; Zupanc *et al.,* 2013), which suggests that further optimization of the biological micropollutant removal is possible.

In Recent years, Moving bed biofilm reactor (MBBR) is a novel technology for wastewater treatment. This type of biological treatment begins in the 1970s. The moving bed biofilm reactor (MBBR) was first developed for treatment of municipal wastewater in terms of nitrogen removal (Odegaard *et al.,* 1994). Afterwards, other applications of the MBBR process were developed such as treatment of industrial wastewaters, nitrification in water treatment for land based fish farming and removal of soluble organic matter in secondary treatments of municipal wastewater (Helness *et al.,* 2005). In moving bed biofilm process suspended porous polymeric is used as a carrier which moves continuously in the aeration tank and the active biomass grows as a biofilm on the surface of carriers (Loukidou and Zouboulis, 2001). In this context, more than 90% of biomass is attached to the media rather than suspended in the liquid (Schmidt and schaechter, 2011). The advantage of this system in comparison to a suspended growth one is the higher biomass concentration, less sensitivity to toxic compounds, lack of long sludge settling period (Loukidou and Zouboulis, 2001), less prone to the process upsets from poorly settling biomass (Schmidt and schaechter, 2011), cost effectiveness (Fang, 2011) and the achievement of both organic and ammonia removals efficiently in single stage (Horan *et al.,* 1997). Moving bed biofilm filter within its small footprint has a positive property of the area requirement which is one fifth to one third of that needed for activated sludge treatment as well as a lower effect of temperature on the rate of biological nitrification (Salvetti *et al.,* 2006). However, the operational costs are higher in MBBR than that of activated sludge treatment. These systems could be efficient for BOD removal and tertiary nitrification and denitrification following suspended or attached growth nitrification (Metcalf and Eddy, 2004). As the MBBR system has the important advantage of flexibility of carrier's fill fraction, these systems have become very popular for use in industrial applications and applications with high variation in the expected load in time (Haandel and Lubbe, 2012). Some factors have been reported to affect the performance of MBBR. The high specific area of the carrier media controls the system performance which is as a result of very high biofilm concentrations presence in a small reactor volume. It was reported that typical biofilm concentrations range from 3000 to 4000 g TSS /m3, which is similar to values obtained in activated sludge processes with high sludge ages. The percentage of reactor volume comprised of media is limited to 70%, with 67% being typical (Odegaard *et al.,*2000). However, wastewater characteristics and specific treatment goals are the main factors determining the percentage of media required in the reactor.

This article aims to design and fabricate a modified aerobic-anaerobic tank system with the concept of MBBR process and Anaerobic filter process and monitoring the performance of developed aerobic-anaerobic modified septic tank system (MSTS). This project demonstrates a modern low-cost onsite wastewater treatment technology tasted with varying hydraulic loading rates with attached growth biological treatment.

Materials and Methods

Experimental procedure

Description of the pilot-scale experimental plant

A modified anaerobic aerobic septic tank system with four compartments has developed of which initial two is anaerobic reactors, third is moving bed biofilm reactor and rest one is sedimentation tank. The walls and internal layer are fabricated with clear acrylic plastic (celluloid sheets). The reactor is rectangular in shape (as shown on the Figure 1 & 2). The total volume of the reactor was 52L and has a length of 61 cm, height of 28 cm and a width of 31 cm. The MSTS volume is 52 L or 0.052 m^3.

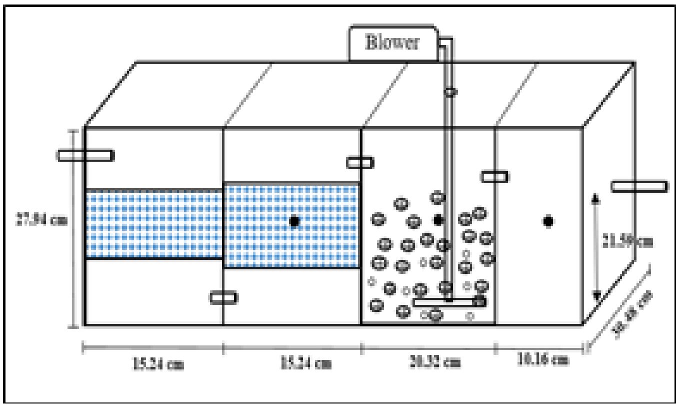


Figure 1: Schematic Diagram of Modified septic tank system **(Capacity:** 61 cm x 28 cm x 31 cm)

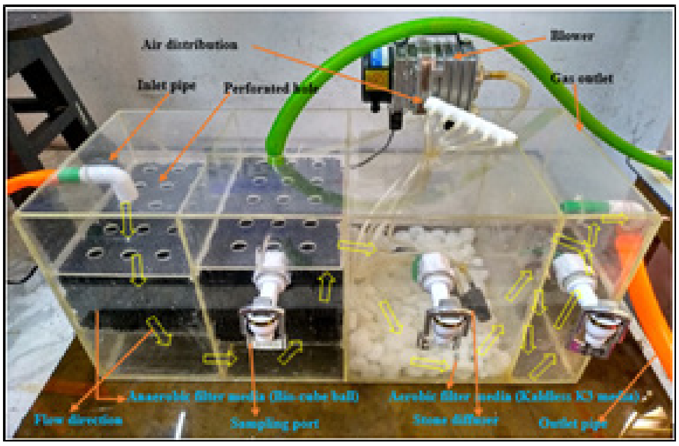


Figure 2: Experiment set up with specification

The MSTS made with 5mm plastic acrylic sheet is shown in the Figure 2. An equalization tank was set with the main Reactor shown in the following figure 7. The capacity of equalization tank was 60 L that can supply wastewater needed for one day and placed at the top of so that wastewater could enter in the system by gravity. An inlet pipe was inserted at 1inch above the top of the modified tank. Flow of the first chamber is down flow, second, third and fourth chamber is up flow. There is an anaerobic filter are two chamber. First anaerobic filter layer of the first chamber is set 3 inch bottom from the tank with 4 inch height and second anaerobic filter of the second chamber is set 2.5 inch bottom from the modified tank system with 5.5 inch height. Two rectangle acrylics with perforated hole are used to hold the anaerobic filter. Every acrylic plate contains 15 holes at the same intervals so that wastewater can easily pass over the anaerobic filter layers without risk of clogging. A perforated acrylic plate is shown in the Figure 6. A water dispenser tap is inserted every chamber except first chamber at 3 inch top from the bottom of the tank for collection of the sample. A three inch soft PVC (see in the Figure 8) plastic clear transparent pipe is connected with every water dispenser tap at the inner part of the tank because of sample could be collected at the same region in the modified tank system. Before and after feeding of the system is shown in Figure 9 and 10.

