Treatment of Mixed Sewage-septage Wastewater Using Lab-scaled Integrated Fixed Film Activated Sludge Process

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Abstract: *In this research, the mixed sewage-septage wastewater (MSSW) was treated using appropriate lab-scaled biological treatment system that is Integrated Fixed Film Activated Sludge (IFAS) process. The fabious media was used as the bio-carriers in this activated sludge process. The oxygen was supplied at the rate of 8 m^3/day for the aeration process. This study was performed from December 2016 to July 2017. Depending on the results obtained from the experiments, the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) concentration of MSSW could be reduced with the treatment efficiency varied from 87.1% to 98.8%, 85.3% to 98.8% and 96.6% to 99.8%, respectively. For all considered parameters to be reduced in this research, the optimum treatment efficiency was obtained at the experiment conducted at the 181 days after acclimatization for aerobic microbes in the IFAS process with the around 98.6% of BOD removal efficiency, around 98.1% of COD removal efficiency and around 99.8% of TSS removal efficiency.*

Key Words: *Mixed Sewage-septage Wastewater, Integrated Fixed Film Activated Sludge (IFAS) process, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS)*

1. INTRODUCTION:

Generally, both the sewage and septage are composed of grease, debris, grit, hair, different organic and inorganic pollutants and disease causing pathogens. The sewage comes from the sewerage system which conveys the grey water from kitchens, bathrooms, etc., and black water from toilets. The septage comes from the septic tank in which there are human excretes from the toilets. In some developing countries, there is no space for disposing septic wastes that are pumped from the septic tanks of the residential areas. Thus, the vacuum trunks carry this septage wastewater to the municipal wastewater treatment plants and make dilution with sewage. After that, MSSW is treated using appropriate treatment processes in these plants. Otherwise, this MSSW can cause water pollution that can damage the water quality for domestic, drinking and recreational purposes. Moreover human health problems such as cholera, typhoid, dysentery, skin and eye infections can be occurred due to using and contacting with this contaminated water.

Municipal wastewater is typically treated using physical, chemical and biological treatment processes in order to reduce organic or inorganic pollutants in the wastewater before disposing it to the environment. Among these treatment processes, Integrated Fixed Film Activated Sludge (IFAS) process that is one of the biological treatment processes, was applied in this research for the reduction of BOD, COD and TSS concentration in the MSSW.

Integrated Fixed-film Activated Sludge (IFAS) Technology provides for additional biomass within a wastewater treatment facility in order to meet more stringent effluent parameters or increased loadings without the direct need for additional tankage. IFAS systems allow for the additional bacterial population to exist on a fixed surface, thereby eliminating the need to increase the suspended growth population. There are a number of different approaches to IFAS implementation but the various configurations fall into one of two basic types: "dispersed media" entrapped in the aeration basin, and "fixed media", such as structured sheet media or knitted fabric media, fixed-in-place in the aeration basin. The Integrated Fixed-film Activated Sludge (IFAS) process combines the advantages of conventional activated sludge with those of biofilm systems by combining the two technologies in a single reactor. IFAS technology has been incorporated into municipal and industrial wastewater facilities for both new construction and upgraded plants in many variations of suspended growth (1).

2. MATERIALS AND METHODS:

2.1. Research Methodology

In this research, there were five steps of methodology that were to fabricate the lab-scaled physical models for IFAS process, to collect mixed sewate-septage wastewater (MSSW) sample from the Yangon City Development Committee (YCDC) wastewater treatment plant, to operate lab-scaled treatment system systematically, to determine the concentration of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) of MSSW before and after passing lab-scaled treatment system and finally, to evaluate the different removal efficiencies of lab-scaled treatment system through the ten times of experiments.

