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Removal of Total Coliform and TSS for Hospital Wastewater by Optimizing the Role of Typha Angustifolia and Fine Sand-Gravel Media in Horizontal Sub Surface Flow Constructed Wetland

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ABSTRACT

This study aims to evaluate the performance of a pilot-scale Horizontal Subsurface Flow Constructed Wetland (HSSF-CW) utilizing Typha angustifolia and fine sand-gravel media in removing total coliform and TSS from hospital wastewater. Three pilot-scale HSSF-CW cells measuring 1.00 x 0.45 x 0.35 m^3 were filled with gravel sand media with a diameter of 5 - 8 mm as high as 35 cm with a submerged media depth of 0.30 m. There were three treatments, namely the first cell (CW1) without plants, the second cell (CW2) was planted with a density of 12 Typha angustifolia plants, and the third cell (CW3) was planted with a density of 24 Typha angustifolia plants. The three HSSF-CW cells received the same wastewater load with total coliform and TSS contents of 91000 MPN/100 mg and 53 mg/L, respectively, with Hydraulic Loading Rates 3.375 m^3 per day. Wastewater was recirculated continuously to achieve the equivalent HSSF-CW area requirement. The experimental results show that the performance of CW3 is more efficient than CW1 and CW2 in total coliform and TSS removal for hospital wastewater. The pollutant removal efficiency at CW3 reached 97.69% for total coliform with two days hydraulic retention time and 43.00% for TSS with one day of hydraulic retention time. This study concludes that the HSSF-CW system using sand-gravel media with a diameter of 5 - 8 mm with a submerged media depth of 0.30 m and planted with Typha angustifolia with a tighter spacing proved to be more efficient in removing total coliform and TSS from hospital wastewater.

1. INTRODUCTION

It was hoped that a hospital's presence with the complexity of its activities would not increase environmental pollution. In the Regulation of the Minister of Health of the Republic of Indonesia Number 7 of 2019, it was stipulated that the hospital must have a Wastewater Treatment Plant (WWTP) with wastewater treatment results that meet quality standards as required in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number: P.68/Menlhk/General Secretariat/Kum.1/8/2016. Maximum levels of Biological Oxygen Demand (BOD) 30 mg/L, Chemical Oxygen Demand (COD) 100 mg/L, Total Suspended Solids (TSS) 30 mg/L, oil and fat 5 mg/L, ammonia 10 mg/L, and total coliform 3000 MPN/100 ml.

Some research results show the low performance of WWTP in several hospitals. B. & Mallongi (2018) examined the characteristics and quality of BOD and COD of wastewater in general hospitals in the Jeneponto Regency.

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The results showed that BOD levels at WWTP outlets, on average 58 mg/L, did not meet quality standards, and COD levels at WWTP outlets were on average 92,3 mg/L does not meet quality standards. Harlisty, Akili, & Kandou (2016) analyzed the ammonia and coliform total content of public hospital wastewater in Bitung City. The results showed that the total coliform content at WWTP outlets averaged 160,000 MPN/100 ml did not meet quality standards. Prayitno, Kusuma, Yanuwiadi, & Laksmono (2013) examined the characteristics and efficiency of WWTP hospitals in Malang City. The results showed that the characteristics of wastewater in three hospitals in Malang City contained contaminants that exceeded quality standards, such as BOD 31%, orthophosphate 24%, phenol 50%, 42% free chlorine, and 17% lead higher than the quality standard with an average efficiency of WWTP of 58%. Rahmawati & Azizah (2005) examined the content of BOD, COD, TSS, and total coliform in hospital wastewater in Nganjuk. The results showed that the average BOD level after treatment was 30.57 mg/L, and the total coliform level after treatment was 9,943 MPN/100 ml, which did not meet the quality standard. The performance of hospital WWTP in Palu was also reported to below, where the average total coliform range of 45,000 - 676,000 MPN/100 ml and TSS 59 - 147 mg/L at the hospital WWTP outlets still exceeded the quality standard (Akhmad, Darman, Aiyen, & Hamsens, 2020).

