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Effect of Temperature on Theperformance of Porous Membrane Activated Sludge Reactor (PMASR) Treating Synthetic Wastewater.

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ABSTRACT

A research was done to assess membrane technology as one of the few non-pollutant and environment friendly techniques for treating synthetic wastewater. The objective of non-chemical activated sludge is to remove soluble and insoluble organics from industrial wastewater and to convert it into flocculent microbial suspension that settles well in conventional gravity clarifiers. The system was operated underperformance of Porous Membrane Activated Sludge Reactor (PMASR) treating synthetic wastewater at various temperatures (27, 32, 37, 42 and 47 ° C). Results demonstrated highest percentage of soluble chemical oxygen demand (COD) removal (90.45%) obtained at 27 °C. In addition, as the temperature of the reactor increased, the soluble COD removal efficiency improved up to 90.45% at 47 °C, while the lowest percentageof soluble COD removal (24.27 %) was obtained at 32 °C. Furthermore, the Mixed Liquid Volatile Suspended Solid (MLSS) levels between 80 - 10 mg/L (at 42 °C) and the Mixed Liquid Volatile Suspended Solid (MLVSS)of 80 mg/L at 47 ° C and 32 ° C were recorded. The lowest rate of MLVSS was achieved at10 mg/L (42 °C). Finally, the highest and lowest Dissolved Oxygen (DO) concentration was obtained at 5.1 mg/L and 1.7 mg/L (at 27 ° C) respectively. In conclusion, the increase in temperature exhibited direct relationship with DO concentrations and the treatment efficiency.
Keywords: Submerged membrane activated sludge reactor, wastewater, chemical oxygen demand, mixed liquid volatile suspended solid, mixed liquid volatile suspended solid

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INTRODUCTION

In Malaysia, a huge number of industrieshavetremendously increased production of plastics, metals and chemicals in order to fulfill the needsof human life. Decisive actions should be done to minimize serious issues such as increasethe cost in potable water treatment or public health and safety. Otherwise, they can affect severelythe social health and natural environment. Approximately, ten thousands of new organic materialsare added to industrial wastes each year [1]. New organic materials mainly consist of complexes, whichthey require high treatment cost through conventional systems.

According to Environmental Quality report 2004, in Malaysia, about 431,000 ton a year of industrial wastes, mainly composed of textile or chemical discharges, pharmaceutical outputs, agricultural and municipal wastes, are produced. The effluent from industrial waste is highly toxic and dangerous for public health that seriously affects the natural environment. Generally, factories do not discharge the wastes based on authorized regulations by the related organization or department and exceeds the limitation that was regulated officially. Therefore, it is urgent to develop appropriate treatment system for handling the huge amount of wastewaters.

Aerobic biological processes operated at high temperatures are highly effective in treating high temperature industrial wastewater due to combine conventional aerobic and anaerobic processes including rapid biodegradation kinetics and low biological solids production respectively [2].

In addition, Biological methods are based on microorganisms used for degrading organic and nitrogenous matters from wastewaters. Also, the method consists of environment preparation for growing microorganismswith ability of removing the discharged substances.Usually, Biological removals of organic substances are done through anaerobic and aerobic decomposition processes. Under anaerobic conditions (absence of oxygen or nitrate) like digesters, lagoons, anaerobic filters etc. organic substances are converted to methane and carbon dioxide (biogas) as well as water and small fraction of new biomass (sludge). The non-injection of oxygen in anaerobic systems greatly reduces the cost. In aerobic conditions (presence of oxygen) such as activated sludge reactors, aerated lagoons and bio rotors organic substances are converted to carbon dioxide, water and biomass. However, biological methods cannot remove refractory organic compounds.

Principal biological processes are the activated sludge, the rotating biological contractors, sequencing batch reactor (SBR), reed beds, biological aerated filters and lagoons [3]. Biological treatment processes are usually carried out in suspended growth systems such as aerated lagoons, conventional activated sludge, sequencing batch reactors (SBR) and lately membrane bioreactors (MBR) [4].

In aerobic treatments, microbes consume organic materials as thesource of energy in the presence of oxygen. In addition, an aerobic process oxidizes NH3–N into nitrate or biomass. The most common aerobic biological treatments are AS, SBR, AL and RBC [5]. Aerobic treatment systems include the activated sludge process; extended aeration activated sludge process, activated sludge with granular activated carbon, natural or genetically engineered microorganisms and aerobic contactors. Among the aerobic processes, the trickling filter and the activated sludge processes have been used to treat industrial and domestic/municipal wastewater. In the past few years the treatment of wastewater by a modified activated sludge process, the sequencing batch reactor (SBR) has gained recognition. The SBR systems do receive worldwide attention and several thousand SBR facilities have been designed, built and putted into operation [6, 7]. Most sewage treatment facilities are still based on continuously operated activated sludge processes. Aerobic systems have several advantages such as relatively easy operation, lower equipment cost, produce a better quality supernatant with lower nitrate and phosphorus concentrations, thereby protecting the liquid side upstream and can achieve comparable solids reduction with shorter retention periods, less hazardous cleaning and repairing tasks [1].

Since its introduction in the late 1980s, submerged membrane bioreactor (MBR) has been successfully used for treatment of different kinds of wastewater [8]. While temperature increase causes poor solid settling which leads to insufficient solid–liquid separation [9] for conventional activated sludge system, such problem was not encountered by the MBR at thermophiles condition [10]. However, the soluble Chemical Oxygen Demand (COD), soluble nitrogen and turbidity in the supernatant still need more investigations. Membrane bioreactor (MBR) is a promising technology, which has been applied to treat a wide range of municipal wastewater in different regions around the world [11]. In addition, the thermophilic membrane bioreactor (MBR) process has many advantages such as high biomass concentrations, high loading rates and producing good-quality effluent [9, 12].