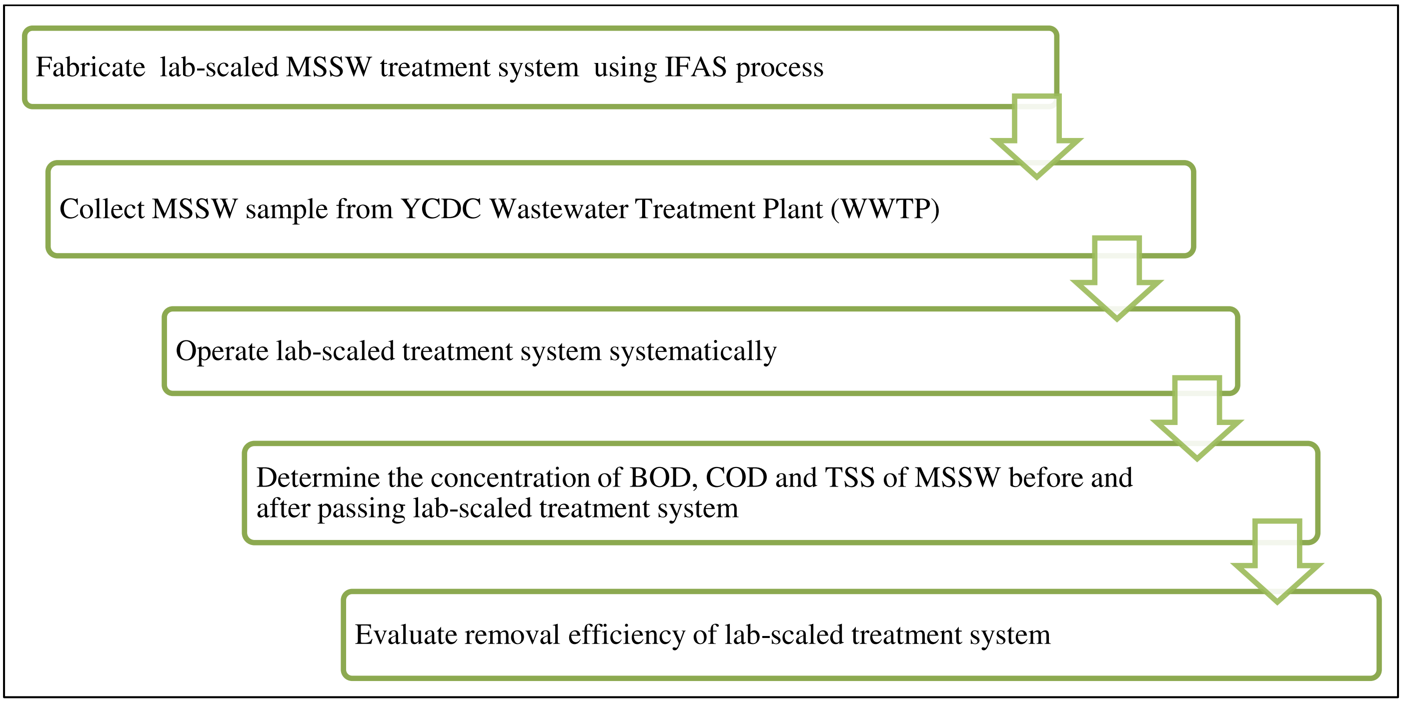

Fig 2.1. Flow Chart of Research Methodology

2.2. Fabrication of lab-scaled IFAS Process

In order to construct the lab-scaled IFAS process, water taps and plastic pipes with diameter of 1 cm as well as the acrylic sheets were used. The fabious media that are the products of Hitachi Zosen Company Limited, Japan, were used as the bio-carriers for the aerobic microorganisms. About 0.002 m^3 of fabious media was mixed with MSSW sample in the aeration tank which volume was about 0.012 m^3. This fabious is made of polyester polypropylene with porosity about 83% and its shape is cylinder with gear cross section. The diameter and height of each fabious are about 8 mm and 8 mm, respectively.

The dimensions of lab-scaled aeration tank, primary and secondary sedimentation tanks for the treatment of MSSW are described in the Tab. 2.1. As shown in Fig 2.1, there was the upper part of primary sedimentation tank that can store about 0.0075 m^3 of wastewater so that the influent flow rate to secondary sedimentation tank can be reduced to required flow rate for the achievement of sedimentation process. The bed layers of the sedimentation tanks were inclined in order to dispose sludge easily.