To design a special aerobic and anaerobic tank system including combination of anaerobic and aerobic chamber and filter media. The medium-scale anaerobic-aerobic tank made with 5mm plastic acrylic sheet. There are four chambers in this tank system. The process flow of the system is given bellow in the following Figure-

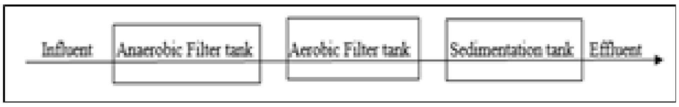


Figure 3: Process flow of MSTS filter system

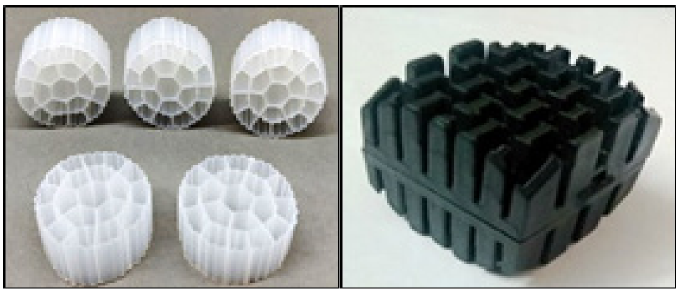
First two chambers are anaerobic filter tank where plastic biocube balls (Shown in the Figure 4b) are used as filter media. Biocube ball is made with polypropylene and combined with rectangular sponge in the ball where maximum solids retain in the filter media and anaerobic bacteria attached growth in the filter media. In the anaerobic tank, denitrification process is take place. Second chamber is aerobic chamber where Anoxkaldles K3(Shown in the Figure 4a) media was is used as plastic media. Aeration was take place by an aerator and nitrification process was occurred in this chamber and last one is sedimentation chamber. A 30 watt capacity blower was used to continue the aeration process. Plastic carrier was moved with moving part of the water.

Characteristic of different carrier media

The MSTS was configured with different media such as Kajdless K3 and Biocube Ball and those have different surface area and filling ratio. The characteristic of different carrier media used in experiment is given below in the Table-

Table 1: Characteristic of different carrier media used in experiment (adopted from manufacturer)

Cham-ber	**Com-mer-cial Name**	**Mate-rial**	**Shape**	**Specif-ic sur-face area**	**Di-men-sion**	**Filling Factor**
Anaer-obic Filter	Bio-cube Ball	poly-pro-pylene	Rect-angu-lar	378 m^2/m^3	30mm; 30mm	40%
Aer-obic Filter	Anox-kaldes K3	poly-pro-pylene	Cylin-drical	500 m^2/m^3	12mm; 25 mm	70%



(a) (b)

Figure 4: (a) Kaldes Media used in aerobic chamber
(b) Biocube ball media used in anaerobic filter

In the MBBR process, small high density polyethylene (HDPE), polypropylene, plastic, ceramic, porous carrier elements with a large surface area are used for the growth of microorganisms within the reactor. In the reactor, Aeration pattern is operated in such a manner that the upward movement of the carrier takes place across the surface of the reactor. It protects from clogging so that the entire reactor will be in active biologically causing higher biomass activity.

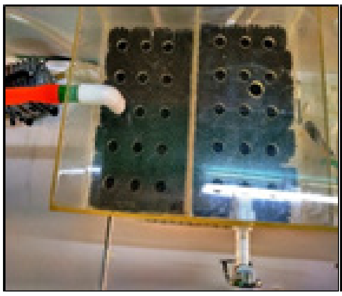


Figure 5 : Top view of anaerobic filter layer

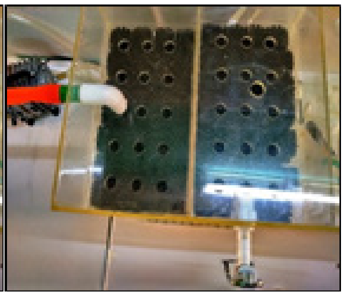


Figure 6: Perforated acrylic sheet used in anaerobic filter layer

Figure 7: Equalization tank connected with Reactor

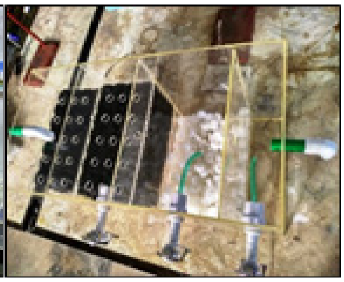


Figure 8 : Flexural plastic PVC pipe adjust with dispenser water tap

Figure 9: Full set up of modified septic tank before feeding

Figure 10: Modified septic tank after feeding

Operational condition:

The anaerobic-aerobic filter tank volume is 0.052 m^3 and 52 litre capacity. This tank system was operated 20 days for getting stable condition and then operated different operational condition and 5 days for getting stable condition ending every phase of operation; these conditions is given below in the Table-

Table 2: Different operational condition in experiment

Phase no	Flow	Hydraulic Retention Time	Duration Day
1	9 ml/minute	104 hours	01 To 30
2	12 mL/min	72 hours	31 To 60
3	19 mL/min	48 hours	61 To 90
4	36 mL/min	24 hours	91 To 120

Sample collection

After installing the MSTS, Faecal sludge collected from selected septic tank (local pit latrine) according to standard sampling method and insert into MSTS. Sample was collected from conventional septic tank effluent. It was collated by the plastic container. Each container capacity was 30 liter. This sample will be tested in laboratory. Regular monitoring will be done and parameter will be measured in laboratory. Selected parameters namely Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Volatile Suspended Solid (VSS), Ammonia Nitrogen (NH_3-N), Phosphate (PO_4-P), Nitrate Nitrogen (NO_3-N), Faecal coliform (FC), pH etc. will be measured. At least 3-5 samples will be tested routinely. Characteristic of Septic tank effluent is given bellow in the Table 3-

Table 3: Characteristic of septic tank effluent

Parameter	Unit	Concentration Range
	Number of samples=40	
BOD_5	mg/l	284-715
COD	mg/l	397-1236
TSS	mg/l	324-793
TS	mg/l	1736-2589
TDS	mg/l	981-1796
VSS	mg/l	97-212
NH_3-N	mg/l	58.40-93.47
PO_4-P	mg/l	24.21-62.47
NO_3-N	mg/l	18.38-56.27
FC	Nos/100ml	1743-3974
pH	-	6.32-8.20

Table 4: Equipment and/or chemicals used in laboratory examined

SL	Tested Parameter	Unit	Used Equipment/Chemicals/Reagents
1	pH	-	pH meter (Lovibond, Senso Direct pH 110)
2	DO	mg/l	DO meter (Hach , HQ – 40d (multi)
3	BOD	mg/l	MnSO4, NaSO2SO4, KI, NaOH, H2SO4, Starch Solution
4	COD	mg/l	Spectrophotometer (HACH, DR 2700, program no – 955, 171220/600 n m, single wavelengths)
5	TS	mg/l	Evaporation Dish, Filter paper (0.2 micron), Drying Oven, Measuring scale
6	TDS	mg/l	
7	TSS	mg/l	
8	TC/FC		Petri dish, Auger, Filter paper
9	Nitrate	mg/l	Spectrophotometer (HACH, DR 2700, program no – 951, HR PP, 30 mg/L multi wavelengths)
10	Phosphate	mg/l	SM 4500-P E
11	Ammonia Nitrogen	mg/l	VELP SCIENTIFICA UDK 129

Based on initial tested parameter the treatment method and unit processes will be selected and volume of reactors will be calculated. Regular monitoring will be done and parameter will be measured in laboratory. Investigating and maintenance the septic tank routinely.

