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PERFORMANCE STUDY OF PILOT-SCALE ANAEROBIC-AEROBIC FILTER SYSTEM FOR FAECAL SLUDGE TREATMENT

Subinoy Biswas Nayan*[1], Quazi Hamidul Bari[2], Pronab Kumar Debnath[3] and Jobaer Ahmed Saju[4]

[1]Post-graduate student, Department of CE, Khulna University of Engineering & Technology, Bangladesh, e-mail: nayan1701553@stud.kuet.ac.bd
[2]Professor, Khulna University of Engineering & Technology, Bangladesh, e-mail: qhbari@ce.kuet.ac.bd
[3]Post-graduate student, Department of CE, Khulna University of Engineering & Technology, Bangladesh, e-mail: pronab.pb@gmail.com
[4]Post-graduate student, Department of CE, Khulna University of Engineering & Technology, Bangladesh, e-mail: jubayerahmed005@gmail.com

***Corresponding Author**

ABSTRACT

In Bangladesh, the wastewater is being dumped without any plan. The outlet of most of the septic tank is connected with public sewer and maximum drain outlet is connected with river and this is very harmful for our ecosystem. The disposal of human excreta required treatment before its discharge into the environment. The objectives of the study were to design and fabricate an anaerobic-aerobic filter system (AAFS) system 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 NH_3-N, 72% for NO_3-N, 92% for PO_4 and outstanding removal was 92% for FC. This anaerobic-aerobic system is a feasible option of onsite domestic wastewater treatment for the people of the developing country like Bangladesh. Treated wastewater of the system has been meet national standards for wastewater discharging.

Keywords: *On site wastewater treatment, Anaerobic, Aerobic, Attached growth system.*

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 & 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 & 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 & Abdullah 2015). The outlet of most of the septic tank is connected with rain water sewer. Consequently, untreated wastewater is directly discharged 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 households 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 has 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 does not treat 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. 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 micropollutant 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 micropollutant 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 micropollutants (Andersen et al., 2003; Schaar et al., 2010). Despite this improvement, numerous micropollutants 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 & Zouboulis, 2001). In this context, more than 90% of biomass is attached to the media rather than suspended in the liquid (Schmidt & 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 & Zouboulis, 2001), less prone to the process upsets from poorly settling biomass (Schmidt & 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 & 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 & 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 filter system. This project demonstrates a modern low-cost onsite wastewater treatment technology tasted with varying hydraulic loading rates with attched growth biological traetment.

2. METHODOLOGY

2.1 The structure and working principle of Anaerobic-Aerobic Filter System

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.

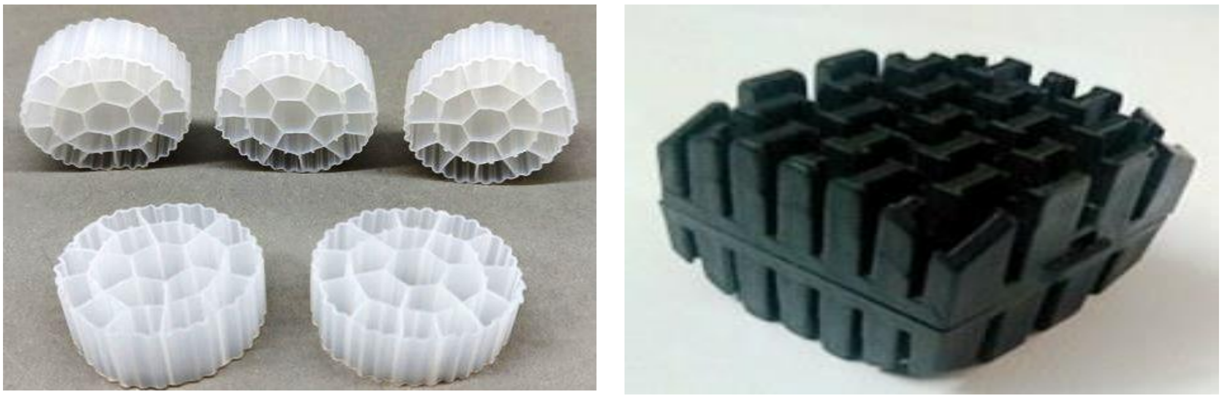
Figure 1: Process flow of anaerobic-aerobic filter system