For the treatment of recalculated newsprint white water, [13] compared several alternatives and found MBR as the most reliable technique utilized under high temperatures. MBR is an advanced water treatment technology. The integration of MBR with the thermophilic aerobic process effectively solves the difficulty of solid–liquid separation [10, 12].

Thermophilic aerobic treatment is particularly suitable for operating as a high-rate wastewater treatment since the degradation rates achieved are higher than those under mesophilic conditions, which means more compact reactor configurations [14, 15, 16] and low sludge yield under thermophilic conditions. A number of aerobic thermophilic wastewater treatments used to treat different wastewaters under high VLRs, low HRTs [17, 18, 9, 19, 2, 16]. They resulted high COD removals, considerable sludge disposereduction and cost minimization.

Thermophilic treatment has been claimed to have the advantage over mesophilic treatment in several aspects such as higher loading rates, faster chemical reaction rates, faster microbial growth rates, lower net sludge yield, increased solubility of organics, increased removal of specific substrates, and increased destruction of pathogens [20, 21, 15, 22, 2]. Compared to the mesophilic aerobic processes, thermophilic aerobic processes possessed some negatives such as high oxygen consumption, lower oxygen transfer rate, foaming problems, lower effluent quality and poor sludge settling characteristics [23, 24, 25].

The optimum temperatures for common bacterial activities in activated sludge processes are ranging between 25 and 35 °C. When the temperature drops to about 5 °C, the autotrophic nitrifying bacteria practically cease functions and even the chemo-heterotrophic bacteria mineralizing carbonaceous material become essentially dormant at 2 °C [26, 27].

In this study, efficiency of submerged membrane activated sludge reactor in treating synthetic wastewater was studied in order to determine the functionality of reactor as an effective alternative technique in treating industrial wastewater. Furthermore, the research followed by analyzing the effect of various laboratory scale aerobic digester temperature on system performance.

MATERIALS AND METHODS

Submerged Membrane Activated Sludge reactor

The reactor used was a cylindrical shape with 380 mm height and 242 mm in diameter. The operational volume of the reactor estimated 20 liters including a membrane with 380 and 180 mm in diameter and hopper bottomed. The membrane was composed of a polymer material (HDPE) with a thickness at 3.5 mm. In addition, the size of membrane pores ranged from 0.1 to 1 mm as secondary clarifiers. Furthermore, Peristaltic pumps were used to supply the required feed. Aeration was provided by laboratory compressed air system equipped with a diffuser stone located in the reactor. The DO meter at a minimum range of 1.5 mg/L was applied to maintain DO concentration continuously.

Operational method of Submerged Membrane Activated Sludge reactor

The operational method of the submerged membrane Activated Sludge reactor was divided into four main sections asflow rate determinations, organic loading rate determinations, preparation of the synthetic wastewater (feed and nutrients) and seeding process of the Submerged Membrane Activated Sludge Reactor.

Organic Loading rate determination

The organic loading rate (OLR) was determined in order to get the process flow rate, concentrations and quantity of the synthetic wastewater that need to be prepared. The organic loading rate is calculated using following equation.

$$OLR = \frac{\left(\frac{500}{10^6}\right)\times 20}{20/1000} = 0.55\ kg/m^3.d \qquad (1)$$

In the operation of Submerged Membrane Activated Sludge reactor, the COD concentration of the synthetic wastewater was sustain between 500 and 600 mg/L with assumption of 500 mg/L as real COD value. Input volume (V_{in}) and total volume (V_{total}) of the reactor were 20 L. Thus, based on equation (1), the OLR value of the reactor was recorded at 0.5 kg/m^3.d as a constant valueduring wholeof Submerged Activated Sludge study.

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Effects of food and nutrient

Synthetic wastewater is a feeding solution with chemical substances, which are produced in order to equalize the characteristics of actual wastewater. The composition of synthetic wastewater that was prepared consisted of 6 chemicals substancesglucose, ammonium chloride (NH_4Cl), magnesium sulphate ($MgSO_4.7H_2O$), calcium chloride ($CaCl_2.2H_2O$), dipottasium hydrogen phosphate (K_2HPO_4). This chemical substance was measured according to the required mass. The composition of synthetic wastewater used in this study is presented in Table 1.**Table 1: Chemical composition of the synthetic wastewater**

Components	Concentration (g/L)	Composition Function
K2HPO4	0.09	pH, source of K, P
CaCl2.2H2O	0.007	pH
KH2PO4	0.05	Source of K, P
(NH4)Cl	0.32	Source of N, S
MgSO4.7H2O	0.60	Source Mg, S
Glucose	0.50	Source of C and Energy
Distilled water		

The chemical components presented in Table 1 was measured and then poured into1 L beaker. 1 L of distilled water was added and solution wasmixed using stirrer. Specific dilution was prepared by adding 3 L distilled water into the prepared synthetic composition. Because of the lack of storage area and to avoid bacterial growth in the feed tank, synthetic wastewater compositions were arranged daily. Submerged membrane activated sludge reactor was operated 24 hours with the hydraulic retention time (HRT) of 2 days. 5 cycles were run with the temperatures at 27° C, 32° C, 37° C, 42° C, 47° C and each temperature analysis was measured after 13 days.