Table 2.1. DIMENSIONS OF LAB-SCALED PHYSICAL MODELS FOR IFAS PROCESS

Physical Models	Dimensions				Remarks
	Length (m)	Depth (m)	Width (m)	Volume (m^3)	
Aeration Tank	0.2	0.38	0.15	0.012	-
Primary Sedimentation Tank	0.3	0.2	0.1	0.0125	Bed slope angle = 20º
Secondary Sedimentation Tank	0.3	0.24	0.1	0.005	Bed slope angle = 25º

2.3. Collection of MSSW Sample

Since there are no disposal site for the septage in Yangon City, the vacuum trucks deliver the septage to the YCDC wastewater treatment plant. Moreover, the sewage from six downtown townships also dispose to this WWTP. Thus, this WWTP has to treat the mixed sewage-septage wastewater and dispose to the Yangon River. The wastewater sample needed for this research was collected from the influent tank of YCDC wastewater treatment plant (WWTP).

2.4. Operational Conditions of lab-scaled IFAS Process

The lab-scaled IFAS process was operated with the influent flow rate about 0.3 m^3/ day for aeration tank and primary sedimentation tank. The influent flow rate of secondary sedimentation tank was reduced to about 0.02 m^3/day in order to obtain the necessary settling velocity of the sludge particles. About 0.003 m^3 of returned activated sludge recycled to the aeration tank so that the required F/M ratio in the aerobic reactor. The rate of oxygen supply for aeration system was about 8 m^3/day.

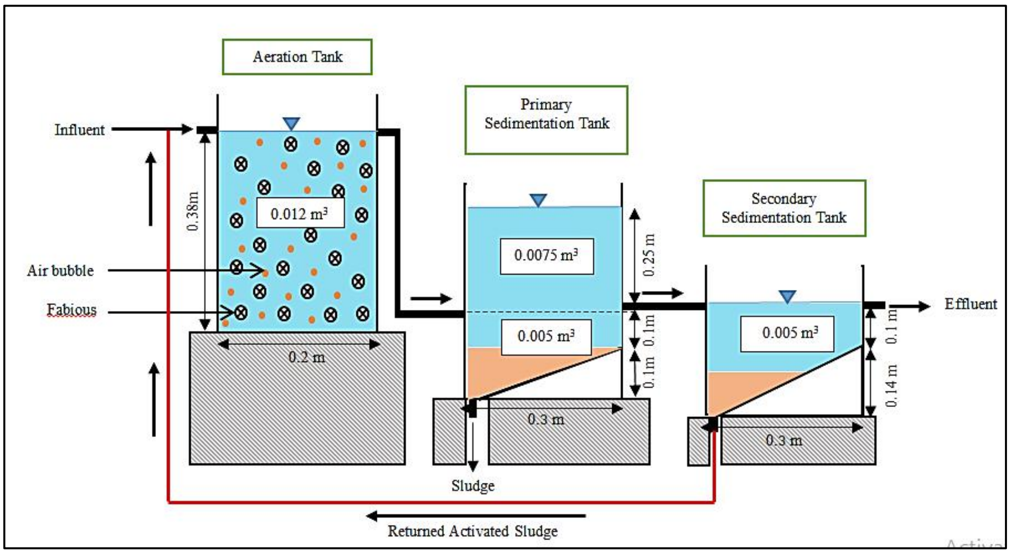

Fig. 2.2 Lab-scaled Physical Models for IFAS Process

2.5. *Determination of Influenced Parameters on Lab-scaled IFAS Process*

Typically, in the IFAS process, there are two components that are aeration and sedimentation. In case of aeration tank, the variation of the Food to Microorganisms ratio (F/M ratio) and Sludge Retention Time (SRT) were mainly considered, while the horizontal velocity of wastewater (V_h) and settling velocity of sludge particles (V_s) were mainly controlled in the sedimentation process. In order to determine the settling velocity of sludge particles, density of sludge, density of water, diameter of sludge, acceleration due to gravity and viscosity of water sample were 1034 kg/m^3, 1000 kg/m^3, 5 x 10^{-5} m, 9.81 m/s^2 and 0.0008629 kg/m-sec, respectively. The equations used for calculation of the F/M ratio, SRT, Vh and Vs are mentioned in the followings (5) and (7).

