Journal of Engineering Science and Technology
Vol. 14, No. 3 (2019) 1751 - 1763

THE PERFORMANCE OF ATTACHED AND SUSPENDED GROWTH PROCESS IN INTEGRATED FIXED ACTIVATED SLUDGE

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Abstract

River Water Treatment Plants (RWTPs) have been constructed along Klang River and its tributaries under River of Life Project (ROL) to upgrade urban River water quality. RWTPs apply Integrated Fixed-Film Activated Sludge (IFAS) system in biological process to treat polluted Klang Rivers and its tributaries. This system is based on the activity of attached growth biomedia and often defined by the content suspended growth biomedia. Hence, suspended biomass activity is usually not been evaluated, however, it is neglected. Therefore, this paper is to evaluate the biomass content, the following parameters have been used; Mixed Liquor Volatile Suspended Solids (MLVSS) for expressing the suspended growth system and Total Volatile Solids (TVS) for expressing the attached growth system. MLVSS content for all RWTPs was found very low due to dilution from rainwater since Klang River experienced several high intensity rainfall events. From total 6 RWTP stations have been monitored, RWTP Sg. Kemensah, RWTP Sg. Sering and RWTP Sg. Gisir have showed low amount of biomass in the oxidation chamber due to low organic loading and matured biofilm formation in RWTP Gisir. On the other hand, RWTP Sg. Belongkong and RWTP Sg. Kemunsing showed satisfactory biomass growth. For RWTPs, the biological treatment process involving attached growth system are considered the best option as compared to suspended growth. It has been shown that under ROL project, all RWTPs are able to remove a large number of contamination despite of their low MLVSS content (0.2-50 mg/L) and low loading influent capacity (10-30 mg BOD/L). In addition, it has been noticed that low hydraulic retention time (2 hours) and low aeration rate (5.0-7.0 L/min) are the factors that can ensure an effective biofilm growth and total reduction of pollutants in RWTP. These process factors may be an interesting subject to be addressed in further research topics, starting from the results of this paper. This paper will present the introductory and amount of hybrid growth system in IFAS process including attached and suspended growth process.

Keywords: Attached growth process, Hybrid growth system, IFAS, MBBR, Suspended growth process.

1. Introduction

The past decade has seen rapid concern about sustainable River management become rise [1-7]. Recently, researchers have shown an increased interest in River management [8-14]. River of life (ROL) project is the Malaysian Government initiative to transform and upgrade the polluted urban Klang River. ROL project is one of the key initiatives under the 10th Malaysian Plan to revitalize the Klang River into a heritage and commercial centre for initiating a greater Kuala Lumpur and Klang Valley. Specifically, hybrid River Water Treatment Plants (RWTPs) were originally constructed along Klang River and its tributaries within the River of Life (ROL) Project. According to Malaysian Department of Irrigation and Drainage [14], besides RWTPs, other few connected technologies have also been adopted; gross pollutant trap, water quality pond, trash rack, log boom aimed to control water quality pollution in Klang River.

In this project, RWTPs apply Integrated Fixed-Film Activated Sludge (IFAS) in biological process to treat polluted Klang Rivers and its tributaries. The biological treatment approach was selected for this project due to its proper, cheap, environmental friendly, easy for maintenance and low administrative and operational cost [15]. The performance of the mentioned hybrid system has been evaluated in terms of comparison between attached growth biomedia and suspended growth biomedia process [16]. The hybrid system proved effective in reducing the chemical oxygen demand (COD) and ammoniacal nitrogen (AN) up to the level below the discharged limit. Starting the year of 2014, the RWTPs were monitored under Malaysian Department of Irrigation and Drainage in order to detect any violations of effluent parameter limits as regulated in National Water Quality Standard (NWQS) limit addressed to Water Quality Index (WQI) Standard Class IIB as presented in Table 1 [17].