Laboratory Analysis

In this study, selected water quality parameters are tested at the Environmental Engineering Laboratory in KUET. All the laboratory tests have been conducted as per standard methods (APHA, 2012). The tested water quality parameters included various types of physical, chemical and bacteriological characteristics. The tested water quality parameters along with respective standard methodologies information have been shown in Table 4.

Results and Discussion

In the study, different pH fluctuation are shown in the Figure 14(a) is shown at different HRT. There was no much variation found of pH in this study except 3rd chamber of the MAASTS because of nitrification mechanism. In the 3rd chamber the pH is increased due to acid formation is occurred in the nitrification process because previous studies shown that there is a strong relation between nitrification rate and pH. When a well nitrification process occurred in a system, the values of pH is increased. On another side, there is a strong relation between dissolved oxygen and pH and that was the time when dissolved oxygen is increased due to aeration then pH values of significantly high. The average values of pH in influent were 7.08, 1st and 2nd chamber were 7.46 and 8.17 respectively and last chamber was 7.5 (shown in the Figure 4.2). After analyzing the pH values, it can be said that a simultaneously nitrification and denitrification process may be successfully occurred in the MAASTS. However, at HRT=104 h and 48 h, the values of pH was not significantly varying due to longer HRT because of it was seemed in the previous study, a pH change generally does not vary over a long period.

The height percent of BOD removal occurred in phase three. The organic load of the reactor was increased gradually. The mean values of BOD removal was get 79 percent removal of the MSTS. The values of BOD effluent concentration are gradually decreasing till phase 3 but at phase 4. The values of effluent slightly increase because of high organic load but there was not so significant change in last phases of the investigation. The value of effluent in phase three is 107.73 mg/l. According to Metcalf and Eddy 1991 (Third Edition) in the page of 109 and Table 3-16, it can be seen that the wastewater can be classified as-

(i) Week with BOD 110 mg/L
(ii) Medium with BOD 220 mg/L
(iii) Strong with BOD 400 mg/L

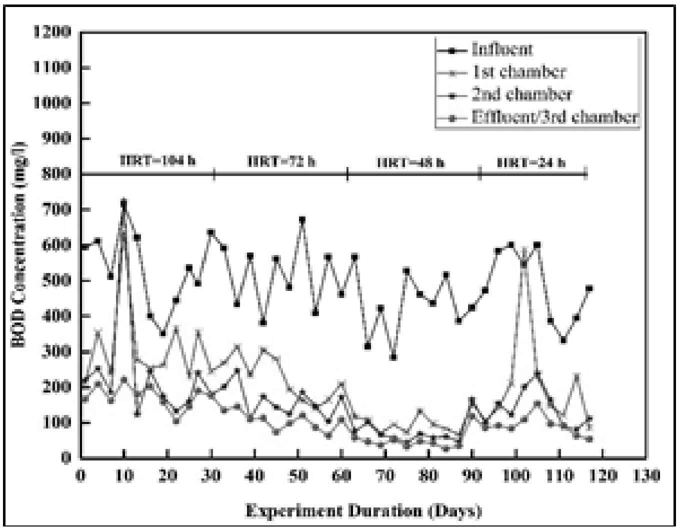
The tested wastewater is falls in category of Strong domestic wastewater. This strong domestic wastewater achieved removal efficiency 66%, 79%, 89% and 80% (Shown in the Figure 11b). As effluent from this treatment does not meet the effluent standard of ECR 97 for BOD with 40 mg/L. Therefore another stage of treatment may be required for discharging into the surface water bodies. In addition, the results of the study were better than the results of M.M and Kamel and Hegazy (2006) who obtained more than 65% reductions of BOD operating the baffled septic tank at 60.5 h HRT. The maximum 89 % of COD removal was found in phase 3 (HRT=48 h). These results are better than the results obtained by Coelho *et al.,*who obtained removal efficiencies from 70–75%, treating domestic wastewater using conventional septic tank at 48 h HRT. The COD value in influent range was 397 to 1142 mg/l .The minimum and maximum value of 1st chamber was 148 and 730 mg/l respectively, 2nd chamber was 84 and 634 mg/l respectively and the rest chamber was 29 and 550 mg/l respectively. The average value of COD in effluent was 227.9 mg/l where the standard COD value for discharging is 400 mg/l. Almomani and Khraisheh (2016) investigated by sing moving-bed biological reactor with different hydraulic retention time. MBBR effectively reduced septic tank effluent chemical oxygen demand by 85 % over 180 days of operation. The influent and effluent concentration of COD in this study were 5514 mg/L to 250 mg/L. In this study, MAASTS could reduce septic tank effluent chemical oxygen demand by eighty nine percentages over 120 days of operation. It is cleared that the removal efficiency of MAASTS COD is more effective than these previous work.

The TS values in influent range was 1736 to 2589 mg/l .The minimum and maximum value of 1st chamber was 316 and 1641 mg/l respectively, 2nd chamber was 319 and 969 mg/l respectively and the rest chamber was 119 and 561 mg/l respectively. The highest reduction of TS was occurred in 1st chamber due to maximum solid and garbage was retained in the anaerobic filter media. The maximum reduction value of TS reduction with maximum removal percentage found in phase 3 (HRT=48 h). The average values of influent and effluent were 771 and 228 mg/l respectively. AAFS effluent TS value is agree with the standard discharging value of Bangladesh. The results of the study were better that the results of Gulhame and Ingale (2015) presented an institutional analysis of wastewater using moving bed biofilm reactor. The results show that the average removal efficiency of Total Solid was 81 %.