$$F/M \text{ ratio} = Q_{in} (S_0 - S) / [(V)(X_v)]$$

Where, F/M ratio = Food to Microorganisms ratio in the aeration tank, Q_{in} = Influent flow rate (m^3/day), S_0 = Soluble BOD_5 of influent, S = Soluble BOD_5 of effluent, V = Volume of aeration tank (m^3) and X_v = Volatile Mixed Liquor Suspended Solids (MLVSS) concentration.

$$SRT = TSS_A / TSS_W$$

Where, SRT = Sludge Retention Time (days), TSS_A = Amount of Total Suspended Solids in the aeration tank (lb/day), TSS_W = Amount of Total Suspended Solids in the wasted sludge (lb/day)

$$V_h = Q_{in} / (W \times D \times 86400)$$

Where, V_h = Horizontal velocity of wastewater in the sedimentation tank (m/s), Q_{in} = Influent flow rate (m^3/day), W = Width of the sedimentation tank (m) and D = Depth of the sedimentation tank (m).

$$V_s = (\rho_s - \rho_w)d^2 g/(18 \mu)$$

Where, V_s = Settling velocity of sludge particles in the sedimentation tank (m/s), ρ_s = Density of sludge particles (kg/m^3), ρ_w = density of water (kg/m^3), d = Diameter of sludge (mm), g = acceleration due to gravity (m/s^2) and μ = Viscosity of water (kg/m-sec).

2.6. *Determination of BOD, COD and TSS Concentration in MSSW*

The concentration of BOD, COD and TSS concentration in the wastewater sample were measured by using the standard methods described in 12th Edition of Standard Method for the Examination of Water and Wastewater Including Bottom Sediments and Sludge, APHA.

2.7. *Evaluation of Treatment Efficiency of Lab-scaled IFAS Process*

The water samples from the influent tank and effluent tank of lab-scaled IFAS process were collected and determined their concentrations of BOD, COD and TSS in the laboratory of Environmental Engineering Department of Yangon Technological University (YTU). The following equation was used to determine the optimum removal efficiency of the lab-scaled treatment system through ten times of experiments.

Removal Efficiency (%) = $(C_i - C_e)/C_i$ x 100

Where, C_i = Concentration of influent (mg/l) and C_e = Concentration of effluent (mg/l)

3. RESULTS AND DISCUSSION:

According to the outcomes of the experiments, the BOD and COD removal efficiencies gradually increased as longer the days after acclimatization process of aerobic microbes in the activated sludge process. The average wasted sludge was about 300 ml/day. The TSS removal efficiency was not changed significantly throughout the experiments. However, due to the lack of electricity during experiment period, at the 202 days after acclimatization process, the BOD and COD removal efficiency slightly decreased as the shortage of oxygen supply. Depending on the results of the experiments, the optimum treatment efficiency was obtained at the 4^{th} experiment for BOD, COD and TSS removal process from MSSW with more than 98% of their removal efficiencies.

The Table 3.1 shows the different F/M ratio, SRT and MLSS concentration in the aeration tank along the different experiments. The varied BOD, COD and TSS concentration of influent and effluent of lab-scaled IFAS process are described in Table 3.2, 3.3 and 3.4 as well as Fig. 3.1, 3.2 and 3.3, individually.