Mohiyaden et al. [18] explained that the IFAS system are often dependent on the activity of the attached biomedia growth and it often defined by low suspended solid content. Hence, the activity of suspended solid in the aeration tank activity was not investigated and practically it was neglected. [5, 6]. Therefore, the research study aimed to understand the interaction between mass transfer and the exchange of biomass between the liquid and solids phase in order to evaluate biological system in IFAS. The objective of this papers is to investigate the attached growth; total volatile solid (expressed as TVS) and suspended growth; mixed liquor volatile suspended solid (expressed as MLVSS) that used IFAS River water treatment plants.

Table 1. NWQS classes IIB [17].

Parameter	Unit	Classes IIB
NH_3-N	mg/l	0.3
BOD	mg/l	3.0
COD	mg/l	25.0
DO	mg/l	5.0-7.0
pH	-	6.0-9.0
TSS	mg/l	50.0
Turbidity	NTU	50.0
WQI	-	76.5 - 92.7

2. Materials and Method

A site was constructed starting the year of 2013 around Wilayah Persekutuan Kuala Lumpur and Selangor State, Malaysia. The detailed RWTP operation and data collection can be referred to from a previous publication [18]. For carrying out analytical analysis, samples were manually collected from the oxidation chamber of the RWTP. The samples for MLVSS and TVS for biofilm concentration were stabilized in the field and transported on ice, along with samples for laboratory experiments according to APHA standard method [19].

2.1. MLVSS for suspended growth biomedia process

Roridges et al. [21] found biomass content in a biological carrier in the Moving Bed Biological Reactor (MBBR) and Integrated Fixed Activated Sludge System (IFAS) system may be quantified using Volatile Suspended Solid (VSS) [20]. Biomass content was represented by live, dead biomass and some inert materials. Total Solids (TS) in the aeration tank are usually recorded to design and control the process in activated sludge-based conventional treatment plants. Meanwhile, Total Dissolved Solids (TDS) are recorded to evaluate the suitability of water intended for domestic supplies and industrial purposes. The Total Suspended Solids (TSS) and Volatile Suspended Solid (VSS), are recorded to evaluate the level of pollutants in influent waters and act as a key parameter for wastewater treatment operation.

2.2. TVS for attached growth biomedia process

There are two parameters recorded to evaluate the biofilm formation in the study, which are TVS and MLVSS present in the RWTP oxidation tanks. According to Bertino [22] method, biofilm layer formation represents the development of attached growth process. Thus, the amount of biofilm growth can be measured using TVS on the biomedia surface. TVS is mostly contained organic biomass. The attached biomass, which is fixed on biomass carriers. A few samples of biomedia carriers were taken out from the RWTP oxidation tank to be tested in the laboratory.

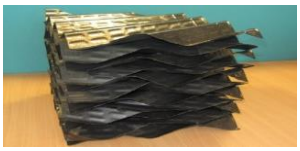
Samples without biofilm are initially identified, codified and weighted as showed in Table 2. The biomedia was removed manually using knife and needle until the attached biomass on the carriers were slugged off from the carriers using recorded distilled water. The GFC Whatman's 1.2 μm filter paper and porcelain dishes were weighted before filtration. Then the solution of biomass and mL washing water was filtered through a filter paper. The filter paper and porcelain dishes were then kept in the oven at 105 ºC at least for 1 hr followed by desiccation for 20 minutes and measured weight as "A". The filter paper was again kept in a furnace at 550 ºC for 20 minutes followed by desiccation for 20 minutes and measured weight as "B". TVS on biomedia were done monthly in duplicate. Based on studies by Mohiyaden et al. [18], TVS were calculated as mention in Eq. 1.

$$TVS = \frac{[A]-[B]}{sample\ volume \times biomedia\ weight} \quad (1)$$

where,

A = Weight of filter and porcelain dish + residue after oven 105 °C.
B = Weight of filter and porcelain dish + residue after ignition.