For SS, The values of influent and effluent vary from 324 to 620 mg/l and 52 to 185 mg/l respectively. The removal percentage of SS about all HRT was 78%. The average values of influent and effluent were 662 and 99 mg/l respectively in entire experiment. The efficiency of TSS removal was slightly decreased in last 30 days of experiment due to height organic load. These results are in line with those obtained by Koottatep *et al.,*(2004) who obtained average removal efficiency of 76% for TSS when treating wastewater using anaerobic single-baffle septic tank at 48 h.

The maximum and minimum values TDS concentration in influent was 1474 and 981 mg/l and effluent was 345 and 67 mg/l which was significantly reduced by MSTS. The average value of TDS removal efficiency was achieved 84% by the system. The average value of effluent was 195 mg/l is agree with the effluent discharging standard value which is 2100 mg\l. Thakur and khedikar (2015) carried out an investigation for the treatment of domestic wastewater by using moving bed biofilm reactor. The experiment carried out for the varying HRT range of 24 hrs and 48 hours shows TDS removal efficiency is seen up to 40%. In this experiment with MAASTS could reduce high label of TDS concentration from septic tank effluent.

The highest and lowest values for VSS were 185 to 97 mg/l for influent and 119 to 32 mg/l for effluent. The values of VSS were suddenly increased in 1st chamber due to detachment of biomass. The biomass in the bio cube at anaerobic chamber was growing rapidly due to high level of organic firstly retained in the bio cube. The highest removal percentage was achieved in HRT 48h which was 65% and it was indicated that the MSTS was applicable to biodegradation of a wide range of VSS concentration. The reduction of VSS is reduced shown in phase 4 during experiment and when the velocity of material is increased



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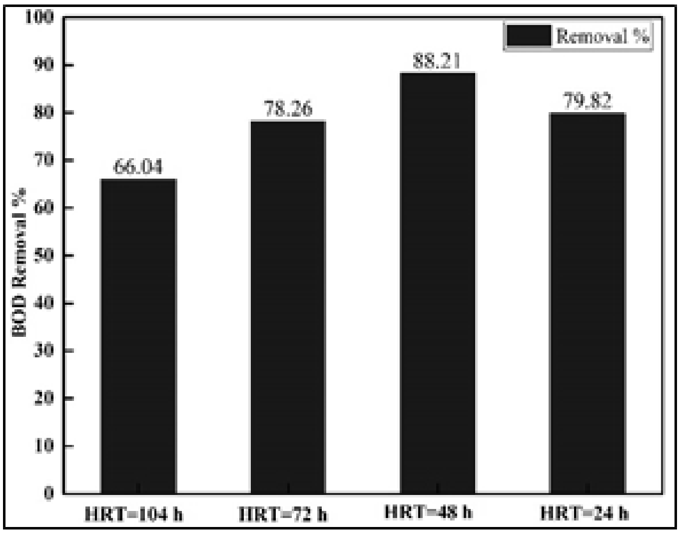

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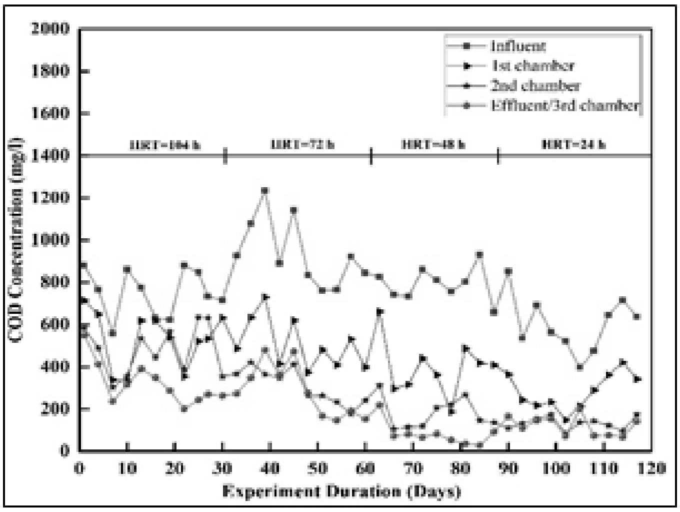

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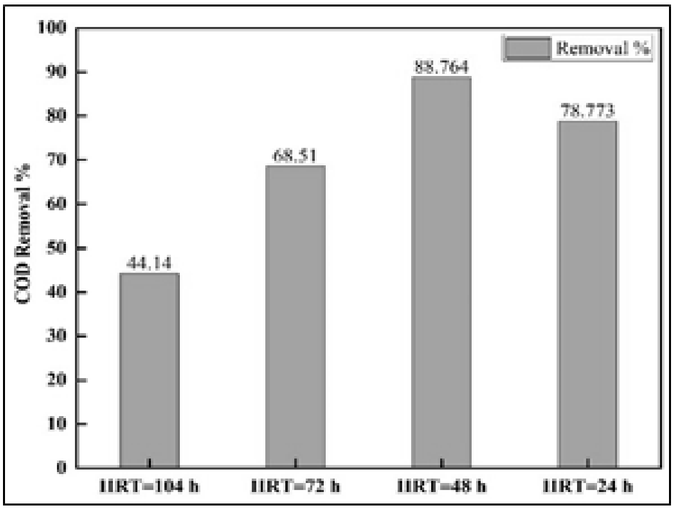

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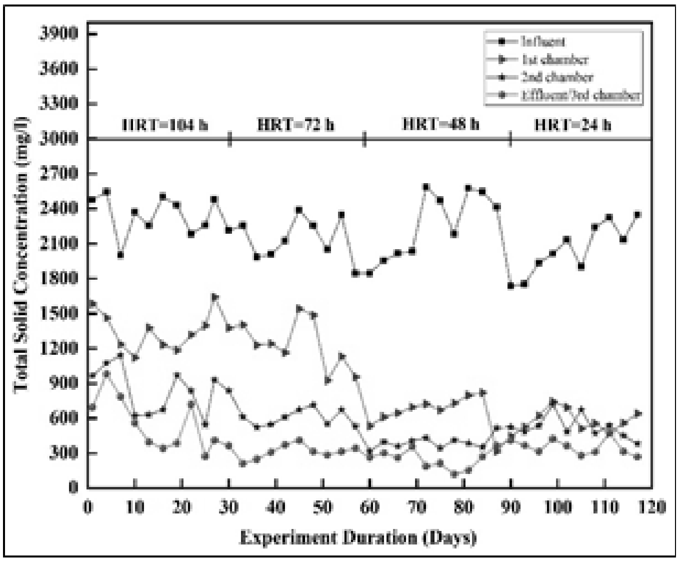