Table 3.1. DIFFERENT VALUES OF F/M RATIO AND SRT DEPENDING ON DIFFERENT MLSS CONCENTRATION

Experiments	F/M ratio (d^{-1})	SRT (days)	MLSS (mg/l)	Remarks
First	0.58	5.64	2818	
Second	0.10	14.78	7392	
Third	0.12	13.14	6570	
Fourth	0.13	12.08	6038	Optimum
Fifth	0.08	17.76	8880	
Sixth	0.18	10.04	5022	
Seventh	0.57	5.55	2776	
Eighth	0.24	8.38	4192	
Ninth	0.26	8.18	4090	
Tenth	0.19	9.44	4722	

As tabulated in Tab. 3.1, the optimum treatment efficiency for BOD, COD and TSS removal from MSSW was recorded in 4^{th} experiment with about 0.13 d^{-1} of the F/M ratio, about 12 days of SRT and about 6038 mg/l of MLSS concentration in the aerobic reactor.

Table 3.2. BOD CONCENTRATION IN INFLUENT AND EFFLUENT OF LAB-SCALED IFAS PROCESS

Days after acclimatization process of aerobic microbes	Influent (mg/l)	Effluent (mg/l)	NEQG Values (mg/l)	Efficiency (%)
125 days	1020	48	50	95.3
165 days	1080	18	50	98.3
174 days	1440	18	50	98.8
181 days	2100	30	50	98.6
189 days	1800	48	50	97.3
196 days	600	30	50	95.0
202 days	420	54	50	87.1
209 days	780	66	50	91.5
238 days	480	12	50	97.5
245 days	660	33	50	95.0

Note: NEQG Vlaues – National Emission Quality Guidelines Values Issued by Ministry of Environmental Conservation and Forestry (MOECAF), Myanmar

In comparing with National Emission Quality Guidelines (NEQG) issued by Ministry of Environmental Conservation and Forestry (MOECAF), it can be seen that the BOD concentration of treated effluent discharged from eight experiments can meet with the guideline values while the BOD concentration of effluent from remaining two experiments were slightly greater than the guideline values.

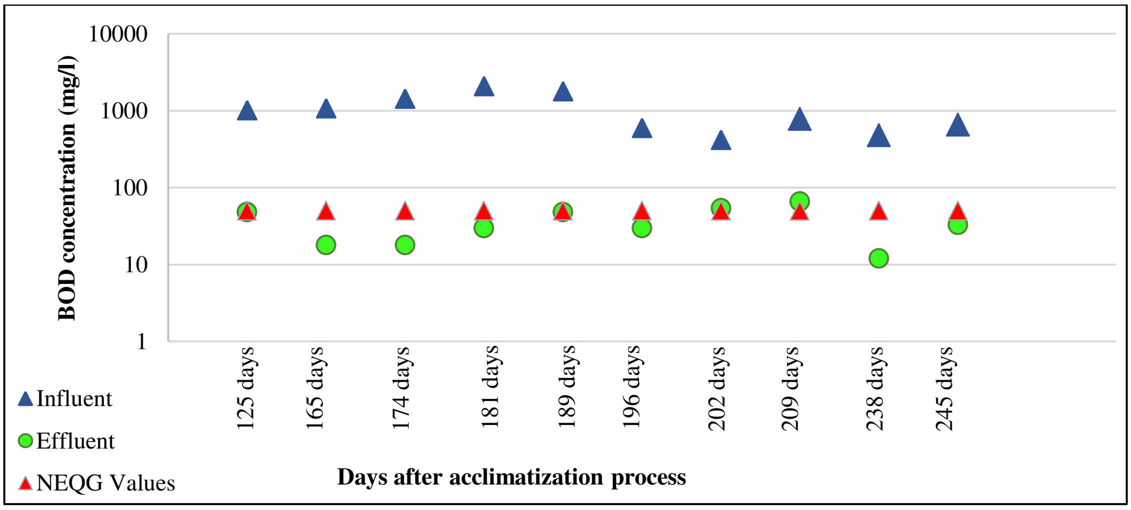

Fig. 3.1 BOD Concentration of Influent and Effluent of Lab-scaled IFAS Process

As shown in Table 3.2 and Fig. 3.1, the BOD removal efficiency varied between 87.1% and 98.8%. The maximum removal efficiency of BOD was recorded as 98.8% at the 174 days after the acclimatization period for aerobic microbes in the activated sludge process. At that time, the F/M ratio and SRT were about 0.12 d^{-1} and 13 days.