First two chamber are anaerobic filter tank where plastic biocube balls 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 taking place. Second chamber is aerobic chamber where Anoxkaldles K3 media was is used as plastic media. Aeration was taking place by an aerator and nitrification process was occurred in this chamber and last one is sedimentation chamber. A 30watt capacity blower was used to continue the aeration process. Plastic carrier was moved with moving part of the water.

2.2 Characteristic of different carrier media:

Table 1: Characteristic of different carrier media used in experiment

Chamber	Commercial Name	Material	Shape	Specific surface area	Dimension	Filling Factor
Anaerobic Filter	Biocube Ball	polypropylene	Rectangular parallelepiped	378 m^2/m^3	30mm; 30mm	40%
Aerobic Filter	Anoxkaldes K3	polypropylene	Cylindrical	500 m^2/m^3	12mm; 25 mm	70%



(a) (b)

Figure 2: (a) Kaldes Media used in aerobic chamber
(b) Biocube ball media used in anaerobic filter

The carrier elements can be installed in anaerobic, anoxic reactor or aeration basin. 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, agitation pattern is designed in such a manner that the upward movement of the carrier takes place across the surface of the screen. It protects from clogging so that the entire reactor will be in active biologically causing higher biomass activity.

2.3 Operational condition:

The anaerobic-aerobic filter tank volume is 0.052 m^3 and 52 litre capacity. This tank system was operated different operational condition, these conditions is given below in the table-

Table 2: Different operational condition in experiment

Phase no	Flow	Hydraulic Retention Time
1	9 ml/minute	104 hours
2	12 mL/min	72 hours
3	19 mL/min	48 hours
4	36 mL/min	24 hours

2.4 Sample collection:

After installing the anaerobic-aerobic tank, faecal sludge collected from selected septic tank according to standard sampling method and insert into anaerobic-aerobic tank. Sample was collected from conventional septic tank effluent. Sample was collated by plastic container. Each container capacity was 30 liters.

(a) (b)

Figure 3: (a) Samples were collected from a conventional septic tank
(b) Sample collection plastic container

This sample will be tested in laboratory. Regular monitoring will be done and parameter will be measured in laboratory. Selected parameters namely Dissolved Oxygen, 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
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

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.

3. RESULTS AND DISCUSSION

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 purification tank. 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 49 mg/l and this is meet the maximum permissible value of ECR 1997 of Bangladesh government. The permissible value of BOD is 50 mg/L by law of the Bangladesh government.

The maximum 89 % of COD removal was found in phase 3 (HRT=48 h). This result is 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. AAFS effluent COD value is agree with the standard discharging value of Bangladesh. 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.

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.

The maximum and minimum values TDS concentration in influent was 1474 and 981 mg/l and effluent were 345 and 67 mg/l which was significantly reduced by AAFS. The average value of TDS removal efficiency was achieved 84% by the system. The average value of effluent was 195 mg/l is agreeing with the effluent discharging standard value which is 2100 mg\l.

The highest and lowest values for VSS was 185 to 97 mg/l for influent and 119 to 32 mg/l for effluent. The values of VSS was 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 AAFS 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 so that the mixing is poor and oxygen transfer is inhibited.

In the AAFS, 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 good to discharge.

Under a different hydraulic loading time, the 77 % maximum average Nitrate removal was found in the AAFS 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 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.

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 AAFS effluent which was occurred in HRT=104 h. The average values of removal percentage in entire experiment 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.

