Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2022.28811

271 (2022) 108–115
September

Water quality effluent treatment using macro-composite technology at a residential flat area: hydraulic retention time effects

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Received 30 December 2021; Accepted 3 August 2022

ABSTRACT

Most of the causes of river pollution are due to the impact of human activities through the development of new construction projects, agriculture, industry and others. As an alternative to deal with this problem, macro-composite has been used as a pretreatment process to treat wastewater before discharge into the river. Therefore, this study aims to characterize the water quality of the effluent and to investigate the treatment efficiency of different hydraulic retention times (HRTs) using macro-composite technology in treating the effluent from Flat Taman Jaya. The parameters tested were chemical oxygen demand (COD), biochemical oxygen demand, ammonia nitrogen (NH_3–N), pH, total suspended solid (TSS), turbidity and total phosphate (TP). The efficacy of the macro-composites was tested by immersing 70% of the macro-composites into the 750 mL wastewater sample for five different periods. The results of each wastewater sample were measured after 2 d of treatment. The results showed that the most efficient treatment was achieved with the macro-composite at 3 d HRT with COD, NH_3–N, TSS, turbidity and TP removal of 80%, 97%, 60%, 49% and 89%, respectively, at pH 7.33.

Keywords: Water quality; Hydraulic retention times; Water pollution

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1. Introduction

Generally, water pollution occurs due to existing of the contaminant in the water bodies become a serious environmental issue in this world [1–10]. Water pollution is a serious problem in Malaysia that impact the sustainability of the water resources [11]. Most of the sources of river pollution are due to the impacts of human activities from the development of new construction projects, agricultural, industries and others [12,13]. Many researchers have come out with a lot of good ideas and technology to solve this problem [14–19]. As an example, various types of treatment processes have been invented to remove the contaminant in the wastewater before being discharged to the river such as electrochemical treatment [20], membrane technology [21], photocatalytic processes [22], magnetic field application [23], photocatalytic-membrane technology [24], and biological way [25,26].

However, the water quality of some rivers in Malaysia is still in deteriorating condition due to the several limitations on these treatments such as low removal efficiency and less economical. Besides, 9% of the rivers in the country are considered polluted (class III and IV). While another 39% and 52% recorded the water quality of the river in Malaysia are slightly polluted (class III) and clean (class I and II), respectively [27]. Low water quality due to water pollution can expose several critical conditions, such as climate change, human health, population growth, and ecosystem quality [28].

Due to the critical condition of the river in Malaysia, the innovation of an alternative sustainable technology called macro-composite is developed to improve the water quality [29]. The macro-composite provides an efficient treatment process of wastewater which involves both physical treatment and biological treatment of the pollutants [30]. Furthermore, this product is made from materials such as aggregates, activated carbon, cement, sand and zeolite [31,32]. It is considered as one of the sustainable technologies invented by Plat-COM Ventures since all these materials are natural, environmentally friendly, economical, and safe to be used as wastewater treatment [33]. Thus, the macro-composite can be as a pre-treatment process in treating the wastewater before discharge to a water source such as a river [29,34].

Due to the lack of information on this newly developed technology towards the improvement of the river's water quality near a residential area, this study aims to characterize the water quality of the effluent and to investigate the treatment efficiency of different hydraulic retention times (HRTs) using macro-composite technology in treating the effluent from Flat Taman Jaya. Findings from this study can be a good strategy to develop an effective pretreatment process to treat wastewater before discharging to the environment.

2. Materials and method

A major part of this research involves the characterization of the wastewater and treatment of the wastewater using the macro-composite at different HRTs. At first, the sampling work was done which consists of in-situ testing and laboratory analysis. For in-situ testing, the parameters were determined directly at the sampling site [35]. Meanwhile for laboratory analysis, the samples were collected and taken as laboratory sample [36]. Then, all the data collection were analyzed and were followed by a discussion of the findings.