Table 3.3. COD CONCENTRATION IN INFLUENT AND EFFLUENT OF LAB-SCALED IFAS PROCESS

Days after acclimatization process of aerobic microorganisms	Influent (mg/l)	Effluent (mg/l)	NEQG Values (mg/l)	Efficiency (%)
125 days	4800	704	250	85.3
165 days	4400	192	250	95.6
174 days	4480	112	250	97.5
181 days	11520	224	250	98.1
189 days	7360	160	250	97.8
196 days	5120	64	250	98.8
202 days	2560	128	250	95.0
209 days	3200	80	250	97.5
238 days	4160	64	250	98.5
245 days	4160	96	250	97.7

Note: NEQG Vlaues – National Emission Quality Guidelines Values Issued by Ministry of Environmental Conservation and Forestry (MOECAF), Myanmar

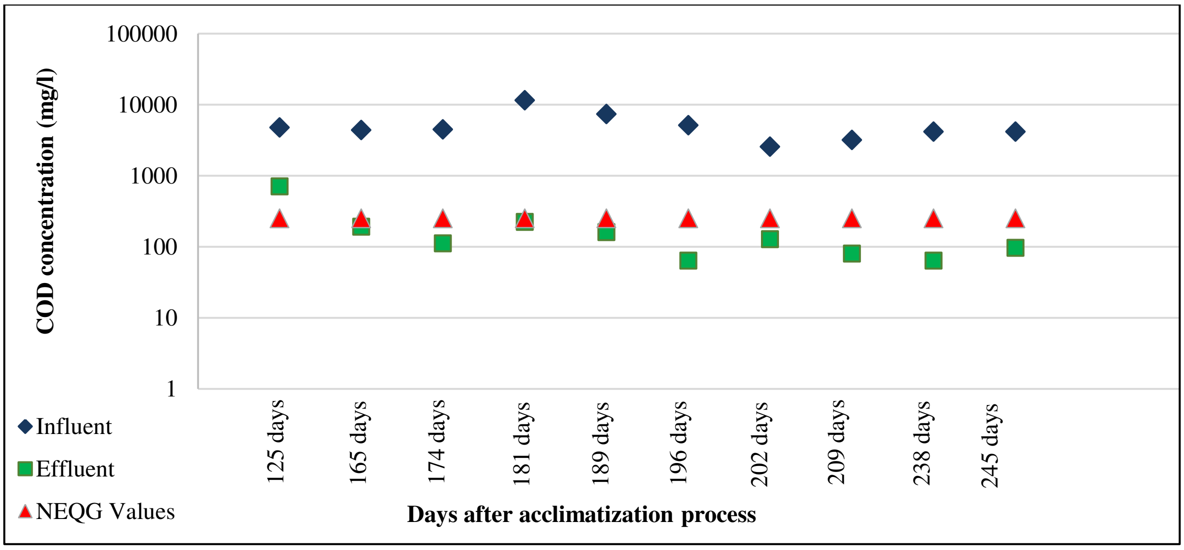

Fig. 3.2 COD Concentration of Influent and Effluent of Lab-scaled IFAS Process

In Myanmar, the COD concentration of the treated effluent should be lower than about 250 mg/l according to the National Emission Quality Guidelines (NEQG) issued by Ministry of Environmental Conservation and Forestry (MOECAF). In this research, it can be seen that the COD concentration of treated effluent can satisfy with the guideline values except the concentration of effluent discharged from first experiment. As shown in Table 3.3 and Fig. 3.2, the COD removal efficiency varied between 85.3% and 98.8%. The maximum removal efficiency of COD was recorded as 98.8% with the F/M ratio was about 0.18 d^{-1} and SRT was about 10 days, at the 196 days after the acclimatization period for aerobic microbes in the aerobic reactor.