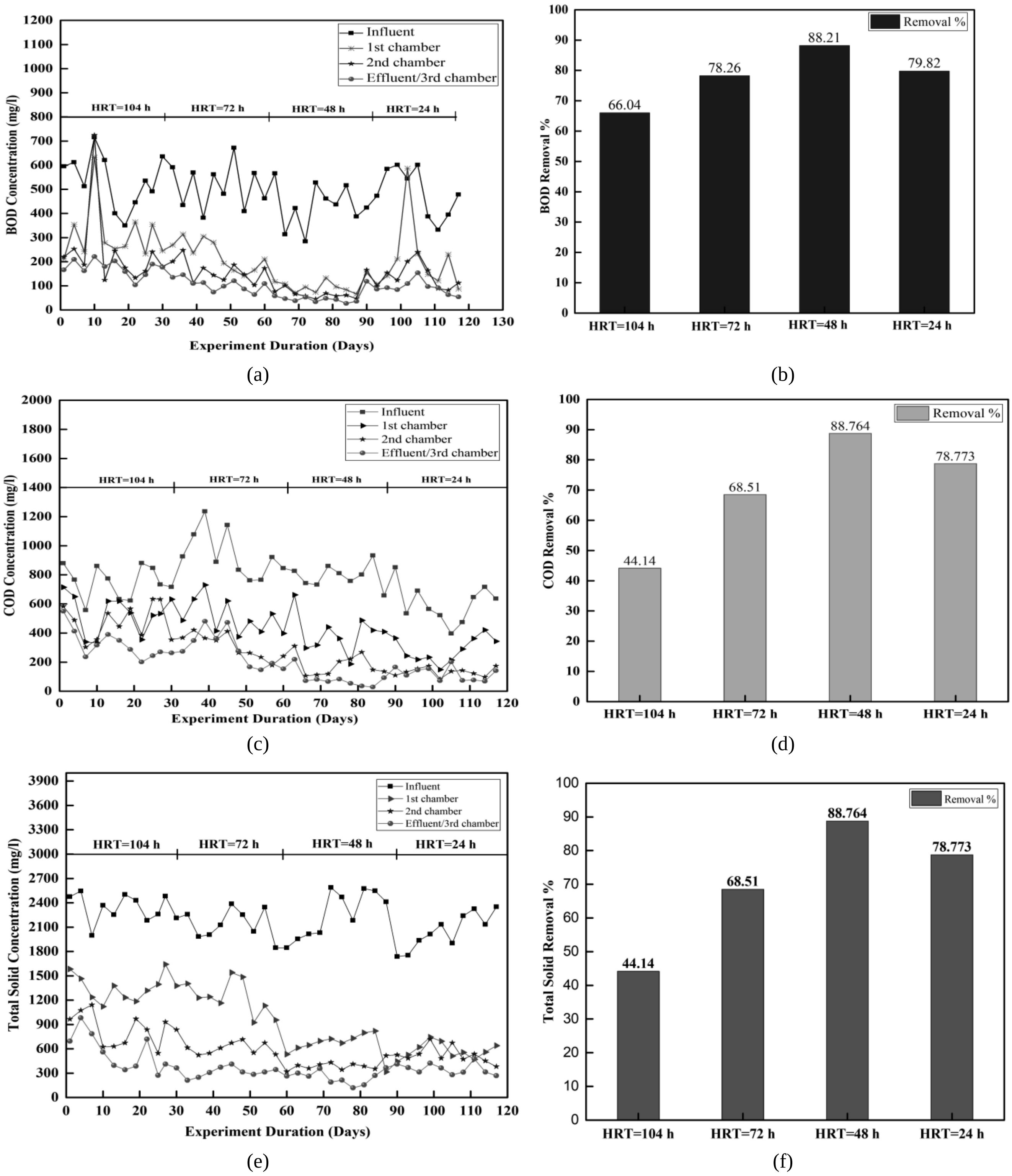


Figure 5: (a) BOD concentration in entire experiment (b) BOD removal percentage in experiment (c) COD concentration in entire experiment (d) BOD removal percentage in experiment (e) TS concentration in entire experiment (e) TS removal percentage in experiment