Research, development, and implementation of wetland construction (CW) are currently receiving attention in both developed and developing countries. According to Puspita, L., Ratnawati, E., Suryadiputra, I.N.N. dan Meutia (2005), CW is an artificial ecosystem designed by utilizing complex interactions between media/substrate, water plants, and microorganisms to treat almost all types of wastewater. The media/substrate acts as a place where microorganisms attach, thereby expanding the constructed wetland system's surface. The substrate also plays a role in supporting aquatic plants, assisting the filtration process (especially in subsurface flow constructed wetland), and collecting sediment. Water plants act as providers of oxygen for decomposing pollutants, media for the growth and development of microorganisms, restrain the flow rate from facilitating the solids sedimentation process, and assist in the filtration process (especially the root parts of plants). Moreover, prevent erosion, absorb nutrients and other pollutants, and prevent the growth of pathogenic viruses and bacteria by releasing certain substances such as antibiotics. Microorganisms act as decomposers of pollutants. Microorganism life grows well because of the transfer of oxygen from plant roots. CW is considered a green and sustainable technique that requires lower energy input, less operational and maintenance costs, and adds aesthetic value (Kumar & Dutta, 2019).

In general, there are two types of CW systems, namely surface flow systems, and subsurface flow systems (Leady, 1997). There are two types of subsurface flow systems: Vertical Subsurface Flow Constructed Wetland (VSSF-CW) and Horizontal Subsurface Flow Constructed Wetland (HSSF-CW). In the VSSF-CW, water is flowed on the system's surface and then seeps through the substrate and plant roots until it reaches the bottom of the wetland to get out of the system. Meanwhile, in the HSSF-CW, wastewater flows below the media's surface horizontally through the water plants' root zone between gravel/sand. Wastewater treatment with subsurface flow systems is recommended for the following reasons: It can treat domestic, agricultural, and some industrial wastes including heavy metals; High processing efficiency (80%); and, The planning, operation, and maintenance costs are cheap and do not require high skills (Tangahu & Warmadewanthi, 2001). Also, according to Kadlec & Knight (1996), the subsurface flow CW system has advantages, such as simple construction, making it easy to manufacture; flexible in choosing placement locations; flexibility in operating systems; low cost, because if we use a gravitational system, the only energy from the outside is sunlight; since the waste does not come into contact with the outside air, it will not smell; performance is reliable; not being a place for mosquitoes to grow; and can be presented as a garden that has aesthetic value.

The research results by Akhmad et al. (2020) stated that HSSF-CW has the opportunity to be adopted as an alternative to hospital wastewater treatment systems in Indonesia, especially in Palu. Several factors support such as the tropical climate and various water plants that thrive throughout the year. Khiatuddin (2003) mentions that the types of plants often used for subsurface constructed wetland are submerged plants or amphibious plants. In Palu, water plants are abundant, namely Typha Angustifolia. This plant is a sizeable grass-like plant that inhabits wetland, especially near the coast and in the mountains. However, until now, this plant has not been utilized properly. Recently, Typha Anguistofolia has begun to be used as a filter plant to increase constructed wetland effectiveness as part of industrial wastewater treatment plants (Abdulgani, H., M. Izzati, 2013). Because studies on the use of HSSF-CW, especially for hospital wastewater treatment, are still minimal, it is essential to research the performance of HSSF-CW in total coliform and TSS removal for hospital wastewater in Palu using the Typha Angustifolia.