Table 2. Biomedia specification.

Biomedia	Brush	Fill
Picture		
Description	Brush filaments	Corrugated
Material	Polypropylene (PP) for filament	UV
Density	10 kg/m³	50 kg/m³
Volume	0.018 m³/m	0.432 m³/m
Specific	49.4 m²/m³	243 m²/m³
Hydraulic	0.6-1.0 kg/m³/d	N/A
Porosity	> 95%	> 90%
Sample	37.28 g	6.02 g

3. Results

TVS is as dry weight of biofilm formed on the biomedia carriers in the biological aeration tank. The scope of the TVS measurement is to quantify the amount of biofilm that was formed and to monitor the biofilm growth. The measurement of TVS is an estimation of the amount of organic matter present in the solid form. TVS were recorded every month starting November 2016 to December 2016. After the TVS in the reactor value was tested, a MLVSS test was conducted to determine the operational behaviour and biological inventory of the system. Many researchers applied VSS for activated sludge assessment besides COD, TOC, biomass growth, sludge yield and microbial respiration [16]. The measurement of MLVSS was done for the estimation of amount of organic matter present in the aeration tank. In addition, MLVSS also used as an estimation of the biomass concentration in conventional activated sludge system [14]. For the month November and December 2016, there are total 36 MLVSS samples and 28 TVS samples were recorded. As referred to results in Figs. 1 to 5, MLVSS results for each 6 IFASs are plotted based on location of oxidation tank in each IFAS, which are divided by different chamber location. Influent will flow through chamber 1 (CH1/CH A1/CH B1), then chamber 2 (CH2/CH A2/CH B2) and finally to chamber 3 (CH3/ CH A3/ CH B3).

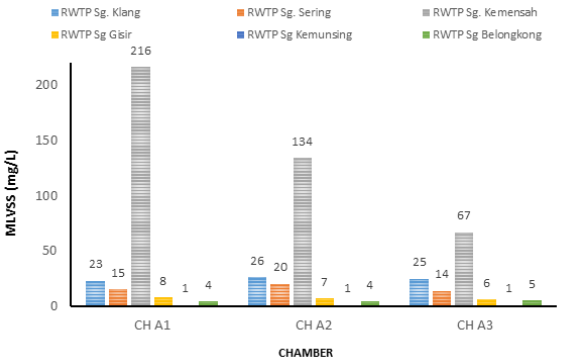
4. Discussion

4.1. Suspended growth biomedia analysis

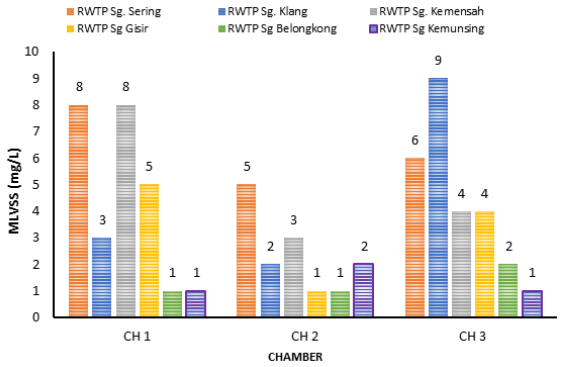
Figure 1(a) illustrated about the MLVSS values for 6 IFASs for the month of November 2016. Based on figure mentioned the highest value for MLVSS is IFAS Kemensah River for all chamber; 216 mg/l, 134 mg/l and 67 mg/l respectively. IFAS Kemunsing River showed the lowest value of MLVSS; less than 1 mg/L.