2.1. Wastewater sampling and storage

The wastewater was collected from the Skudai River near Flat Taman Jaya (Fig. 1). After sample collection, the sample was transferred to a container and stored at a temperature of 4°C in the environmental laboratory. Immediate storage of the sample is important to maintain the quality of the samples and minimize the microbial activities present in the effluent.

2.2. Analytical methods

To determine if there were any differences between the original and final effluent readings before and after the treatment, several water quality parameters were measured when conducting the experiment. It is noteworthy to ensure the effluent complies with the required standard and can be disposed to the environment safely. The parameters measured were biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), NH_3–N, total phosphate (TP), pH, and turbidity. During the experiment, all the solutions were diluted 1:9 dilution factor which has been expressed as 1 mL of sample with the addition of 9 mL of distilled water. Table 1 indicates the equipment and method used to conduct the test.

2.3. Batch treatment setup

The treatment of the wastewater sample using macro-composites was conducted by placing 750 mL of wastewater sample and 70% of macro-composites into the container. The same amount of wastewater sample and the macro-composites was added to another five containers with different HRT. Each container was labelled as 1, 3-, 5-, 7- and 9-d HRT. At the end of the period, the treated sample was collected for the evaluation process. All the sample in the container was tested to determine the COD, BOD, TSS, NH_3–N, pH, turbidity, and TP. After that, the wastewater was treated using the macro-composites and only the critical parameters were analyzed to ensure the effectiveness of the macro-composites in treating the wastewater. To achieve the effectiveness, the sample was analyzed by comparing the initial characteristics of the parameter value with the value after the treatment using the macro-composites.

3. Results and discussion

3.1. Characterization of wastewater

The initial characterization of the wastewater was done by analyzing the concentration of the COD, BOD, TSS, NH_3–N, TP, turbidity, and pH. The results of the initial wastewater characteristics were recorded and stated in Table 2. According to the results, most of the water quality

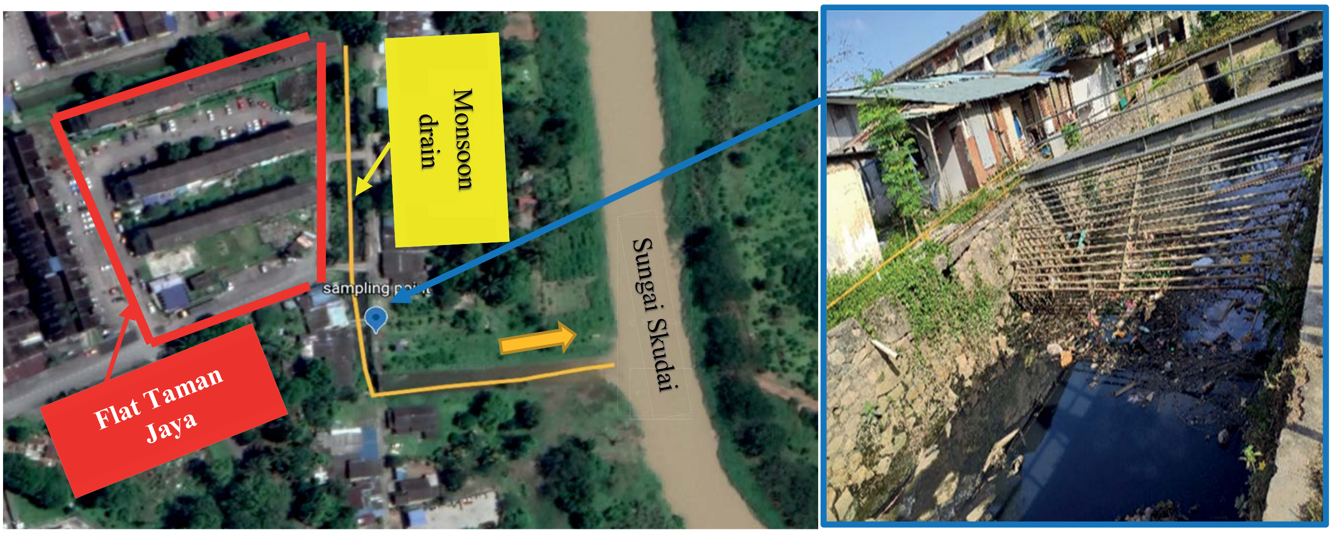

Fig. 1. Sampling location (1°32′37″ N 103°39′36″ E) at monsoon drain.