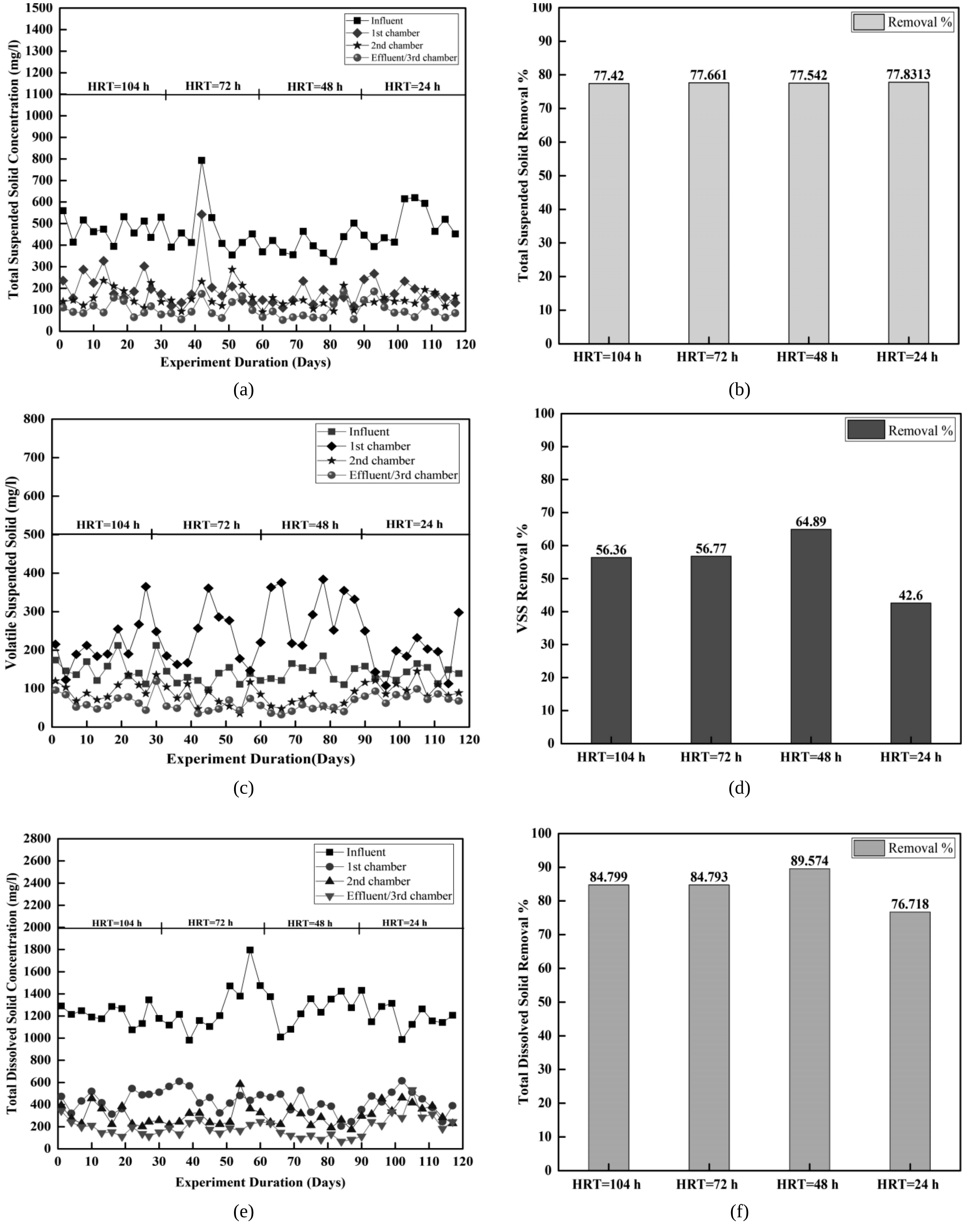


Figure 6: (a) TSS concentration in entire experiment (b) TSS removal percentage in experiment (c) VSS concentration in entire experiment (d) VSS removal percentage in experiment (e) TDS concentration in entire experiment (e) TDS removal percentage in experiment