Horizontal Sub Surface Flow Constructed Wetland (HSSF-CW) typically produces low effluent of organic matter and suspended solids. However, for E. coli removal, this system was suitable in combination with other technologies, such as chlorine or ultra-violet disinfection (Headley et al., 2013). However, the practice of disinfection with chemicals such as chlorine can create other health and ecological problems due to trihalomethane formation (Toscano et al., 2013). Also, UV disinfection was not always suitable for disinfection of waste from HSSF-CW because the development of a biofilm-like coating on light bulbs can block UV rays (Richter & Weaver, 2003). A modified HSSF-CW developed by Headley *et al.* (2013) using 8-16 mm gravel media with a depth of 1.00 m added with artificial aeration was proven to reduce the E. coli concentration deficient levels consistently. It was just that at a relatively high loading level, an extensive electrical input was required to drive the air pump. The increased removal of Fecal Coliform in aeration filters may be due to aerobic conditions that allow free-living protozoa and other predators to become active even in winter. However, other removal mechanisms, such as competition, sedimentation, filtration, and proteolysis, may also occur (Mara & Johnson, 2006). The strategy carried out in this study to optimize aerobic conditions in HSSF-CW was to maximize the role of Typha angustifolia roots, using river gravel sand media that is finer with a diameter of 5 - 8 mm, and the depth of the submerged media was limited to 0.30 m.

Typha angustifolia can develop aerenchyma in its root cortex and release oxygen so that dissolved oxygen concentrations increase in the rhizosphere, facilitating the aerobic degradation of pollutants (Pincam & Jampeetong, 2020). The roots of water plants emit exudate to create an environment unsuitable for the survival of the pathogen (Avelar, de Matos, de Matos, & Borges, 2014a). Also, act as filter media and reduce water velocity, thereby increasing sedimentation (Saeed & Sun, 2012). The effect of more acceptable media is very significant on Total Coliform, Escherichia coli, and Escherichia Fecal removal (Morató et al., 2014), also providing conducive conditions for root growth. The depth of submerged media is limited to 0.30 m, considering adjusting the depth that can generally penetrate the roots of Typha angustifolia. Thus, the anaerobic zone can be minimized when the aerobic zone becomes optimal in the HSSF-CW cell without using an air pump.

This study aims to evaluate the performance of a pilot-scale HSSF-CW in removing total coliform and TSS from hospital wastewater, with the target of processing results meeting the standards of the Minister of Environment and Forestry Regulation No. P.68/MENLKH-SETJEN/2016 with shorter hydraulic retention times.

2. METHOD

2.1. Location of Wastewater Sources Used in Experiments

The wastewater used in this experiment comes from the inlet of the WWTP in a public hospital in Palu; located at 0 ° 53'57.38 ″ S, 119 ° 50'52.63 ″ E at an altitude of approximately 100 m asl; areas with an annual rainfall of less than 1000 mm and an average annual temperature of 27 ° C ("Palu, Indonesia Travel Weather Averages." Weatherbase. Retrieved 4 August 2020). The wastewater used is mixed wastewater from household activities in hospitals, hospital clinical activities, and laboratory activities.

2.2. Experimental Design and Setup

There were three HSSF-CW cells made of glass fiber with dimension of length (L) 1.00 m, width (W) 0.45 m, and height (h) 0.35 m. The slope of the base cell (S) was set to 0.005. Submerged media depth (d) 0.30 m. According to USEPA (1993), gravel sand media with a diameter of 5 - 8 mm have porosity (n) and hydraulic conductivity (K_s) values of 0.35 and 5000 m^3/ m^2/h, respectively. Using (Equation 1), the maximum hydraulic loading rate (Q) that can be charged to the HSSF-CW is 3.375 m^3/day.

The surface area of the HSSF-CW system (A_s) was set based on the hydraulic retention time (t) equal to 1 for easy calculation. By using (Equation 2), the A_s value is equal to 32 m^2. The surface area of the existing pilot CW cell was only 0.45 m^2. Therefore, to achieve an equivalent area of 32 m^2, the effluent must continuously recirculate back to the influent tank.

$$Q = A_C . K_{S.} . S \quad (1)$$

$$A_S = \frac{Q\ .\ t}{d\ .\ n} \quad (2)$$

Where, Q: Hydraulic Loading Rate (m^3/d); A_c: Cross-sectional Area CW (m^2); K_s: Hydraulic Conductivity (m^3/m^2/day), and; S: Cell Base slope; A_s: Surface Area CW (m^2); t: Hydraulic Retention Time (days); d: Submerged Media Depth (m), and; n: Media Porosity.