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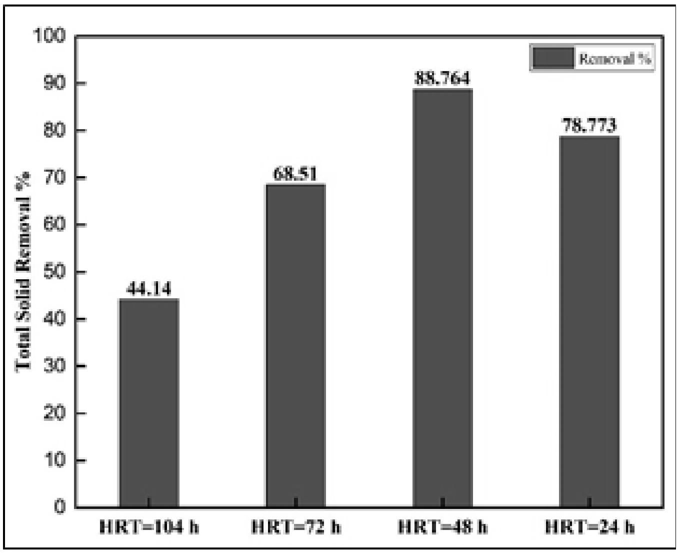


f

Figure 11: (a) BOD concentration in entire experiment (b) BOD removal percentage in experiment
(c) COD concentration in entire experiment (d) BOD removal percentage in experiment
(e) TS concentration in entire experiment (f) TS removal percentage in experiment

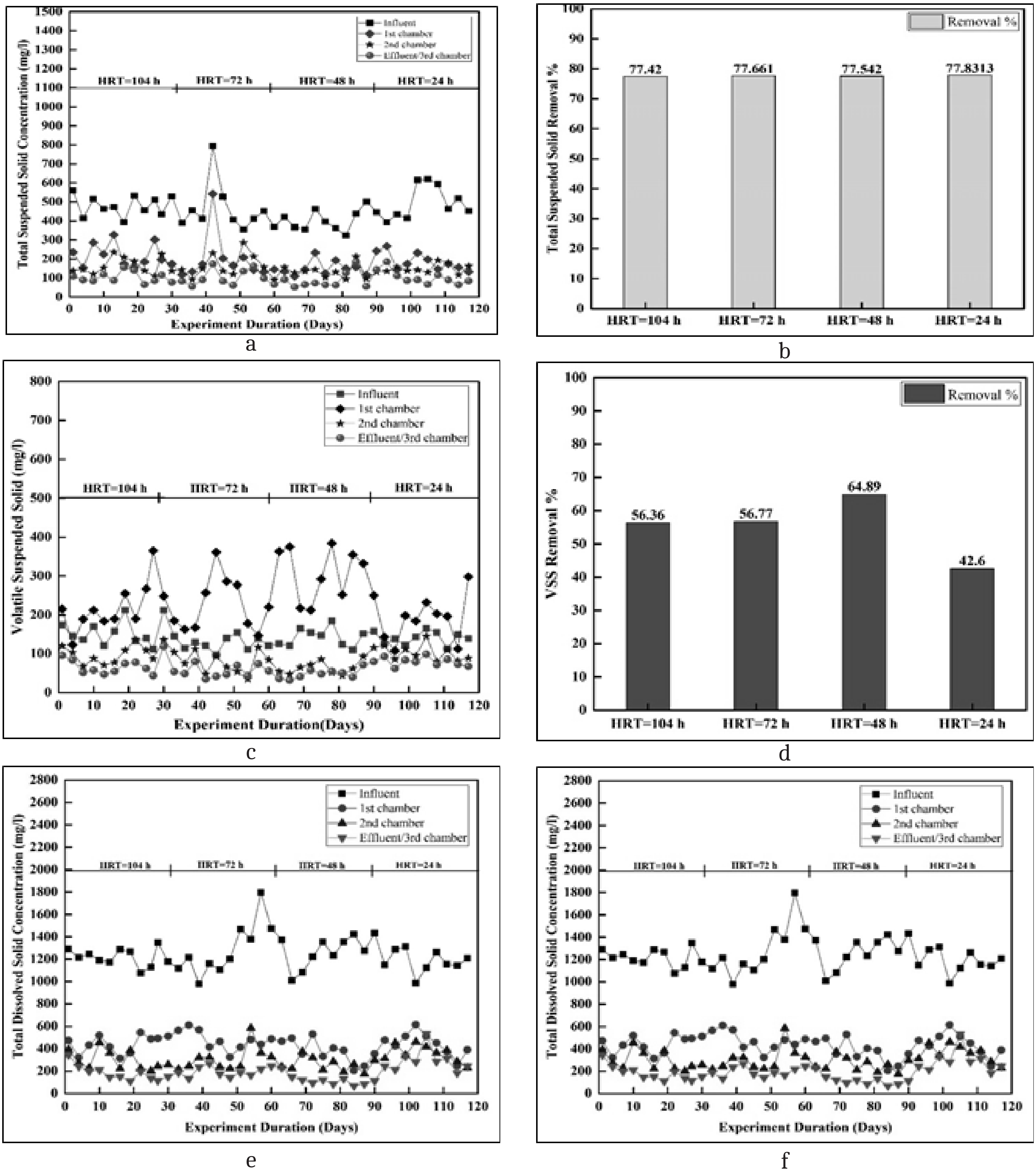


Figure 12: (a) TSS concentration in entire experiment (b) TSS removal percentage in experiment
(c) VSS concentration in entire experiment (d) VSS removal percentage in experiment
(e) TDS concentration in entire experiment (f) TDS removal percentage in experiment

so that the mixing is poor and oxygen transfer is inhibited. Shi and Ren (2018) also found in her study, the feed VSS concentration varied from 7 to 55 gm/l and the effluent VSS concentration ranged from 4.40 to 31 gm/l. Removal efficiency ranged from 37.14 % to 61%.

From that place, maximum VSS removal % was found 65% in this study. However, it was indicated that the MAASTS was applicable to biodegradation of a wide range of VSS concentration.