Table 1
List of equipment and methods used

	Equipment	Methods
BOD, mg/L	Dissolved Oxygen Meter	–
COD, mg/L	DR6000 Spectrophotometer	Method 8000 Reactor Digestion
NH_3–N, mg/L	DR6000 Spectrophotometer	Method 8038 Nessler
TSS, mg/L	DR6000 Spectrophotometer	Photometric Method (Method 8006)
TP, mg/L	DR6000 Spectrophotometer	Method 8048 PhosVer 3 (Ascorbic Acid)
pH	pH Meter	–
Turbidity, NTU	Turbidity Meter	–

parameters had high concentrations and harmful if directly discharge into the environment without any treatment.

3.2. Macro-composites treatment at different HRTs

There were five samples analyzed with different HRTs to determine the effectiveness of the macro-composites in treating the wastewater at Flat Taman Jaya. The sample consists of 750 mL wastewater were tested on 1, 3, 5, 7, and 9 d. The results of the treated wastewater were compared by determining the percentage removal efficiency with the initial value of untreated wastewater. All the parameters have a different graph pattern. Out of all the parameters, the percentage removal of NH_3–N and turbidity has increased gradually, and this showed that the macro-composites are effective in treating the ammonia in the wastewater. However, the removal for other parameters recorded is also a good result but the graph fluctuated due to some reason.

3.2.1. COD removal

The COD removal after the treatment with different HRTs is shown in Fig. 2. From the graph, the COD percentage removal increases gradually from day 1 to day 3 treatment with the percentage of 41% and 80% respectively. However, the graph indicates an unstable result from day 5 to day 9 of the treatment where the percentage removal suddenly declines at day 5 of the treatment with 66% of removal. The highest COD percentage removal recorded were on day 7 of treatment where the reading of the COD was only 29 mg/L left in the sample. The value occurrence of fluctuations in the value of COD every day may be due to the microorganisms have not been able to adapt to the wastewater sample in every stage. Several microorganisms which may able to change value of COD are

Table 2
Initial characterization of wastewater

Parameters	Value
COD, mg/L	167
BOD, mg/L	138
TSS, mg/L	2.5
NH_3–N, mg/L	0.64
TP, mg/L	0.54
Turbidity, NTU	36.7
pH	7.01

Sediminibacterium, Cellvibrio, Rheinheimera, Limnobacter and Pseudarcicella [37]. Compared to Elgarahy et al. [38] and Siyal et al. [39], the bacterial growth in the biofilm in the first few days of the treatment is not significant and unstable.

3.2.2. TSS removal

The TSS removal after the treatment with HRTs is shown in Fig. 3. TSS removal continually increases from day 1 to day 9 treatment. On the first day of the treatment, only 4% of the TSS removal percentage was recorded with the highest reading of TSS in the sample which is 2.5 mg/L. However, on day 9 of the treatment which is the last day the reading of the TSS keeps decreasing until 1.8 mg with 28% of the percentage removal. The activated carbon, zeolites, and additional sand can remove the suspended solids up to 80% in the wastewater effectively as reported by Maharani et al. [40].

3.2.3. NH3–N removal

The NH_3–N removal after the treatment with different HRTs is shown in Fig. 4. It shows the removal continually to increase from day 1 till day 9 of treatment. The removal increases drastically at day 1 of the treatment which is at 95%. At the end of the treatment, zero NH_3–N reading in the sample as it achieves 100% of the percentage removal. This condition occurs because the macro-composites consist of the natural zeolite and activated carbon which have a better reduction of the NH_3–N. The combination of the hydrophobic surface of activated carbon and the hydrophilic surface of zeolites naturally acts as an ion exchanger adsorption [41,42]. Various studies have been done using the activated carbon and zeolites to treat the NH_3–N. As an example, a study had successfully removed 37% of the ammonia concentration of the leachate sample from Pulau Burung Landfill site using the activated carbon and zeolites [43]. Therefore, that is the reason why the macro-composites effectively treating the NH_3–N in the wastewater.