The effects of Seed Sludge on the determination of synthetic wastewater

The reactor was seeded with aerobic digested pharmaceutical sewage collected from Glaxo Smith Kline (GSK), near Ulu Kelang, Malaysia. First, it was sieved (<3 mm) in order to remove unwanted debris and particles led to a final MLSS concentration ranging from 2000 to 3000 mg/L. Next, the sludge was introduced into the reactor through the anterior inlet of the reactor tank. Later, the remaining volume of the reactor was filled with the synthetic wastewater feeds. Finally, the reactor was stabilized for 24 h prior to experiments and it was also aerated continuously to maintain DO concentration of 1.5 to 3.0 mg/Lusing an aquarium air stone equipped with compressor of 3 L/min air supply.

Experimental procedure

Different temperatures (27 °C, 32 °C, 37 °C, 42 °C and 47 °C) were selectedto study the effect of temperature on the efficiency of submerged membrane activated sludge reactor. A research was carried out to find out the effects of temperature on the efficiency of the system which pH was maintained in the range of 6.5 to 8.0 by adjusting using NaOH [1].

Changes in the temperature of the control reaction were measured at 24 hourly intervals by the use of calibrated pH probe. Nutrients levels were maintained in the ratio of COD: N:P at 100:5:1 [1]. The biomass was considered as acclimatized when MLSS concentration maintained at constant level (2500 mg/L). The reactor was aerated continuously with an aquarium air stone compressed air at 3 L/min to maintain dissolved oxygen concentration between 1.5 to 3.0 mg/L as the typical range for activated sludge process [30]. The operating conditions of reactor with the change in temperature ranging from 27 °C to 47 °C are presented in Table 2 as below.

Table 2: Operating condition of the reactor

Influent COD (mg/L)	Temperature (°C)	HRT (days)	Flow Rate(L/hr)	Operating Days
500 ± 600	27	2	0.42	13
500 ± 600	32	2	0.42	15
500 ± 600	37	2	0.42	13
500 ± 600	42	2	0.42	13
500 ± 600	47	2	0.42	13

Sampling and Analysis

Supernatant liquor was collectedtoanalyze the effluent. Monitored data of procedures including number of test and the frequency is shown in Table 3. Sample analyses including chemical oxygen demand (COD), pH, mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), dissolved oxygen (DO) were determined using the method described by Standard Methods [28].

Table 3: Monitoring schedule for chemical analysis

PARAMETER	TEST FREQUENCY	SAMPLING POINT
Flow rate	1x /week	
COD: Feed In Reactor Effluent	3x /week 3x /week 3x /week	Feed Tank In Reactor Effluent Tank
pH	Daily	In Reactor
Temperature	3x /week	In Reactor
Solids: MLSS/MLVSS	3x /week	In Reactor
DO	Daily	In Reactor
Nitrogen: Feed Effluent	1x /week 1x /week	Feed Tank Effluent Tank
Phosphate: Feed Effluent	1x /week 1x /week	Feed Tank Effluent Tank
Trace Effluent: Feed Effluent	1x /week 1x /week	Feed Tank Effluent Tank

COD measurements

The strength of the applied solution as feed and the effluent organic material concentration were measured using COD test. The COD test involved the oxidation of organic species in a closed controlled environment with ($Cr_2O_7^{2-}$) dichromate ion [28].

In addition, COD measurement was based on the Standard Closed Reflux Method using HACH COD reactor as exactly described in Standards Methods [28].

At the beginning, the HACH COD reflux reactor was preheated until the temperature reached to 150 °C. Sample of 2 ml was added to HACH reflux tube and followed by 2 ml of digestion solution with 0.075 N of potassium dichromate solution containing mercuric sulphate. Then, 3.5 ml of concentrated sulphuric acid including 8.8 g/L of silver sulphate was added. Tubes were tightly sealed and inverted three times to mix properly. The mixtures were refluxed in the HACH COD reactor at 150 °C for 2 hours. After cooling, contents in the tube was transferred to a 100 ml conical flask prior to titration with the fresh 0.025 N ferrous Ammonium Sulphate (FAS) through the ferroin as anindicator. Each sample was done repeatedly and at least two blanks were prepared using distilled water for each batch. The COD value was obtained using the equation (2) as follows.

$$COD = \frac{(A-B)*M*8000}{mLsample} \qquad (2)$$

A= value of FAS (Ferrous Ammonium Sulphate) titrated for blank (mL)
B= Volume of FAS titrated for sample (mL)
M= Molarity of FAS
8000= Mill equivalent weight if oxygen * 1000 ml/L

It should be noted that this test could be applied for samples with concentrations between 40 to 400 mg/L COD. On the other hand, the effluent samples did not require dilution.

Total Suspended Solids (TSS) measurements

TSS tests were carried out thought the filtration of a reactor mixed liquor contentsusing prepared GF/A filter papers [29]. Then, the filter paper was dried in an oven at temperature ranging from 103 °C to 150 °C for at least 1 h and immediately cooled in a desiccator. In addition, Vacuum pump was used in Total Suspended Solids (TSS) measurements. Next, the paper with its dry content was weighted and reached to 0.1 mg using an analytical balance. Finally, initial and final balance readings were utilized to calculate the solids concentrations (mg solids/L) in the samples.

$$\text{mg Total Suspended Solids/L} = \frac{(A-B)x\ 1000}{samplevoL\ (\frac{mg}{L})}$$

A= weight of filter + dried residue, mg
B= weight of filter, mg

Volatile suspended Solids (VSS or MLVSS)

The volatile suspended solids (VSS) or Mixed Liquor Volatile Suspended Solids (MLVSS) is a useful parameter to determine the organic part of the mixed liquor process. In this study, in order to determine the volatile fraction of the suspended solids concentration, an additional procedure was carried out based on total suspended solids determinations [28]. Thus, thefilter paper ignition (at 550 °C) and solid fixed fraction determination were done. Finally, the volatile fraction of the solid was calculated on the difference between the total amounts of solid and the fixed part of the solid.