The surface area of the existing CW reactor is only 0.45 m^2 As = reactor length x reactor width = 1.00 x 0.45 = 0.45 m^2 Since the available reactor surface area is only 0.45 m^2 while the ideal reactor surface area is 32 m^2, we continuously circulate the influent (Figure 1). We assume that the influent circulates continuously for 24 hours in a reactor with a surface area of 0.45 m^2 equivalent to a 32 m^2 reactor.

2.3. Description of Experimental and Construction Arrangements

The experimental arrangement is as shown in Figure 1. There were three pilot-scale CW cells with different treatments, all filled with sand gravel media 5 -8 mm as high as 0.35 m with a submerged media depth of 0.30 m. The first cell (CW1) without planting, the second cell (CW2) was planted with a density of 12 Typha angustifolia plants, and the third cell (CW3) was planted with a density of 24 Typha angustifolia plants. Each HSSF-CW unit consists of three components: the first component is an influent storage tank equipped with a distribution pipe, a water level sensor, a flow meter, and a discharge control valve. Influent was flowed by gravity through the distribution pipe to the inlet cell CW with a maximum controlled flow rate of 3.375 m^3/day; The second component was a CW cell as a place for the processing equipped with a water temperature gauge. The CW cell inlet pipe was placed at the height of 0.30 m from the bottom of the cell, while the outlet pipe was placed at the base of the CW cell with the top elevated 0.30 m to maintain consistency of the water level in the CW cell. In the CW cell, the influent flows slowly through the sand-gravel medium in a horizontal path until it reaches the outlet zone; The third component was the effluent storage tank. The effluent storage tank was equipped with a water pump to circulate the effluent back to the influent tank continuously. The water pump was equipped with an on-off switch connected to the water level sensor in the influent tank.

2.4. Operation of HSSF-CW

The HSSF-CW operation was carried out with the following procedures. 1) Filtering the sand-gravel material to obtain sand-gravel media with 5 - 8 mm granules. It washed clean, then filled in CW cells as high as 0.35 m. 2) Installing and setting the HSSF-CW unit components, regulating the control valve with a maximum outflow of 3.375 m^3/day. 3) Testing the HSSF-CW unit to ensure that all system components were functioning correctly. This test uses tap water. 4) Collecting the Typha angustifolia from natural populations that grow locally and then planted in CW cells 5) Acclimatization process for two weeks. 6) The main experiment, draining the tap water and then filling the hospital wastewater until the influent tank and CW cells were full. The HSSF-CW system was operated by opening the valve on the influent tank.

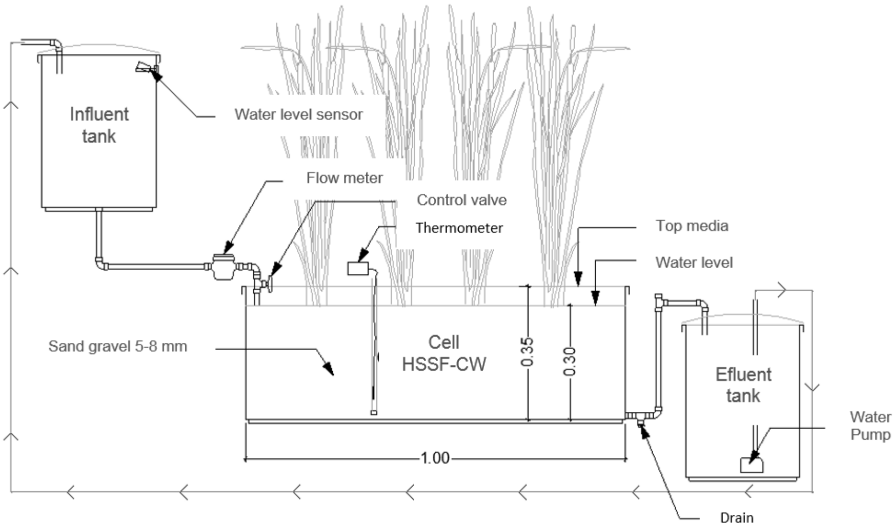

Figure 1. Schematic of pilot-scale HSSF-CW Unit Arrangement

2.5. Sampling and Sample Analysis

Effluent samples were taken from each HSSF-CW unit every day at 09.00 am for one week. Samples were taken and stored in 1000 ml plastic bottles for laboratory analysis of TSS and sterile 500 ml glass bottles for total coliform lab analysis. The TSS laboratory tests were carried out at the Laboratory of Analytical and Environmental Chemistry, Tadulako University, Palu. The total coliform laboratory test was carried out at the Biology Education Laboratory of PMIPA, Tadulako University, Palu.