Figure 1(b) illustrated the MLVSS values for 5 RWTPs for the month of December 2016 due to its availability of sampling works. Based on the figure mentioned, MLVSS results showed a lower value that starts from 1.00 to 9.00 mg/L only. The highest value for MLVSS is RWTP Sg. Klang for chamber 3; 9.0 mg/l followed by RWTP Sg. Sering and RWTP Sg. Kemensah Chamber 1. Sg. Klang and its tributaries (RWTP Sg. Sering and RWTP Sg. Kemensah) experience high

MLVSS value due to high organic loading into RWTP influent. Due to the high intensity of rainfall followed by dilution starts to occur at the Sg. Gombak catchment resulting its RWTP in its tributaries (RWTP Sg. Belongkong and RWTP Sg. Kemunsing) showed the lowest value of MLVSS; less than 2 mg/L.



(a)



(b)

Fig. 1. Overall MLVSS in different location on chamber: (a) November 2016, (b) December 2016.

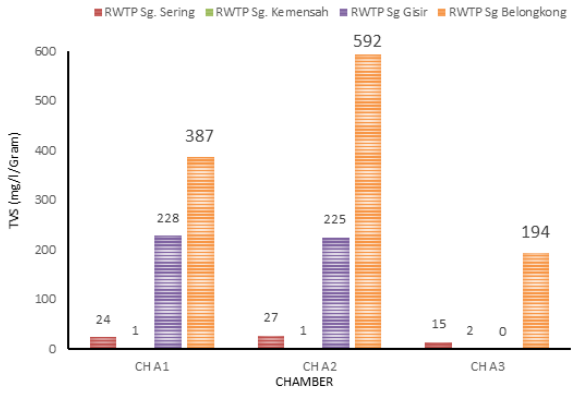
4.2. Attached growth biomedia analysis

TVS is one of the important parameters to measure the biofilm formation from attached microorganism in the attached growth support system.

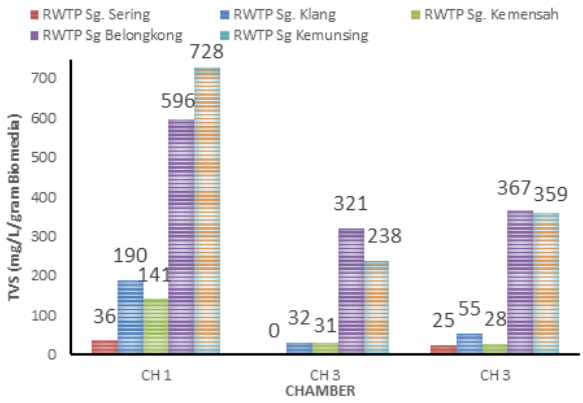
The Graph in Fig. 2 showed the value of TVS (mg/L/gram) for 6 IFASs for the month of November 2016. TVS sampling was conducted at 4 IFAS for the month of November 2016; IFAS Sering River, IFAS Kemensah River, IFAS Gisir River and IFAS Belongkong River as depicted in Fig. 2(a). Overall, IFAS Belongkong River showed a satisfactory development of biofilm with the highest value of TVS: 386.91 mg/l/gram biomedia, 592.46 mg/l/gram biomedia and 193.88 mg/l/gram biomedia for each chamber respectively. Sg. Belongkong showed the highest value for November 2016 because of the BOD influent of the RWTP is the maximum

among Sg. Gombak tributaries (61.6 mg/L) during the month. High BOD level contains high organic content thus, will accelerate the biofilm formation on the biomedia surface. According to Aygyn et al. [23] RWTP Kemensah River showed the lowest amount of biofilm development from 0.606 mg/l/gram biomedia, 1.057 mg/l/gram biomedia and 2.050 mg/l/gram biomedia for each chamber respectively.

As showed in Fig. 2(b) TVS sampling was conducted at 5 RWTP for the month of December 2016; RWTP Sering River, RWTP Kemensah River, RWTP Klang River, RWTP Kemunsing River and RWTP Belongkong River. RWTP Kemunsing River showed the highest amount of TVS with 727 mg/L/gram, 237.486 mg/L/gram and 358.502 mg/L/gram according to chamber location. It was followed by RWTP Sg. Belongkong with value of TVS; 596.06 mg/l/gram biomedia, 321.101 mg/l/gram biomedia for chamber 1, 321.101 mg/l/gram biomedia and 366.555 mg/l/gram biomedia for each chamber respectively. RWTP Sering River showed the lowest amount of biofilm development from 35.667 mg/l/gram biomedia and 24.600 mg/l/gram biomedia for each chamber respectively.