On-line measurements

Dissolved oxygen (DO) and pH were measured using appropriate calibrated probes. Probes were calibrated at pH 4.0 and 7.0 separately to utilize on pH reactions. Dissolved oxygen and pH probes were purchased from Ingold Ltd. (Switzerland). Furthermore, temperature controller consisted the PID controller with PV and SV display.

pH

Hydrogen ion concentration in the solution (pH) plays an extreme important role in the treatment processes. The activity of microorganism is dependent on the pH of the reactor. Most organisms are active in pH between 6.5 and 8. Moreover, most aerobic plants operate within the range of pH 7. To clarify the effect of temperature on the system, an investigation was carried out in the variable pH (between 6.5 and 8.00) by adjusting the feed pH with NaOH. Changes in the temperature of the controlled reaction were measured at 24 h intervals using calibrated pH probe. The pH readings from the reactor were logged daily for the whole of study.

Dissolved Oxygen (DO) effect

Dissolved Oxygen (DO) is the main component of all aerobic biological conversions. Therefore, it can be named, as an essential and effective biological parameter requires continuous inspection oncereaction takes place. The DO level was measured using calibrated DO meter. Throughout the study, the DO levels were measured daily in order to keep the dissolved oxygen between 1.5 and 3.0 mg/L as typical range for activated sludge process [30].

RESULTS AND DISCUSSION

The study was aimed to evaluate the treatment qualityof synthetic wastewater using Submerged Membrane Activated Sludge reactor.Effects of different laboratory aerobic reactor temperatures were identified. In addition, the potential of aerobic treatment under strict controlled conditions was investigated thoroughly.

The duration of experiments and frequency of the data collected are different for each parameter. The chemical oxygen demand (COD), suspended solids (MLSS) and volatile suspended solids (MLVSS) were collected once in two days while the dissolved oxygen and pH were measured daily.

Synthetic wastewater is a feeding solution containing chemical substances, which are produced in order to equalize the characteristic of actual wastewater. The chemical oxygen demand (COD), suspended solids (MLSS) and volatile suspended solids (MLVSS) were collected after two days while the dissolved oxygen and pH were measured daily.

Moreover,Table 4 illustrated the problems were occurred during the reactor start-up and operational difficulties of the reactor during this study.

Table 4: Problems occur during the reactor start-up and operational difficulties of the reactor during reactor during this study

Day	Problems and Operational Difficulties
Start- up of The reactor	Problem in pump calibration. The digital pump performance used in this study does not interrelated with the flow rate illustrated in the pump. The pump performance is relatively lower than the flow rate value shown in the pump.
Start- up of The reactor	The vessels used to cover the porous wall are having many holes. This result the solids that have to be remain in the reactor vessel was going out.
Start- up of The reactor	The porous liners are easily removable and cause the reactor to be overflow.
Start- up of The reactor	Membrane used in this study is not suitable and the pore size is bigger than the suggested value.
Start- up of The reactor	Change of new membrane with better pore size diameter ranges (0.1-1 mm diameter)
Start- up of The reactor	The pH is in acidic which is in the range of 2-4. The pH in the reactor was then being adjusted with the feed of NAOH.
Start- up of The reactor	Overflow problem occurred in the reactor.
16	Membrane Fouling problem occur.

Feed and nutrients characterization (synthetic wastewater)

The characteristics of the synthetic wastewater prepared artificially including pH, biochemical oxygen demand (BOD) (after 5 days), chemical oxygen demand (COD) and soluble chemical oxygen demand (soluble COD) were determined. The results of the respective synthetic wastewater parameters before treating are presented in Table 5 as below.

Table 5: Characteristics of raw synthetic wastewater

PARAMETERS	CONCENTRATION
pH	6.5-7
BOD	250-300 mg/L
COD	500-600 mg/L
Soluble COD	400-500 mg/L

Seed sludge characterization

The reactor was seeded with aerobic digested pharmaceutical sewage collected from Glaxo smith Kline (GSK), near Ulu Kelang, Malaysia. First, it was sieved (<3 mm) to remove unwanted debris and particles. The seeding sludge wascharacterized based on several parameters such as pH, biochemical oxygen demand (BOD5) (after 5 days) and chemical oxygen demand (COD). The results areshown in Table 6.

Table 6: Characteristics of seeding sludge

PARAMETERS	CONCENTRATION
pH	6.5-7
BOD	700-800 mg/L
COD	1600-1800 mg/L

Submerged Membrane Activated Sludge start-up

During the reactor start-up, synthetic wastewater (500 mg/L COD and pH 7) was fed in continuously. The influents were freshly prepared while the effluents were collected on time. Despite of pH and DO, COD of effluent was measured dailywhile the MLSS of the effluents was measured solely once after two days. In addition, COD, MLSS and MLVSS removalswere determined. The correlation between COD removal and pH profile as well as DO profile within treatment period was plotted and discussed which is presented in the next section. Furthermore, the MLSS and MLVSS removal within the treatment period was also plotted. Then, the effect of temperature on the performance of the Submerged Membrane Activated
Sludge Reactor on treating synthetic wastewater was defined. Finally, the effect of the various laboratory aerobic reactor temperatures on the system efficiencywas identified.

Effect of Temperature on COD Removal

Figure 1 illustrates the effect of the temperature on the soluble COD removal by Submerged Membrane Activated Sludge reactor. The experiment length was approximately 67 days. Different temperatures, starting at 27 °C and followed by 32, 37, 42 and 47 °C, were chosen to investigate effects of different temperatures on the efficiency of submerged membrane activated sludge reactor.