In the MSTS, the nitrification process is mainly occurred in the 2nd chamber and full of this process happened in the surface of moving biofilm carrier and why high NH_3-N removal efficiency was achieved in the second chamber of the reactor. The lower and higher value was 58.4 to 93.47 mg/l for influent and 5.21 to 30.62 mg/l for effluent. The highest ammonia removal percentage was achieved in HRT 48h which was 86%. The average values of NH_3-N removal percentage in the study was 15 mg/l and that was quite

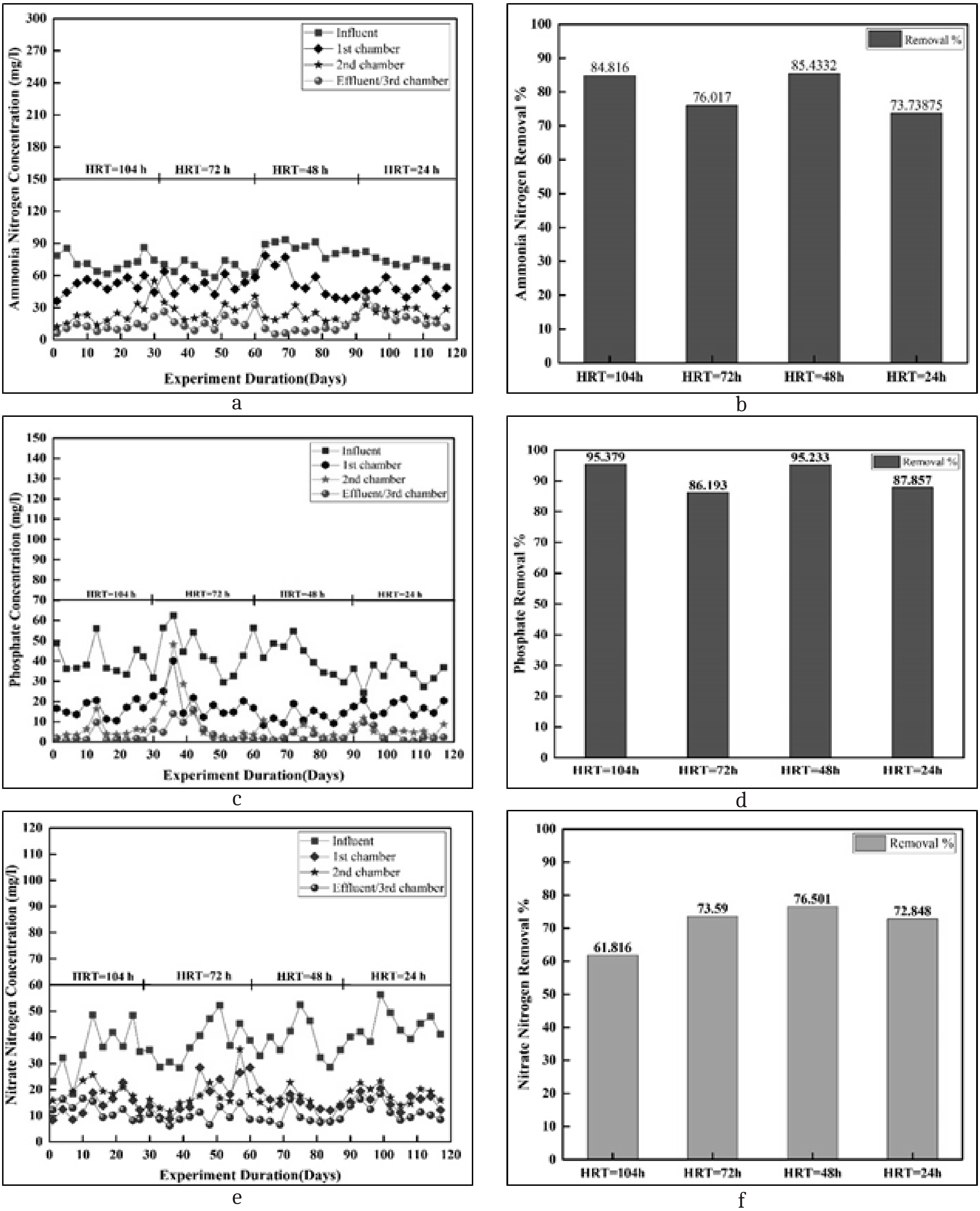


Figure 13: (a) NH_3-N concentration in entire experiment (b) NH_3-N removal percentage in experiment
(c) PO_4-P concentration in entire experiment (d) PO_4-P removal percentage in experiment
(e) NO_3-N concentration in entire experiment (f) NO_3-N removal percentage in experiment

good to discharge. Setiani et al (2019) demonstrated in that study of MBBR application pretreatment of raw water for water treatment plant. He found the efficiency of 54.3 % ammonia removal and aeration rate was 7 L/min. Associate with little reduction of ammonia removal efficiency the effluent quality for ammonia was quite good to discharge.

Under a different hydraulic loading time, the 77 % maximum average Nitrate removal was found in the MSTS effluent. The highest and lowest value was 58.4 to 93.47 mg/l for influent and 5.21 to 30.62 mg/l for effluent. The lowest and highest value was 18.38 to 56.27 mg/l for influent and 6.14 to 18.36