(a)



(b)

Fig. 2. Overall TVS results obtained for different location on chamber: (a) November 2016, (b) December 2016.

4.3. Comparison of suspended growth and attached growth IFAS aeration tank

Biological system in the IFAS oxidation tank is very complex culture systems consisting of microbial cells and colonies embedded in the polymer matrix. The amount of culture can be estimated either by physical properties or physicochemical properties [24]. There are two types of microorganisms living in the biological oxidation tank, which can be categorized as suspended growth microorganism and attached growth microorganisms [25].

The suspended growth as in conventional activated sludge is a nominal process applied as a biological treatment in a water treatment plant. On the other hand, attached growth processes can be obtained by combining biofilm carriers and activated sludge in one treatment step. Addition of carrier media to activated sludge reactors is also a well-established upgrading method for plants with limited nitrification capacity [26]. The method enables retention of slow-growing microorganisms through microbial attachment to the carrier media. Thus, analysis of TVS is very crucial to monitor the amount of attached growth biomass in the IFAS system.

Figures 3 and 4 showed the value of MLVSS and TVS in the same chamber for the month of November 2016. IFAS Gisir River, IFAS Sering River, IFAS Kemensah River, IFAS Belongkong River were analysed. The purpose of this graphic representation was to show the types of bacteria growth (suspended growth or attached growth) in the oxidation tank for each IFAS for current month.

From Fig. 3, it can be noticed that IFAS Kemensah River is categorized as a system with suspended growth for the month of November 2016 with less 5 mg/l/gram of TVS for each chamber. However, the observed difference between MLVSS and TVS in IFAS Sering River was not significant and this showed that IFAS Sering River is still not categorised as suspended growth dominant nor attached growth dominant.

From Fig. 4(a), it can be noticed that IFAS Gisir River and IFAS Belongkong River are clearly classified as attached growth process in their biological reactor. As for overall observation in November 2016, MLVSS content for all IFASs is very low due to dilution from rainwater since Klang River experienced several high-intensity rainfall events. IFAS Kemensah River did not show the progressive biomass growth in the oxidation chamber since it categorized as suspended growth based. On the other hand, IFAS Belongkong River showed satisfactory biomass growth. To understand the total biomass development in each biomedia, the graphs in Figs. 5(a) and (b) is plotted. This figure showed the value of MLVSS and TVS at the same chamber for the month of December 2016. The purpose of this analysis is plotted to show the dominant types of growth for each RWTP for the current month. There are 5 RWTP, which were analysed.

- RWTP Kemunsing River,
- RWTP Sering River,
- RWTP Kemensah River,
- RWTP Belongkong River and
- RWTP `Klang River.