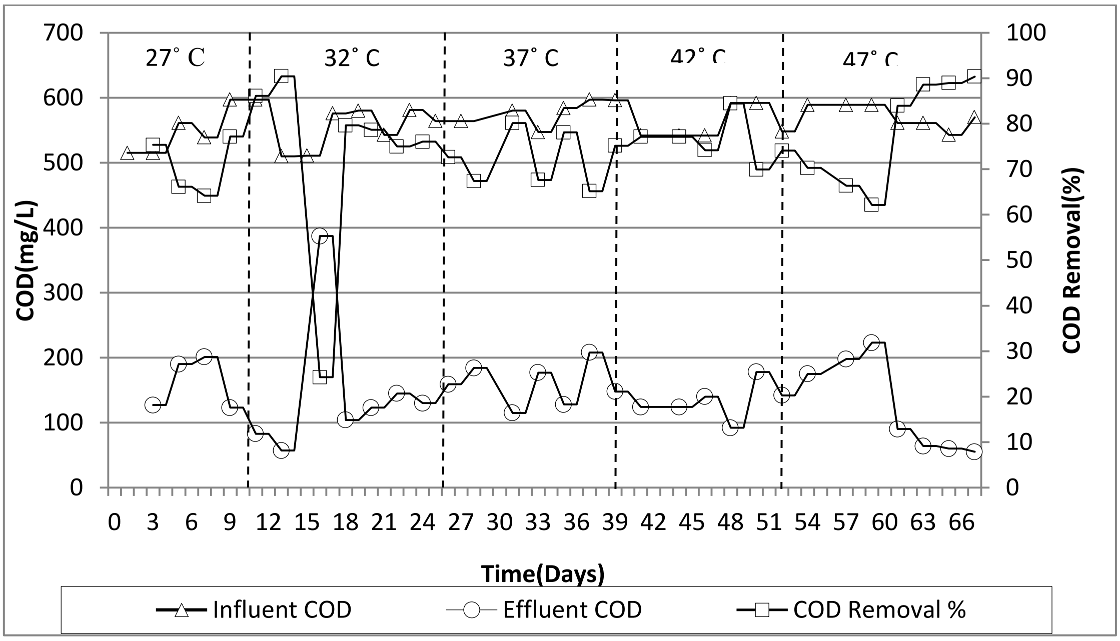

Fig.1–The effect of the temperature on soluble Cod removal of the Submerged Membrane Activated Sludge reactor

According to Figure 1, for 32 °C, the COD removal was recorded by 89.65% at 32°C followed by the highest percentageof soluble CODremoval at 90.45%until it dropped rapidly to 24.27% in day 5. For 27°C, the percentage of soluble COD removal was recorded at 75.34% before slight decrease to next level at day 6 to 9. The soluble COD removal was increased gradually and reached at 76.56% after the third cycle (day 9) of the Submerged Membrane Activated Sludge reactor operation. It is clear that COD removal efficiency of the reactor for 27 °C was 76.56% in sewage. From day 14 to 29, the reactor was operated at temperature 32 °C, while the pH was keptbetween 6.5 and 8.0. First, soluble CODremoval was recorded at 24.17% as the lowest COD removal then increased gradually to 79.65% and stabled at 67.38% as the last cycle of 32 °C. Considerable decrease mainly caused by the foaming problem occurred in the reactor. This problem was prevented using an antifoaming agent (silicone Antifoaming agent), which likely did not inhibit the biomass. The average of soluble COD removal for the temperature study at 32 °C was recorded at 67.66 %. In addition, for 37 °C, 42 °C and 47 °C, there were no significant difference on the soluble COD removal efficiency. However, the COD removal efficiency increased noticeably from 73.89% to 80.06% from 37 °C to 47 °C. Our results introduced a defined sequence based on different temperatures effects on the soluble CODremovalby the order as follows: 32 °C < 37 °C < 42 °C < 27 °C < 47 °C, 67.66 % < 73.89 % < 75 % < 76.56 % < 80.06 % respectively. Best soluble COD removal was achieved at 47 °C where the removal efficiency reached to 80.06 %.

As reported by Metcalf and Eddy [1], temperature conditions in the reactor directly affect biological treatment processes primarily by modulating microorganism metabolic function. According to Daigger [31], the higher temperature leads higher efficiency of the aerobic reactor. Furthermore, results indicated the direct relationship between active reactor temperature and the soluble COD removal efficiency.

It is also expected that high temperature biomass is unable to oxidize the same variety of complex soluble components of which the mesophilic biomass is capable [32]. Couillard & Zhu [33] found high COD removal about 90% under various temperatures (ranging from 45 to 58°C) and high loading rates up to 12 kg COD $m^{-3}d^{-1}$. Johnson & Hall [34] and Suvilampi, J. [35] reported SBR treatment of synthetic TMP white water to fail at 50°C; however, their process experienced a massive sludge wash-out with increased temperature, which apparently caused the process failure. Tripathi & Allen [24] and Suvilampi, J. [35] found slightly lower COD removal between 55 and 60°C (62%) than at 35-45°C (73-75%) in aerobic sequencing batch reactors treating bleach kraft mill effluent (BKME). They suggested the method withlow removals under high temperatures due to the inability of the thermophilic microorganisms to remove the same range of compounds as their mesophilic counterparts.

Effect of temperature on pH profile

The effect of temperature on the pH in the Submerged Membrane Activated Sludge Reactor is shown in Figure 2. The pH was maintained in the range of 6.5 to 8.00 using NaOH. The pH was observed daily in order to keep condition constant (pH between 6.5 and 8.0). Furthermore, pH dictates biochemical reaction kinetics of treatment by controlling enzyme production rate and activity. Optimum pH levels for heterotrophic bacteria fall within a narrow range between 6 and 8. Metcalf and Eddy [1] stated that in aerobic system the best pH should be controlled between the ranges of 4.0 to 9.5 which optimum range was reported from 6.5 to 75. Increases in the reactor pH caused the sludge to become more compressible [36]. From the pH point of view, it can be concluded that reactor was in stable conditions during start-up and synthetic wastewater treatment.