Table 3.4. TSS CONCENTRATION IN INFLUENT AND EFFLUENT OF LAB-SCALED IFAS PROCESS

Days after acclimatization process of aerobic microorganisms	Influent (mg/l)	Effluent (mg/l)	NEQG Values (mg/l)	Efficiency (%)
125 days	5308	180	50	96.6
165 days	4440	66	50	98.5
174 days	4966	40	50	99.2
181 days	11875	26	50	99.8
189 days	7296	28	50	99.6
196 days	8792	116	50	98.7
202 days	2212	12	50	99.5
209 days	2866	49	50	98.3
238 days	3142	28	50	99.1
245 days	3106	38	50	98.8

Note: NEQG Vlaues – National Emission Quality Guidelines Values Issued by Ministry of Environmental Conservation and Forestry (MOECAF), Myanmar

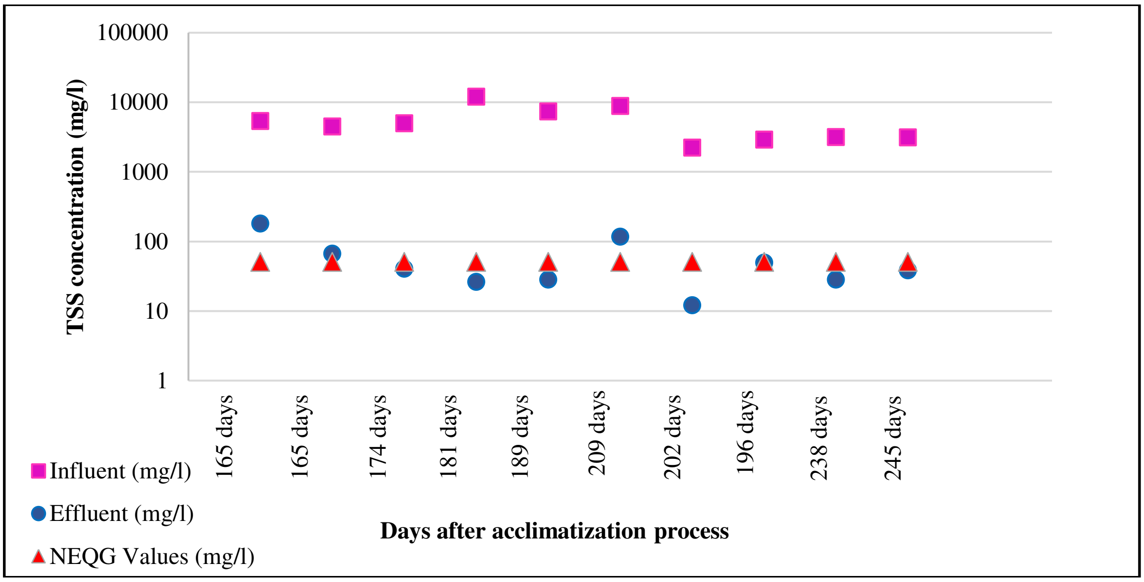

Fig. 3.3 TSS Concentration of Influent and Effluent of Lab-scaled IFAS Process

Since the high concentration of TSS in the effluent can impact significantly the water quality of surrounding water resources, MOECAF declared that TSS of the treated effluent should be 50 mg/l to control the water pollution of receiving water bodies. Based on the results of the experiments, the TSS concentration of treated effluent discharged from seven experiments can satisfy with the guideline values. The remaining three experiments cannot reduce the TSS concentration in MSSW until it reaches under 50 mg/l. As shown in Table 3.4 and Fig. 3.3, the TSS removal efficiency varied between 96.6% and 99.8%. The maximum removal efficiency of TSS was recorded as 99.8% with the F/M ratio was about 0.13 d-1 and SRT was about 12 days, at the 181 days after the acclimatization period for aerobic microbes in the activated sludge process.