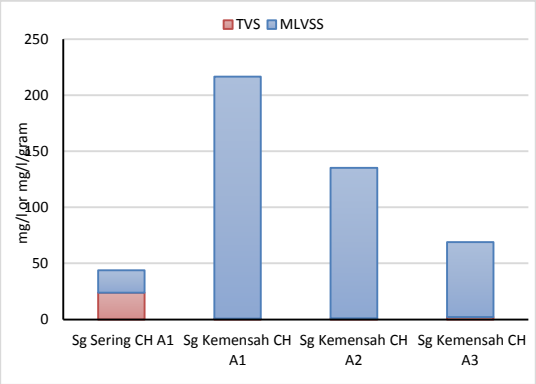
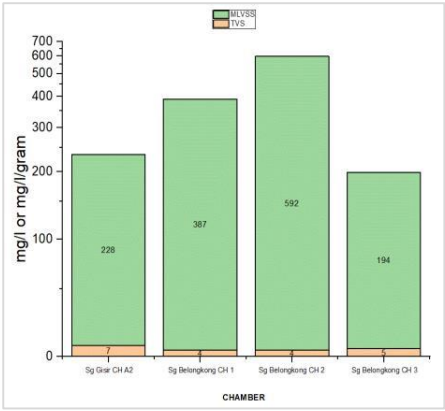
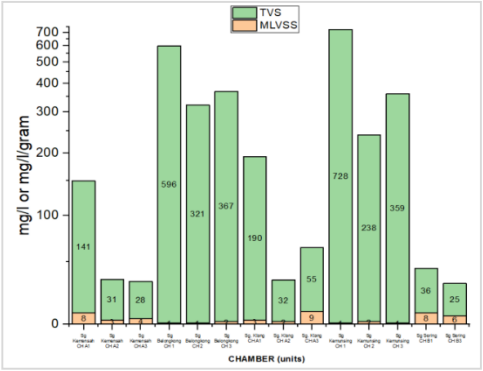


Fig. 3. Suspended growth from different location chamber November 2016.

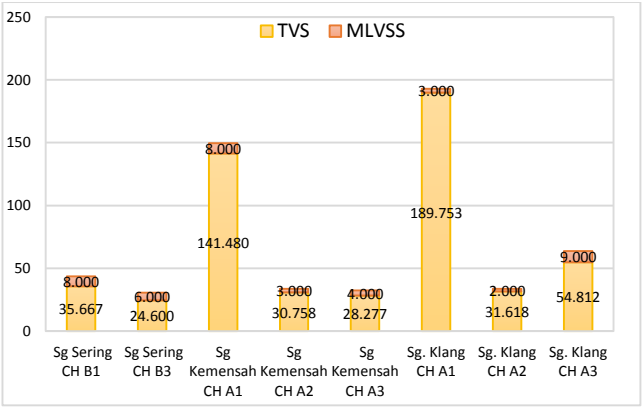


(a)

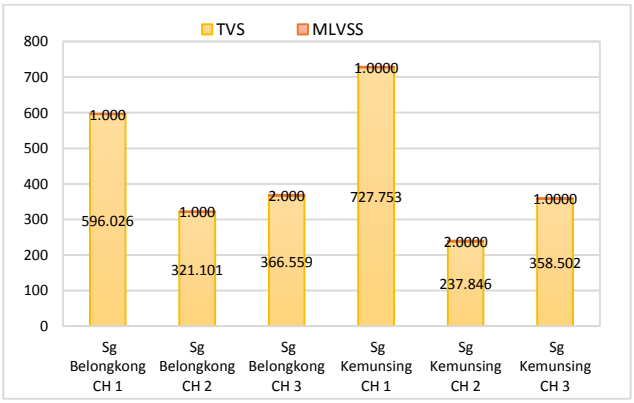


(b)

Fig. 4. Attached growth obtained for different location on chamber November 2016.



(a)



(b)

Fig. 5. Attached growth obtained for different location chamber on December 2016: (a) Klang tributaries, (b) Gombak tributaries.

From Fig. 5, it showed that all selected RWTPs are obviously dominated by the attached growth process. Types of biomedia give a major contribution of the biofilm development in the attached growth process. The plant design also gives a significant impact on the amount of biomass in the biological reactor.

From Fig. 5(a), it can be noticed that RWTP Sering River contains a low amount of biomass. This is most likely due to the presence of filamentous bacteria in the tank. Filamentous bacteria will reduce the dissolved oxygen level but also the performance of biological oxidation process. They could consume the other species of bacteria as food sources, e.g., Actinobacteria, Nitrosomonas, Nitrobacter, etc., and reduce the amount of biofilm colonies embedded in the polymer matrix in the oxidation tank thus, reduce the performance of RWTP.