3.2.4. TP removal

The TP removal after the treatment with different hydraulic retention times is shown in Fig. 5. The results are fluctuant start from day 1 until day 9 of treatment. The highest removal of total phosphate is 89% on day 3 of treatment. However, on day 5 of the treatment, the percentage removal shows an irrelevant result which drops drastically and needs to be deleted. This condition happens might be due to the improper method and technique used while conduct the experiment. Besides, as the time to treat the wastewater increases the removal of the total phosphate decreases. This is due to the initial phosphate concentration was increased. Similar result was found that the phosphate

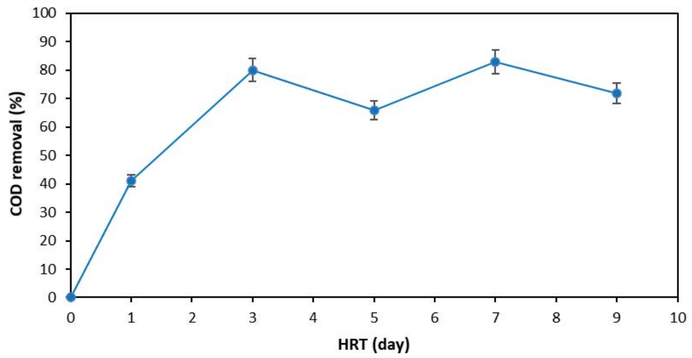

Fig. 2. COD removal by using macro-composites at different HRTs.

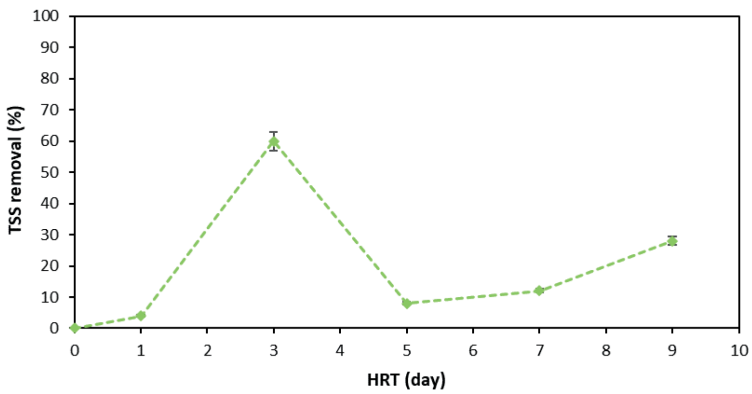

Fig. 3. TSS removal by using macro-composites at different HRTs.

removal efficiency over the activated carbon and zeolite has been decreased from day 2 to day 6 with removal percentage from 77% to 70% [44]. The optimal adsorption sites are occupied first at low concentrations. Furthermore, on day 9 of the treatment, the reading of the total phosphate in the sample is 0.14 mg/L with 74% of the removal.

3.2.5. Turbidity removal

The turbidity removal after the treatment with different hydraulic retention times is shown in Fig. 6. Overall, the graph pattern shows the turbidity removal is constantly increasing from the beginning of the treatment. The highest reading of the turbidity value is at day 1 of treatment with the lowest percentage of removal which is 17%. At the end of the treatment, the reading of the turbidity values was recorded at the highest removal which is at 75% with a 9.35 NTU reading. This is shown that the macro-composites have a high tendency to remove the turbidity value of the wastewater from Flat Taman Jaya.

3.2.6. pH changes

The pH changes after the treatment with different HRTs is shown in Fig. 7. The pH values are fluctuant starting from day 1 to day 9 of the treatment. Before the treatment, the pH value of this sample is 7.01 which is near to the neutral range. However, most of the samples still become more alkaline after the treatment. Previous study showed that the increases of the pH after experience the treatment were affected by the hydration reactions where the minerals formed a new hydration product with the water, releasing alkali metal ions to the sample [45]. On the first day of the treatment, the sample pH change becomes acidic compared to before treatment with a value of 6.57. The highest pH value after the treatment is at day 5 of treatment which is 8.55 with 18% increment. Nevertheless, the overall pH values demonstrated only little changes as they maintained between 7–8 and median pH value at 7.38.