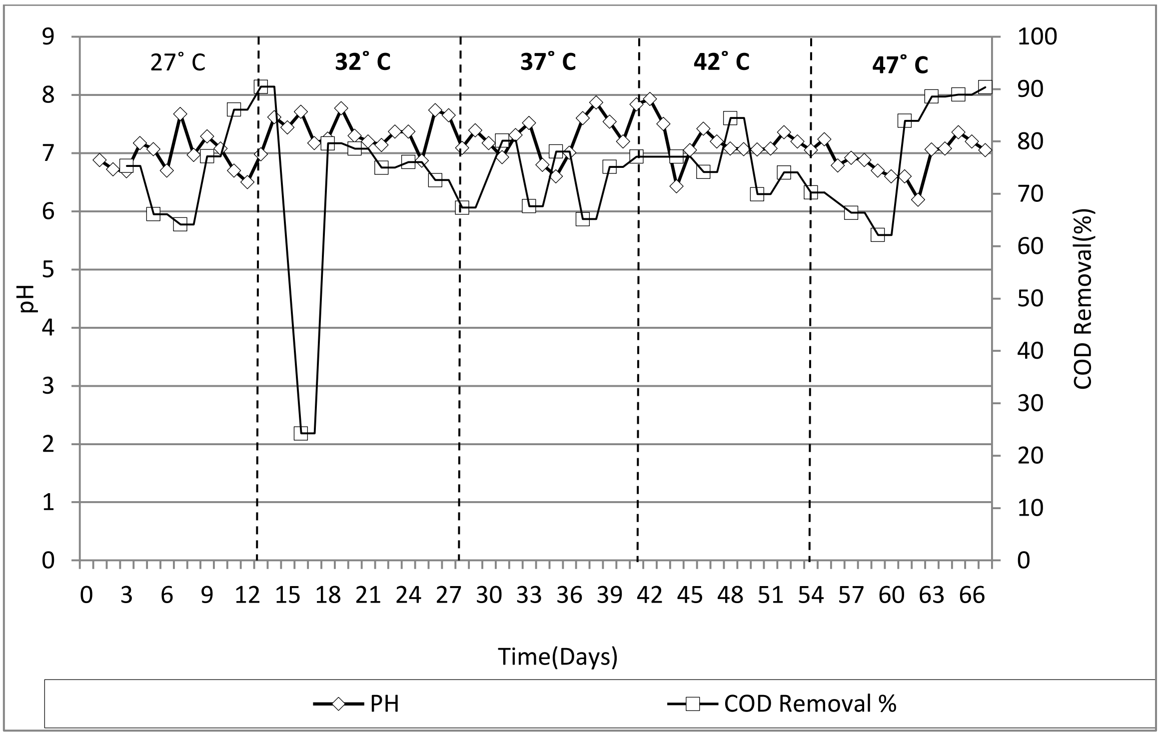

Fig.2–Effect of Temperature on the profile of pH

Effect of temperature on Dissolved Oxygen (DO) profile

The effect of temperature on the dissolved oxygen (DO) in the submerged membrane activated sludge reactor is exhibited in Figure 3. The reactor was aerated continuously using an aquarium air stone equipped with air compressor at approximately 3 L/min to maintain DO concentrations between 1.5 and 3.0 mg/L as typical range for an activated sludge reactor [1].

Based on Figure 3, increasein the temperature directlyaffect on the DO concentrations. The highest and lowest DO concentration was recorded at 27 °C, 5.1 mg/L and 1.7 mg/L respectively. As opposed, low DO concentrations reduced the poor effluent qualities. Generally, at higher DO concentrations higher filtration, better quality of effluent and greater compressible sludge are resulted.

According to Amila Abeynayaka [37] there is reduction in saturated dissolved oxygen at elevated temperatures. However, reduction of dissolved oxygen level and increment of solid solubility are disadvantages of higher temperature.

The sludge washout from the reactor system was measure frequently during the test period (Figure 4 and Figure 5).