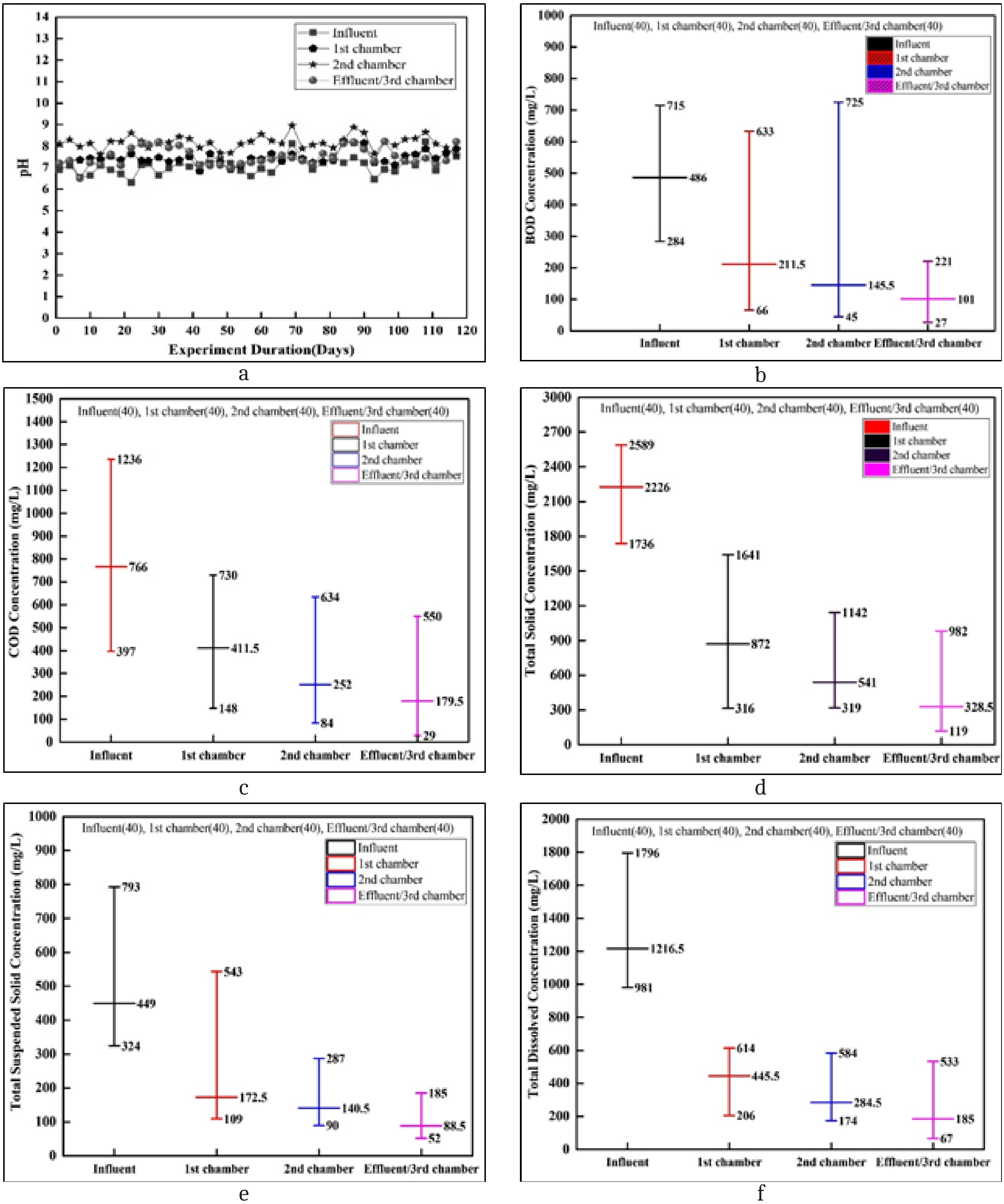


Figure 14: (a) pH variation in entire experiment
(b) Different BOD concentration at different chambers
(c) Different COD concentration at different chambers
(d) Different TS concentration at different chambers
(e) Different TSS concentration at different chambers
(f) Different TSS concentration at different chambers

mg/l for effluent. The average value of effluent was 10.77 mg/l. The average value of removal was 72 percentage in the study under different operational condition. Abbassi et al (2018) found that the effluent of two different type modified septic tank for NO_3 was 14.9 mg/l and 8.2 mg/l respectively. The results of the study were approximate similar to this study.

For phosphate, the highest and lowest values for influent and effluent was 62.47 and 24.21 mg/l respectively. The mean value of influent and effluent was 40.38 and 3.64 mg/l respectively. Under a different hydraulic loading time, the 96% maximum average Phosphate removal was found in the MSTS effluent which was occurred in HRT=104 h. The average values of removal percentage in entire experiment

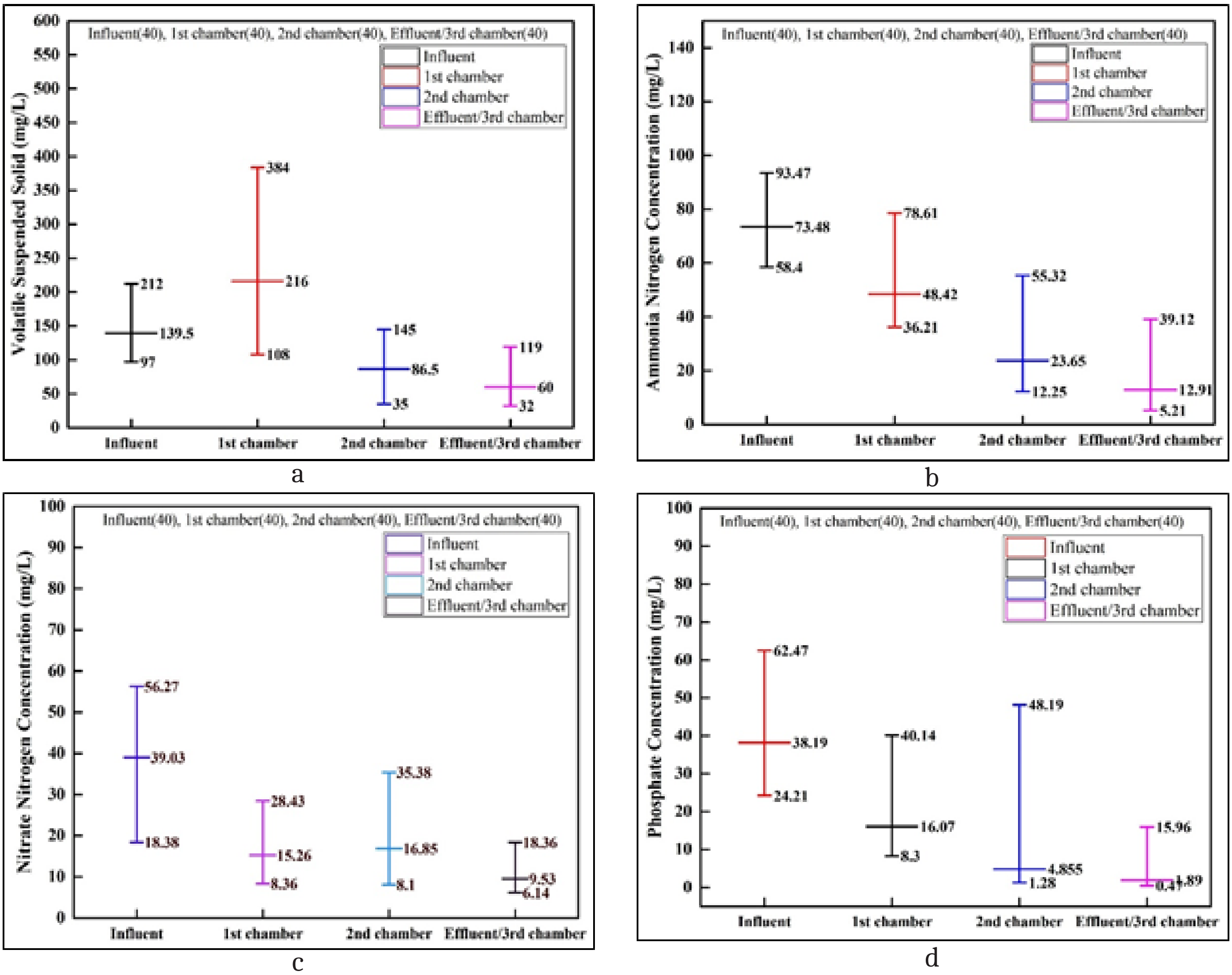


Figure 15: (a) Different VSS concentration at different chambers (b) Different Ammonia Nitrogen concentration at different chambers (c) Different Nitrate Nitrogen concentration at different chambers (d) Different Phosphate concentration at different chambers

Table 5: Result of physical wastewater parameters mean values in entire experiment