3.2.7. Overall effects at different HRTs

From the analysis of the result at every period, it shows that the most efficient treatment using the macro-composites was achieved at 3 d HRT with COD, NH_3–N, TSS, turbidity, and TP removal of 80%, 97%, 60%, 49% and 89%, respectively, with pH at 7.33. Many parameters show maximum percentage removal after the third treatment day; however, some have dropped drastically after the third treatment day. The percentage removal of the parameters

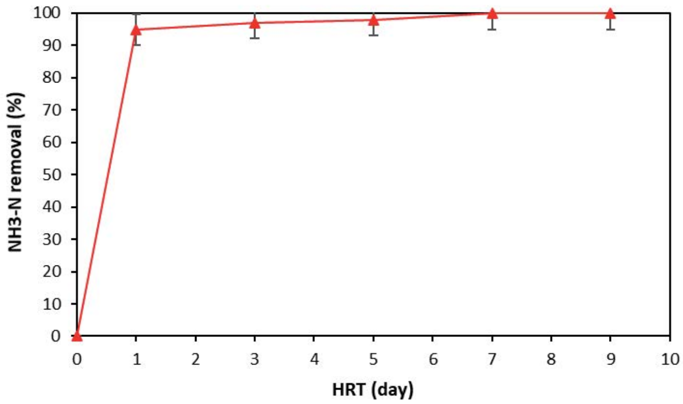

Fig. 4. NH_3–N removal by using macro-composites at different HRTs.

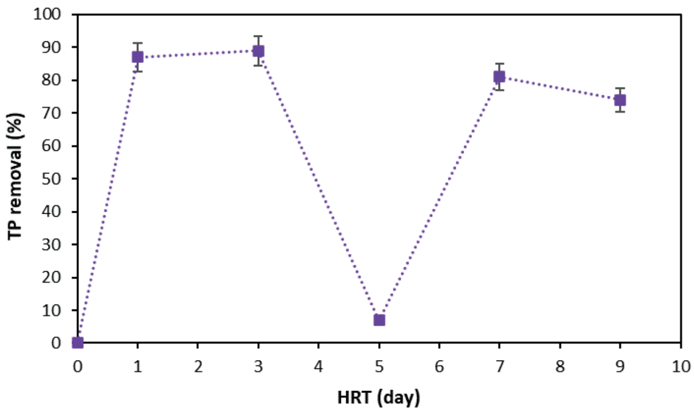

Fig. 5. TP removal by using macro-composites at different HRTs.

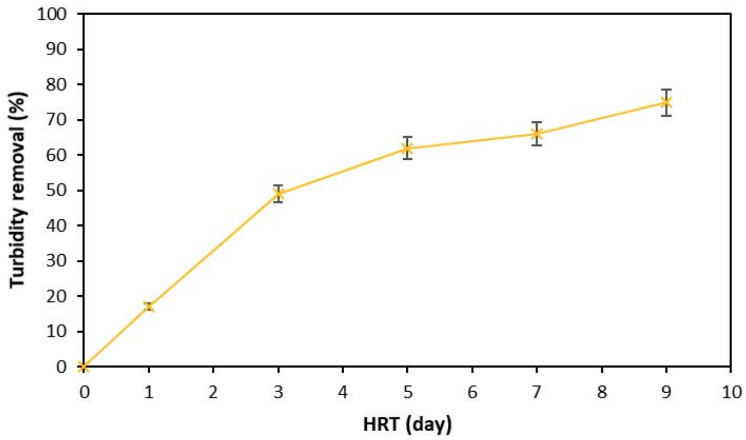

Fig. 6. Turbidity removal by using macro-composites.