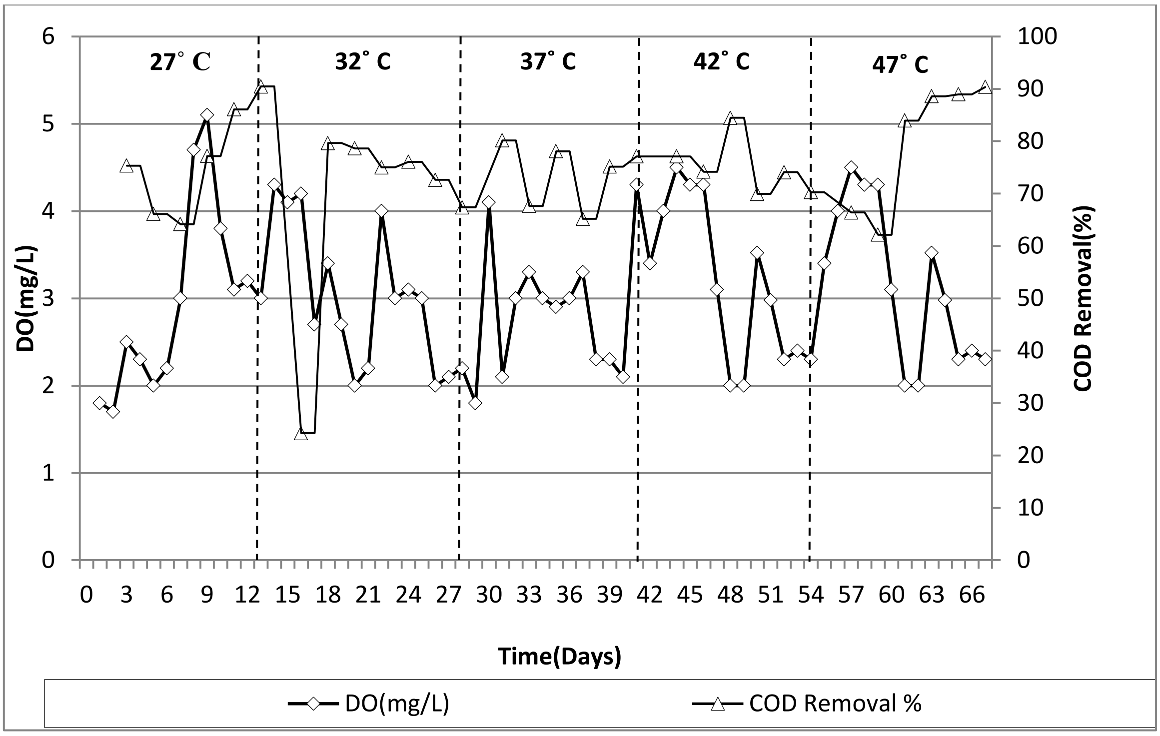

Fig.3– Effect of Temperature on the profile of Dissolved Oxygen (DO)

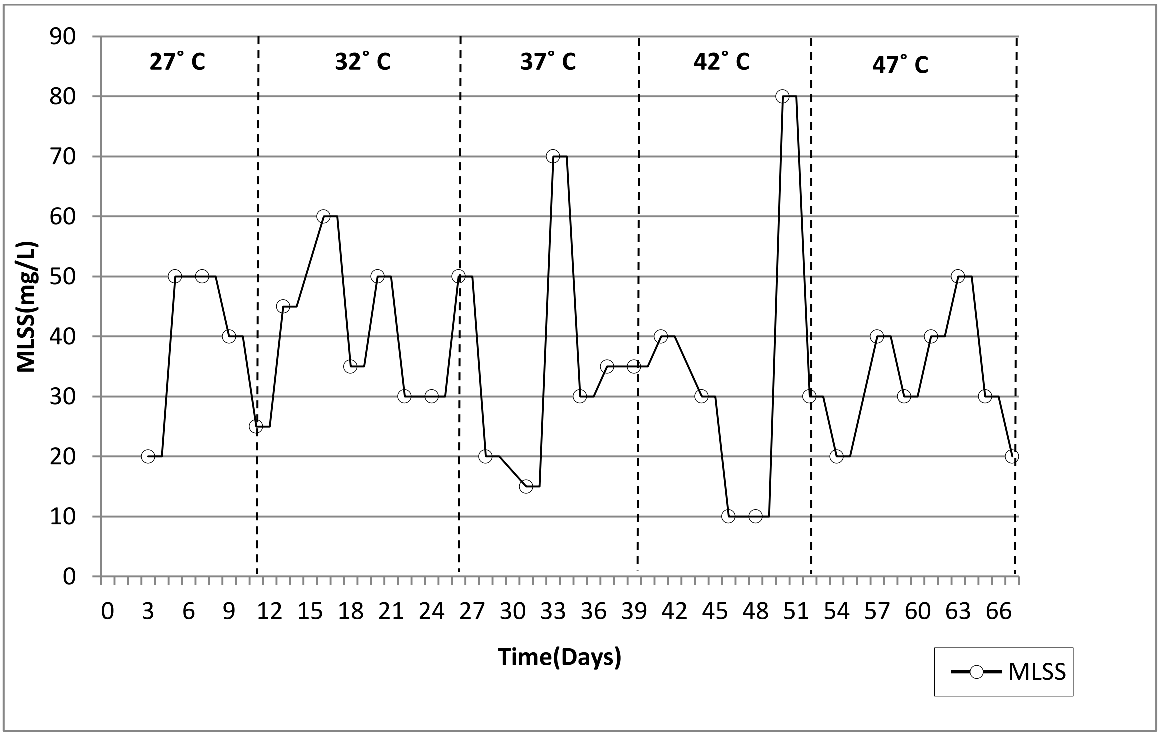

Fig.4 – Effect of Temperature on Mixed Liquor Suspended Solids (MLSS)