The method for the Total Suspended Solid (TSS) test is gravimetrical. The homogeneous sample is filtered with weighed filter paper. The residue retained in the filter is dried to a constant weight at a temperature of 103°C to 105°C. The increase in filter weight represents total suspended solids (TSS). The method for the Total Coliform test uses the MPN (Most Probable Number) method. The Coliforms group used the microbiological quality test of water as an indicator. This group of bacteria has the characteristics: aerobic, facultatively anaerobic, gram-negative rods, and does not form spores-lactose ferments to form acids and gases within 48 hours at 35°C.

2.6. Performance Evaluation of HSSF-CW

The pollutant removal performance from HSSF-CW was calculated from Equation (3).

$$E = \frac{(C_{in} - C_{out})}{C_{in}} x\ 100\% \quad (3)$$

E: Efficiency of the HSSF-CW system; C_{in}: Parameters of wastewater before treatment, and; C_{out}: Parameters of wastewater after treatment.

3. RESULT AND DISCUSSION

3.1. Characteristics of Wastewater Used in Experiments

a. Total Suspended Solids

Laboratory test results showed that the TSS concentrations of wastewater used in this experiment were high, with 53 mg/L (Table 1). However, it was still lower than the average concentrations mean TSS in the previous period (Table 2). The current decrease in TSS concentrations was likely due to reduced hospital activities or patient visits due to the Covid-19 pandemic.

b. Total Coliform

Laboratory test results showed that the total coliform concentrations of wastewater used in this experiment were high, with 91000 MPN/100 ml (Table 1). However, it was still lower than the average concentrations mean total coliform in the previous period (Table 2). The current decrease in total coliform concentrations was likely due to reduced hospital activities or patient visits due to the Covid-19 pandemic.

Table 1. Concentration of TSS and Total Coliform of Wastewater Used in Experiments

Parameters	Concentration	Standard
Total Coliform (MPN/100ml)	91000	3000
TSS (mg/L)	53	30

Source: Laboratory Test Results September 2020

Table 2. Concentration of TSS and Total Coliform of Hospital Inlet Wastewater for the Period 2015-2019

Parameters	Average Concentration					Standard
	2015	2016	2017	2018	2019	
Total Coliform (MPN/100ml)	130808	140183	213333	45000	216375	3000
TSS (mg/L)	126	59	85	145	147	30

Sumber: Akhmad et al. (2020)

Table 3. Concentrations of BOD, COD, DO, and Ammonia in Hospital Wastewater Used in Experiments

Parameters	Concentration	Standard
BOD (mg/L)	22.70	30
COD (mg/L)	65.25	100
DO (mg/L)	3.77	
Ammonia (mg/L)	1.00	10

Source: Laboratory Analysis Results, September 2020

3.2. Another parameters.

- Temperature and pH

According to the standard, the required temperature is 38ºC, and the pH ranges from 6 - 9. Wastewater used in this experiment has a temperature of 30.8ºC and a pH of 7.7, still by the standard.

- BOD, COD, DO, and Ammonia

The concentrations of BOD, COD, ammonia, and DO from the hospital wastewater samples used in this experiment were 22.70 mg/L, 65.25 mg/L, 3.77 mg/L, and 1.00 mg/L, respectively (Table 3). The presence of organic components, nutrients, and dissolved oxygen is essential in the HSSF-CW system because plants and microorganisms need them.