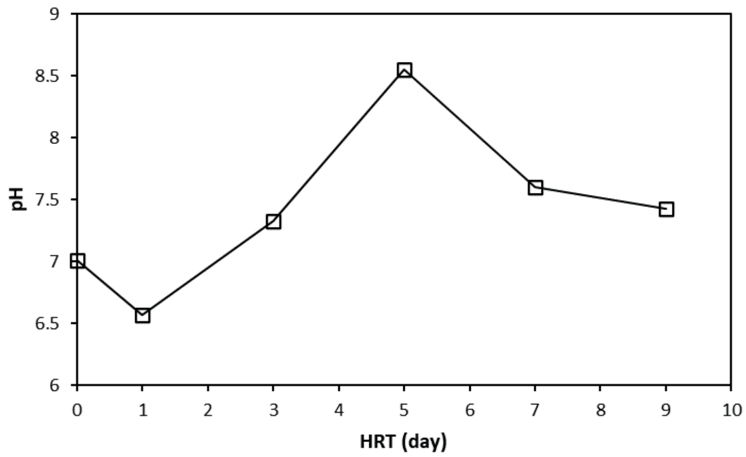

Fig. 7. pH changes by using macro-composites.

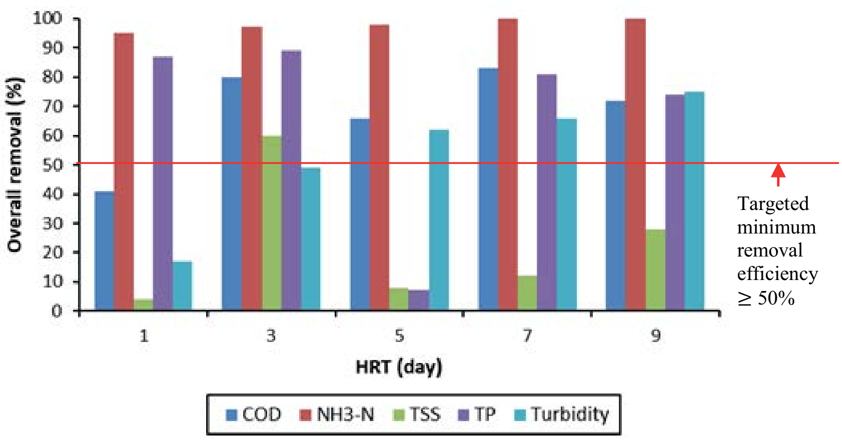

Fig. 8. Overall removal performance at different HRTs.

also increased a little. Previous study confirmed that HRT related to the percentage removal with COD, NH_3–N, and total phosphorus removal percentages of 54%, 48%, and 12% [46]. Thus, overall removal percentage of each parameter at 3 d HRTs have passed more than 50% compared to other HRTs as shown in Fig. 8.

4. Conclusions

The aim of this study was to characterize the water quality of the effluent and to investigate the treatment efficiency of different HRTs using macro-composite technology in treating the wastewater. This study confirmed that the untreated wastewater contained high levels of pollutants which are harmful if the wastewater is discharged directly to the environment without a proper treatment. In addition, it was observed that the most efficient treatment occurred at 3 d HRT with the removal of COD, NH_3–N, TSS, turbidity, and TP of 80%, 97%, 60%, 49%, and 89%, respectively, with pH at 7.33. Future study should focus on more comprehensive assessment and monitoring to ensure that the proposed macro-composite technology can be widely used for wastewater treatment.

Acknowledgments

We wish to express our deep gratitude to many people, researchers, academicians, local authorities, and practitioners. They have contributed to our understanding and knowledge. Also, our thanks extended to our fellow collaborators from Think City for encouragement, guidance, and friendship. Without their continued support and interest, this paper would not have been the same as presented here. The authors also acknowledge the Researchers Supporting Project Number (RSP2022R455), King Saud University, Riyadh, Saudi Arabia for the support.

Conflicts of interest

The authors proclaim that there is no known competing financial interests or personal associations that could have seemed to influence the work stated in this paper.

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