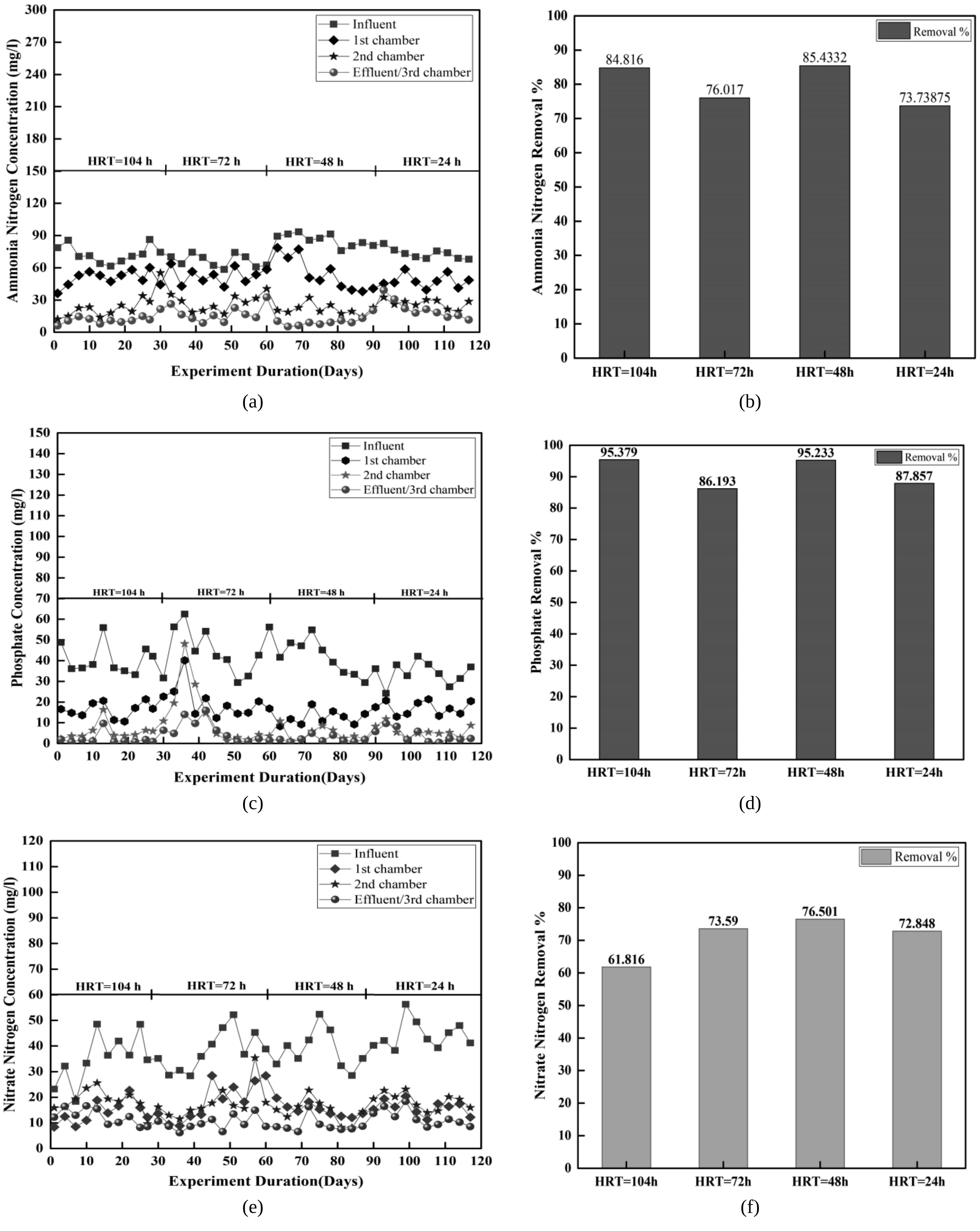


Figure 7: (a) NH_3-N concentration in entire experiment (b) NH_3-N removal percentage in experiment (c) PO_4-P concentration in entire experiment (d) PO_4-P removal percentage in experiment (e) NO_3-N concentration in entire experiment (e) NO_3-N removal percentage in experiment

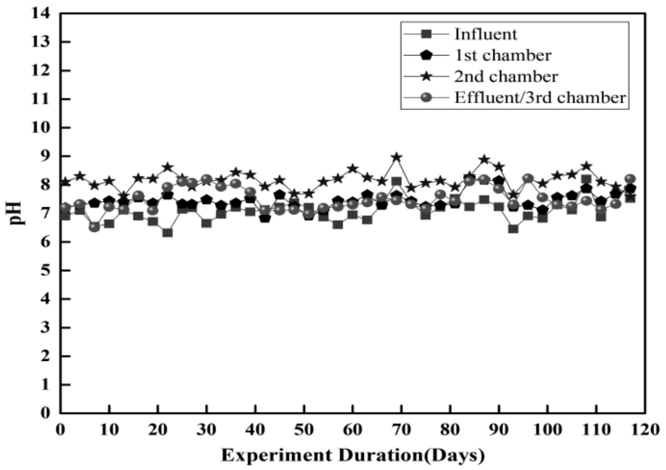


Figure 8: pH variation in entire experiment

Table 4: 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
FC	Nos/100ml	3030.20	215.80	2533.4	190.50	1918	145.60	2018.7	205.90

Table 4 represented the Result of physical wastewater parameters mean values in entire experiment For Faecal Coliform, the highest and lowest values for influent and effluent was 3469 and 1743 nos/100ml respectively. The mean values of influent and effluent was 2375 and 189 nos/100ml respectively. Under a different hydraulic loading time, the 93% maximum average Phosphate removal was found in the AAFS effluent which was occurred in HRT=104 h. The average values of removal percentage in entire experiment was 92%.


(a)


(b)

Figure 9: (a) kaldnes K3 media before using in experiment
(b) kaldnes K3 media after ending the experiment with biomass

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 and outstanding removal was 92% for FC.

It was noticed that the amount of biomass attached to the biocarriers (see in the Figure 9) 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.

4. Conclusion:

Anaerobic-aerobic filter system is a very cost effective and eco-friendly option for the removal of organic matters (OM) from wastewater. This particular research work analysed the removal of OM from the domestic wastewater using combination of MBBR and anaerobic filter. This purification tank was operated for 120 days. In this study, the effects of vital factors such as carrier organic loading rate (OLR) and hydraulic retention time (HRT) affecting the system were investigated. 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:

- Moving Bed Biofilm Career (MBBC) was capable of retaining a considerable quantity of attached biomass which would provide successful performance and achieve appreciable organic removal. Thus, the higher the OLR led to the greater the amount of attached biomass on support material that resulted in consumption of a greater part of the substrate by this biofilm.
- Higher organic removal rates were achieved at 48-hour hydraulic retention time.
- High accumulations of biomass in the biofilm process when coupled with good oxygen transfer capability of the system ensure the high treatment capacity and operational stability. This can make the MBBR process attractive and promising to apply for organic matter removal from wastewater.
- 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 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 and outstanding removal was 92% for FC.
- This anaerobic-aerobic system is a feasible option of onsite domestic wastewater treatment for the people of the developing country like Bangladesh.

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