The BOD/COD ratio of hospital wastewater used in this experiment was 0.35. According to Metcalf, Eddy and Tchobanoglous (2004), a BOD/COD ratio of 0.5 or greater indicates that organic is quickly degraded. A ratio below 0.3 indicates that available organic matter is difficult to degrade by microorganisms. Thus, the organic material from hospital wastewater used in this experiment tends to be difficult to degrade by microorganisms.

3.3. Performance of HSSF-CW on TSS and Total Coliform Removal

a. TSS Removal Efficiency

TSS removal for the three treatments generally showed a downward trend (Figure 2); this shows that fine sand-gravel with or without water plants in the HSSF-CW system is proven to remove TSS parameters. Reducing the TSS concentration to a standard 30 mg/L at CW1, CW2, and CW3 required hydraulic retention times of 2, 2, and 1 days, respectively (Figure 2). The performance of CW3 is still more efficient than CW1 and CW2.

According to Redder et al. (2010), the filtering process's effectiveness does not seem to depend on the type of media used. However, at small particle sizes. Tanner, Sukias, Headley, Yates, & Stott (2012) suggest that the filtration process is better with fine sand than coarser gravel. Watson, Reed, Kadlec, Knight, & Whitehouse (1989) suggested CW Subsurface Flow's performance on TSS removal, the percentage of TSS removal was 51% on gravel use and 94% on using sand media. However, media use with smaller particle sizes still needs to be studied about its susceptibility to clogging in the HSSF-CW system. Also, media with a smaller particle size has a small porosity value that affects the HSSF-CW system's capacity.

Karathanasis, Potter, and Coyne (2003) reported that plant roots provide a more effective filtration medium than gravel alone while increasing the attachment surface area and a food source for microorganism populations. Saeed and Sun (2011) also reported that plant tissue in water also acts as a filter media, releases oxygen, and reduces water velocity, thereby increasing sedimentation.

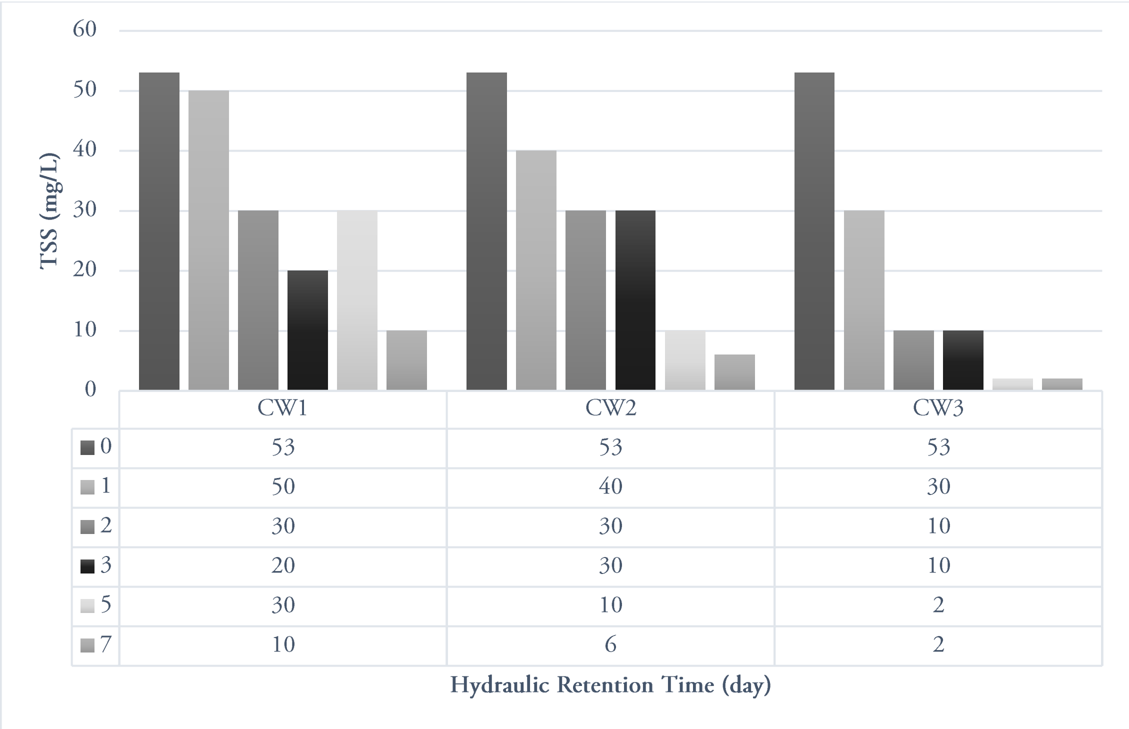

Figure 2. Value of TSS Removal on HSSF-CW According to Treatment and Hydraulic Retention Time