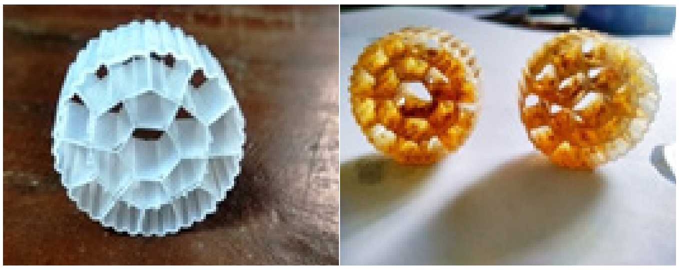
Parameter	Unit	Phase 1		Phase 2		Phase 3		Phase 4	
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
BOD_5	mg/l	527.70	174.10	530.30	112.50	437.60	49.30	481.90	95
COD	mg/l	755.60	403.30	927.20	298.50	797.10	88.80	603.60	121
TS	mg/l	2349.20	76.15	2179.88	85.22	2262.20	86.55	2052	82.55
TSS	mg/l	475.50	105.50	473.40	102.60	400.10	84.30	495.20	104
VSS	mg/l	150.20	65.10	136	60	140.50	48.90	140.80	79.60
TDS	mg/l	1221.70	185	1260.30	186	1279.20	133.20	1205.70	274.10
NH_3-N	mg/l	72.71	10.92	67.82	16.37	84.07	11.26	71.82	18.95
PO_{4}-P	mg/l	40.80	2.10	43.64	6.50	42.98	2.03	34.08	3.91
NO3-N	mg/l	35.31	12.23	38.04	9.93	38.38	8.91	44.25	11.99
pH	-	6.85	7.42	7.02	7.46	7.29	7.55	7.15	7.56

was 92%. It was noticed that the highest reduction of phosphate occurred in the 2nd chamber of modified purification tank system due to nitrification process. Table 14 & 15 is represented the all different parameters in different chambers. Azizi *et al.,* (2013) demonstrated that, in the study of a performance of a modified attached growth bioreactor could remove 43% for PO_4 was achieved in packed bed biofilm reactor, whereas in this study the maximum 96 % phosphate was achieved.

The different values at different HRT, the average values at different HRT and different values at different chamber of each parameter in entire experiment is represent in the following figures 11, 12, 13, 14 and 15.

Table 5 is represented the Result of physical wastewater parameters mean values in entire experiment.

It was noticed that the amount of biomass attached to the biocarriers increased slightly after the start-up of the reactor until it reached a steady state on day 40. However, there was no significant change in the biomass during the 120 days of operation. It was concluded that the biofilms in all the reactors are nonuniform in thickness, but covers most of the inner part of the bio carriers, as the external part of biocarriers showed no signs of biofilm (shown in the Figure 16 a & b). The nonuniform biofilm observed in the present study in all reactors agrees with what was published by Schramm *et al.,* (1996), who showed that nonuniform biofilmis one of the most important characteristic of attached growth nitrifying bacteria used in treating wastewater. Measurements carried out after 40 and 120 days of operation showed that most of the biocarriers inner surface is covered by biofilm, and that no significant changes in biofilm coverage or thickness were observed. Moreover, the statistics of the biofilm coverage and thickness showed that the percentage changes in these parameters between the measurements taken after 40 and 120 days are negligible. This indicates that neither the volume nor the density of the nitrifying biofilm underwent any significant change.



(a) (b)

Figure 16: (a) kaldnes K3 media before using in experiment (b) kaldnes K3 media after ending the experiment with biomass

Overall Performance

The system was observed to remarkably efficient in removing pollutants with the average removal efficiency of 79% for BOD, 70% for COD, 82% for TS, 84% for TDS, 78% for TSS, 56% for VSS, 80% for NH_3-N, 72% for NO_3-N, 92% for PO_4. The aesthetic view of influent and effluent is shown in the Figure 17.

Influent Effluent

Figure 17: Influent and effluent in this experiment

Conclusions

This particular research work analysed the removal of organic matter for the domestic wastewater using combination of MBBR and anaerobic filter. This developed tank system was operated for 120 days with 40 days of start-up time at four different operational conditions. In general, this research ascertained that MBBR with polyethylene media (PE) as biofilm support carrier could be efficient for OM removal from wastewater. Some specific findings of this study can be drawn as follows:

• The effluent from modified septic tank system contain BOD_5 level 27-221 mg/L, COD 29-550 mg/L, TS 119-982 mg/L, TSS 52-185 mg/L, TDS 67-533 mg/L, VSS 32-119 mg/L, NH_3-N 5.21-39.12 mg/L, NO_3-N 6.14-18.36 mg/L, PO_4 0.47-15.96 mg/L.

• The highest BOD, COD, TS, TDS, NH_3-N, NO_3-N, phosphate removal efficiency were achieved at the OLR of 2.77 kg BOD/m^3/d and VSS was at 5.46 kg BOD/m^3/d

• The system was observed to remarkably efficient in removing pollutants with the average removal efficiency of 79% for BOD, 70% for COD, 82% for TS, 84% for TDS, 78% for TSS, 56% for VSS, 80% for NH_3-N, 72% for NO_3-N, 92% for PO_4.

• Higher organic removal rates of maximum parameter were achieved at 48-hour hydraulic retention time with OLR 2.77kg BOD/m^3/d.

• Biofilm layer was formed on biofilm carriers' surface in different HRT except HRT 24 hour because biomass layer was washed out at HRT 24 hour.

• The amount of biomass attached to biocarrier increased slightly after the start-up of the reactor until it reached a steady state after 40 days of operation, the biofilm covers maximum internal area of the biocarrier.

• The approximate size of a modified septic tank for a residence with 200 people is 9.6 m^3 of length, 2.40 m^3 of width and depth of 2.1 m^3 with 0.157 kg BOD/m^3/day of organic loading rate.

Recommendations for future research

Following recommendations have been drawn from the study

• Two stage modified septic tank system may be a feasible option of onsite domestic wastewater treatment having strong initial BOD_5 value over 400 mg/L. This may be evaluated by further research.

• This can replace of our conventional septic tank for the people of the developing country like Bangladesh.

• The modified aerobic anaerobic septic tank system or the design criteria may be also used for wastewater treatment.

• The designed MAASTS may better solution for wastewater treatment in Bangladesh.

• In order to determine the optimal aeration rate, further detailed investigation on the MBBR.

• The blower used in the study had no badly needed air control system for the study.

• There may be further scope for temperature control and steady maintenance. The room temperature of the study was no longer hot but it was below the required level.

• Comparison study using different types of biofilm carriers at different filling rates to investigate the topographic views of the biofilms surface area in MAATS, a variable pressure electron microscope (VPSEM) was needed.

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Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission and manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing. We confirm that the manuscript has been read and approved by all named authors.

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