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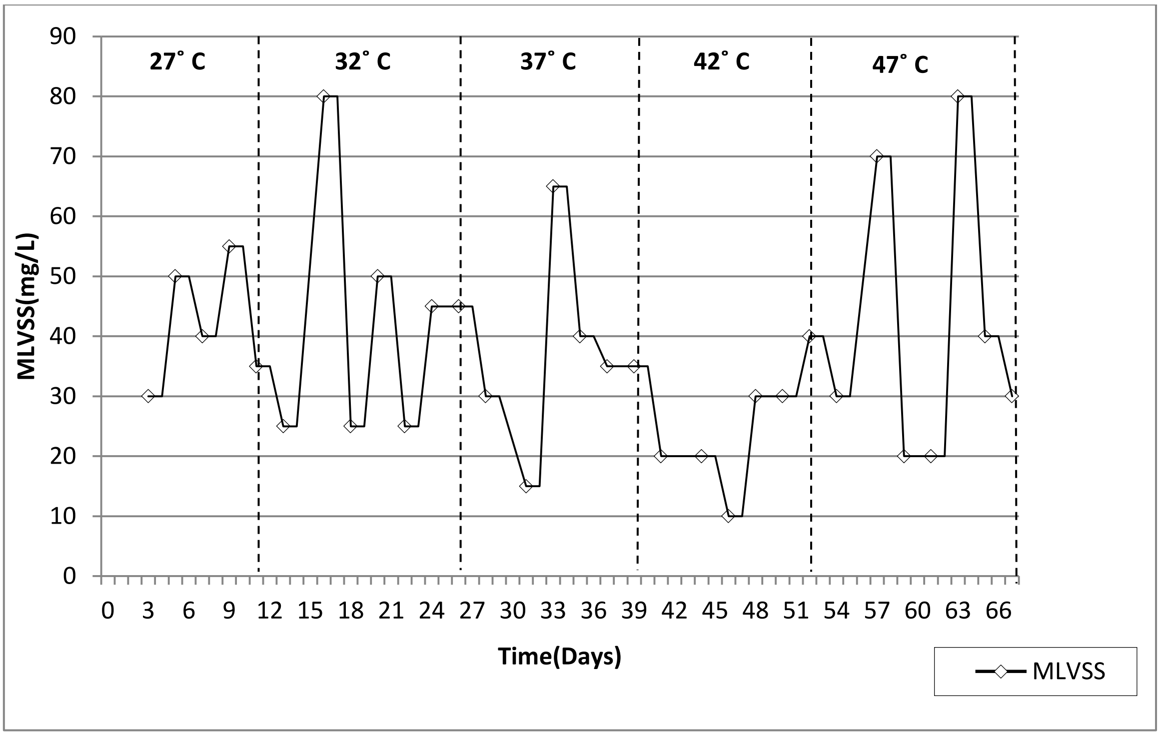

Fig.5–Effect of temperature on Mixed Liquor Volatile suspended Solids (MLVSS)

Effect of temperature on Mixed Liquor Suspended Solids (MLSS)

Figure 4 shows the effect of temperature on the MLSS concentrations. The pattern of MLSS concentrations was slightly different for each temperature range (from 27 °C to 47 °C). At 27 °C, the concentrations of MLSS was increased from 20 mg/L to 50 mg/L followed by gradual decrease to 25 mg./L. At 32 °C, the concentrations of MLSS was first increased to 60 mg/Land then decreased gradually to 30 mg/L for one cycle after 13 days. At 37 °C, the concentration of MLSS was slightly increased from 20 mg/L to 70 mg/L followed by rapid decreaseto 30 mg/L. The higher concentration of MLSS was obtained at 42 °C (80 mg/L) while the lowest concentration was recorded at 10 mg/L (42 °C). The patterns of the MLSS concentration for the temperature of 27 °C, 32 °C, 37 °C, 42 °C and 47 °C was repeated similarly.

Experiments demonstrated that wide range of mixed liquor temperatures used in treatment could increase the yield of MLSS in the treated effluent [38]. As a result, the MLSS concentration was found to be lower, because the highest concentration of MLSS was recorded at 80 mg/L, which was relatively lower compared to desired MLSS concentration for Activated Sludge reactor. Metcalf and Eddy [1] reported a desired biomass concentration of 3000-6000 mg/L of MLSS to run more effective Activated Sludge reactor.

The MLSS reduction as a result of temperature increased at 35 °C and 45 °C (both at 10 LMH flux) could be attributed to the changes in ambient temperature experienced by the microorganisms (biomass shock) as reported in various studies [39, 41, 13, 11]. Hence, microorganisms take time to adapt to the new ambient condition. Additionally, Joãoet al. [41] hypothesized that at higher temperatures; the cells utilize a large fraction of the energy to maintain their vital function and not only to synthesize new cellular material causing reduction in the biomass growth. Juhani Suvilampi [35] reported that thermophilic ASPs had lower MLSS values than the mesophilic ASPs. The thermophilic ASPs gave better SVIs than the mesophilic ASPs. In the thermophilic ASP SVIs were increased, whereas in the mesophilic ASP SVIs were reduced.

Effect of Temperature on Mixed Volatile Suspended Solids (MLVSS)

Figure 5 exhibits the effect of different temperatures on the MLVSS concentration. The highest concentration of MLVSS was obtained at 47 °C and 32 °C (80 mg/L) while the lowest was recorded at 42 °C (10 mg/L).

At 42 °C, the MLVSS concentration was increased from 10 to 40 mg/L. MLVSS concentration for this study (temperature 27 to 40 °C) was first increased to 55 mg/L and later decreased to 30 mg/L. At 32 °C, the highest concentration of MLVSS was recorded may be as a consequence of foaming phenomena.

As reported by Daigger [31], temperature directly affects the rate of MLVSS by its reductions or increases. However, our results showed that temperature does not affect MLVSS concentrations on the system.

CONCLUSIONS

The following conclusions can be drawn from the study:

- The highest soluble COD removal in average was recorded at 47 °C (80.06 %).
- The effect of temperature on the soluble COD removal follows the order of temperature as 32 °C< 37 °C < 42 °C <27°C < 47 °C with 67.66 % < 73.89 % < 75 % < 76.56 % < 80.06 % respectively.
- At low and high temperature, membrane separation is the solely reliable and robust solution for biomass parting suggesting that the treatment is taking place at low sludge ages and in high turbulent conditions.
- The highest specific degradation rate was obtained at 42 °C, 40.2 g.m^3.d while the lowest specific degradation rate was recorded at 32 °C with 1.55 g/m^3.d at day 16 of the experiment. In addition, the specific degradation rate at 37 and 42 °C showed itself much more better than other temperatures (27, 32 and 42 °C). Finally, the high specific degradation rate indicated that sludge was kept in a good condition.

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