Table 4. Efficiency of TSS Removal on HSSF-CW According to Treatment and Hydraulic Retention Time

Treatment	Efficiency (%)				
	1 day	2 days	3 days	5 days	7 days
CW1	6	43	62	43	81
CW2	25	43	43	81	89
CW3	43	81	81	96	96

Source: TSS Removal Efficiency Analysis Results

Table 6. Temperature and pH of HSSF-CW Treated Water according to Treatment and Hydraulic Retention Time

Retention Time	Temperature (°C)			pH		
(day)	CW1	CW2	CW3	CW1	CW2	CW3
Initial	30.8	30.8	30.8	7.7	7.7	7.7
1	29.5	28.7	29.2	8.0	7.5	7.6
2	30.2	29.5	30.0	8.0	7.8	7.7
3	30.7	30.3	30.8	8.2	7.8	7.6
4	30.6	30.3	31.1	8.3	7.9	7.7
5	30.2	29.9	30.3	8.2	7.7	7.5
6	29,1	28.7	29.1	8.1	7.9	7.7
7	30.2	30.0	30.3	8.3	7.9	7.8
average	30.1	29.6	30.1	8.2	7.8	7.7

Source: On-site Measurement Results, September 2020

Table 7. DO and Ammonia Concentrations of HSSF-CW Treated Water According to Treatment and Hydraulic Retention Time

Retention Time	DO (mg/L)			Amonia (mg/L)		
(day)	CW1	CW2	CW3	CW1	CW2	CW3
Initial	3.77	3.77	3.77	1.00	1.00	1.00
1	5.15	5.39	5.09	1.10	1.10	1.20
2	4.93	5.04	5.00	1.20	1.20	1.20
3	4.91	5.00	4.81	1.30	1.20	1.20
5	5.21	5.22	5.24	1.30	1.30	1.20
7	4.45	4.87	5.00	1.20	1.20	1.20
Average	4.93	5.10	5.03	1.22	1.20	1.20

Source: Laboratory Analysis Results, September 2020

b. Total Coliform Removal Efficiency

Total coliform removal in the three treatments showed a downward trend (Figure 3). Either CW1, CW2, or CW3 required two days of hydraulic retention time to achieve a total coliform concentration less than the standard 3000 MPN/100 mg. However, the performance of CW3 is still more efficient than CW1 and CW2 because CW3 has a sharper downward trend (Figure 3).

The efficiency of total coliform removal at CW1 using fine sand-gravel media without plants, the percentage of total coliform removal on the first day was 53.85%. CW2 and CW3 with the treatment of using fine sand-gravel media with plants obtained the percentage of total coliform removal of 83.52% and 91.76%, respectively (Table 5), shows that using fine sand-gravel media with plants provides a more effective filtration medium than using sand-gravel alone. Karathanasis, Potter, and Coyne (2003) reported that plant roots provide a more effective filtration medium than gravel alone.

Several investigations have been carried out to evaluate the effect of plants on indicator bacteria removal in CW. In most of the investigations on HSSF-CW, water plants were shown to promote the removal performance of indicator bacteria positively. However, it was unclear whether this is due to the influence of the plant on the hydraulic system or other causes, such as increased surface area availability in plant roots (Kansiime & van Bruggen, 2001); or root exudates released by plant species that contain bactericidal activity (Tunçsiper, Ayaz, & Akça, 2012). The release of antimicrobial exudates may be toxic to pathogenic microorganisms and change the rhizosphere's physical and chemical environment and render it unsuitable for pathogen survival (Avelar, de Matos, de Matos, & Borges, 2014b).

c. Another parameters.