Low amount of biomass is may be due to abundant of sludge at the bottom of the tank. Abundant sludge can reduce the dissolved oxygen (DO) level, disturb microbial cells and colonies communities, which had been developed on the different carriers, could produce a lot of filamentous bacteria and finally reduce RWTP performance. Mohiyaden et al. [7] reported that bulky filamentous microorganism will interrupt the

settling of sludge characteristics during the aeration process IFAS reactor. This is also evidenced by the significant rise in the Sludge Volume Index (SVI). Borkar et al. [27] proposed that a good attached growth process able to have a low concentration of solids leaving the biological reactors, the absence of filamentous bulking and good settling characteristics of the sludge.

As seen in Fig. 5(b), the highest amount of biomass is RWTP Sg. Kemunsing with total biomass 1328.101 mg/L/gram compared to RWTP Sg. Belongkong with total biomass 1,287.687 mg/L/gram in Gombak River tributaries. The observed difference in the total amount of biomass could be attributed to types of brush media. As referred in Table 2, Brush media contain lower density with 10 kg/m^3 compared with Fill media with 50 kg/m^3. Brush media in RWTP Sg. Kemunsing is lighter and softer compare to brush media in RWTP Sg. Belongkong, which is denser and harder. Lighter and softer biomedia will create more biofilm adhesion and cohesion in the reactors. This flow will promote bacterial adhesion and ensuring superior affinity to biofilm cell attachment. Therefore, the physical types of biomedia play an important role for providing a place for microorganism to be attached and grow on its surface [28].

5. Conclusions

As for overall observation in November and December 2016, MLVSS content for all RWTPs is very low due to dilution from rainwater since Klang River experienced several high intensity rainfall events. RWTP Sg. Kemensah, RWTP Sg. Sering and RWTP Sg. Gisir showed low amount of biomass in the oxidation chamber due to low organic loading and matured biofilm formation respectively. On the other hand, RWTP Sg. Belongkong and RWTP Sg. Kemunsing showed satisfactory biomass growth for the month of November and December 2016. Attached growth biological treatment process for RWTP was proved as being a more efficient process compared to suspended growth process as it showed higher levels of performance parameters for two consecutive months. It can be concluded that all the RWTPs are able to remove tremendous number of contamination although their low MLVSS values (0.2-50 mg/L). High hydraulic retention time (2 hours), low aeration rate (5-7 L/min) and low loading capacity (10-30 mg BOD/L) might be the reasons that make RWTPs can reduce River water pollutants level. These factors may become an interesting research topic to be further developed in connection to the results provided by this experimental study. In addition, attached growth biomedia systems have a great tolerance to variation in hydraulic and pollutants load, ability to reuse effluent for local irrigation, they offer good integration to the landscape, have small footprint, involve low operational and maintenance cost.

Acknowledgement

The authors acknowledge the Universiti Tenaga Nasional and the Malaysia Department of Irrigation and Drainage (DID) for providing financial support on publication and research project. A part of the instrumentation used in this study was supported by Environmental Engineering Laboratory, Sustainable Technology and Environment Research Group (STEG), Universiti Tenaga Nasional (UNITEN).

Nomenclatures

Greek Symbols

μm	Micrometer

Abbreviations

AN	Ammoniacal Nitrogen
CH	Chamber
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
HRT	Hydraulic Retention Time
IFAS	Integrated Fixed Activated Sludge
MBBR	Moving Bed Biological Reactor
MLVSS	Mixed Liquor Volatile Suspended Solid
NWQS	National Water Quality Standard
ROL	River Of Life
RWTP	River Water Treatment Plant
SVI	Sludge Volume Index
TDS	Total Dissolved Solids
TS	Total Solids
TSS	Total Suspended Solids
TVS	Total Volatile Solid
VSS	Volatile Suspended Solid
WQI	Water Quality Index

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