The percentage of removal efficiencies of lab-scaled IFAS process through ten experiments are illustrated in Figure 3.4. The optimum removal efficiency of lab-scaled treatment system was recorded at the 4th experiment because its treatment efficiency for all three parameters such as BOD, COD and TSS were above 98%.

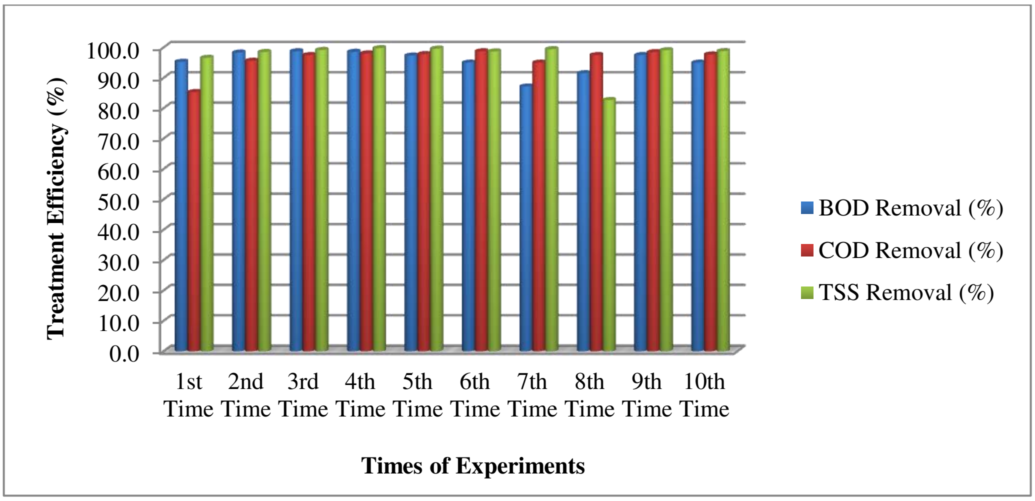

Fig. 3.4 Different Removal Efficiencies of BOD, COD and TSS Along with Ten Times of Experiments

4. CONCLUSIONS:

Depending on the results from this study, it can be concluded that the lab-scaled IFAS process can successfully reduce the concentration of BOD, COD and TSS of the mixed sewage-septage wastewater (MSSW). Consistent with comparison between the concentration of treated effluent and NEQG values, it can be seen that the BOD, COD and TSS concentrations of treated effluent from most of the experiments could meet with the guideline values. Although the maximum treatment efficiency for BOD removal, COD removal and TSS removal were obtained at the third, sixth and fourth experiment, respectively, the optimum treatment efficiency for all three parameters can be recorded at the fourth experiment with about 0.13 d^{-1} of the F/M ratio and about 12 days of SRT.

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REFERENCES:

1. http://archive.sswm.info/category/implementation-tools/wastewater-treatment/hardware/semi-centralised-wastewater-treatments-4
2. APHA. (1969). *Standard method for the examination of water and wastewater including bottom sediments and sludges*. Twelve (Eds.), (pp. 426-495). BOYD Printing Co., Inc., Albany, N.Y. 10019.
3. http://www.ce.memphis.edu/1112/notes/project_1/water_treatment/water_treatment_part_3_sedimentation.pdf.
4. Horald D. M. (2008). Philosophy and the science of subjective well-being. In M. Eid & R. J. Larsen (Eds.), *The science of subjective well-being* (pp. 17-43). New York, NY: Guilford Press.
5. Syed R. Q. (1985). Wastewater Treatment Plants. In CBS International (Eds), *Planning, design and operation* (pp. 306-313). CBS College Publishing, 383 Madison Avenue, New York, N.Y. 10017.
6. MOECAF. (2015). *National environmental quality (emission) guidelines* (pp. 9-11). Myanmar, MOECAF Press.
7. http://dca.ky.gov/certification/Test%20Preparation%20Documents/WWTreatmentPlantOperatorCertificationManual-FinalRevised-040517.pdf.