- Temperature and pH

In the wastewater treatment process, temperature and pH factors affect the performance of the HSSF-CW system. The temperature of the wastewater will affect the activity of microorganisms and plants. According to Suriawiria (1993), the temperature will influence the reaction, where every 10°C temperature increase will increase the reaction 2 - 3 times faster. Besides that, the temperature is also a limiting factor for the life of microorganisms. Considering that Indonesia's climate conditions generally have a tropical climate with a relatively small range of daily temperature differences (amplitudes), the temperature is not a limiting factor. During the experimental process, the water temperature conditions in the CW 1, CW2, and CW3 treatments tended to be stable in the average range of 29.6 - 30.1°C (Table 6).

Generally, nutrients are easily absorbed by plant roots at a neutral pH of 6-7 because at that pH, some nutrients, especially macronutrients, are readily soluble in water. At low pH (acid), many elements of aluminum (Al) are found, which are not only toxic but also bind to phosphorus (P) so that plants cannot absorb the phosphorus. Also, microelements such as Fe, Zn, Mn, Cu become easily dissolved, resulting in too large a quantity and are toxic to plants. In contrast, at high pH (alkaline), microelements Sodium (Na) and Molybdenum (Mo) are found, which are large and poisonous to plants. At a pH of 5.5 - 7, bacteria and fungi that decompose organic matter can thrive (Novizan, 2007).

During the experimental process, the water pH conditions differed between treatments CW1, CW2, and CW3. At CW1, there was an increase in the water's pH, an average of 8.2, CW2 an average of 7.8, and CW3 tended to be stable at pH 7.7 from the initial pH condition 7.7 (Table 6). The increase in the water's pH in the CW1 treatment was probably due to using sand-gravel media made of alkaline limestone. The pH values at CW2 and CW3, which tend to be stable at an initial pH of 7.7, maybe neutralized by plant roots because the partial test was carried out by submerging the roots of Typha angustifolia with the same water sample without sand-gravel media obtained a water pH of 7.4.

- DO and Ammonia

The results of laboratory analysis showed an increase in dissolved oxygen (DO) that was relatively the same at CW1, CW2, and CW3 with an average range of 4.93 - 5.03 mg/L (Table 7); this indicates that the increasing DO not only due to the influence of oxygen released by plant roots. However, it was likely caused more by the diffusion of atmospheric oxygen (Cooper, Job, & Green, 1996) due to wastewater recirculation factor in HSSF-CW.

The laboratory analysis results also showed an increase in ammonia concentrations relatively the same in the CW1, CW2, and CW3 treatments with an average range of 1.20 - 1.22 mg/L from the initial ammonia condition of 1.00 mg/L (Table 7). The increase in ammonia concentration indicates that CW1, CW2, and CW3 was low in ammonia removal. However, it was not an obstacle because the concentration is relatively low. The current literature shows that the performance of the HSSF-CW system often shows low nitrogen removal rates (Vymazal, Greenway, Tonderski, Brix, & Mander, 2005). Lack of biodegradable organics often hinders classical denitrification metabolism (due to dependence on organic carbon) in the CW system (Lavrova & Koumanova, 2010). Also, the sand-gravel media commonly applied at CW does not generate carbon, thus often limiting denitrification (Saeed & Sun, 2012).

4. CONCLUSION

The experimental results show that the performance of CW3 is more efficient than CW1 and CW2 in total coliform and TSS removal for hospital wastewater. The efficiency of pollutant removal at CW3 reached 97.69% for total coliform with two days hydraulic retention time and

43.00% for TSS with one day of hydraulic retention time. HSSF-CW planted with Typha angustifolia with a denser spacing (24 plants per 0.45 m2) using sand-gravel media with a 5 - 8 mm diameter with a submerged media depth of 0.30 m proved to be more efficient in removing total coliform and TSS from hospital wastewater. Apart from the influence of plant roots, there was an increasing DO due to atmospheric oxygen diffusion factors.

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