An opportunity for using constructed wetland technology in hospital wastewater treatment: a preliminary study

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Abstract. The problem faced by many hospitals in Indonesia is the low efficiency of Waste Water Treatment Plant (WWTP) hospitals. If it does not get the attention, it will have an impact on health and environmental pollution. Various technologies have been used but experienced many obstacles. Constructed wetlands based on aquatic plants that have been used in developed countries are very prospects of being developed in regions such as Indonesia with a tropical climate. A preliminary study is needed with the first step to investigate the quality of hospital wastewater in Palu City, Indonesia, as a sample. This study aims to obtain a description of hospital wastewater characteristics and to evaluate the performance of the hospital WWTP in Palu. Data collection was done by taking data indirectly through laboratory test results during 2015-2019. Tabulating data using Excel software to illustrate statistics, then presented in the form of bar charts, interpreting according to the quality standards. Investigation results showed that the characteristics of hospital inlet wastewater in Palu are parameter values varying with four high concentration parameters: total coliform, TSS, Ammonia Nitrogen, and COD. The efficiency level of WWTP hospitals in Palu is relatively low in removing pollutants.

Key words: WWTP hospitals, wastewater treatment, constructed wetlands,

1. Introduction

Hospitals' presence with the complexity of their activities is expected not to add to the negative burden of environmental pollution. Infrastructure requirements such as hospital waste management were regulated in Act Number 44 of 2009. However, at this time, the number of hospitals that conduct medical waste management according to standards has only reached 33.63% (“Data Dan Informasi Profil Kesehatan Indonesia 2018,” 2019).

Regarding hospital wastewater management, Regulation of the Minister of Health of the Republic of Indonesia Number 7 of 2019 requires hospitals to have a Waste Water Treatment Plant (WWTP) with a permit, and the results of liquid waste treatment meet quality standards. Nevertheless, in reality, many large hospitals do not have wastewater treatment facilities (Santoso, 2015). Also, several studies have reported the low efficiency of WWTP hospitals, especially in Indonesia (B. and Anwar, 2018; Harlisty, Akili, and Kandou, 2016; Kusuma, Yanuwiadi, and Laksmono, 2013; Rahmawati and Azizah, 2005).

Wastewater treatment technologies that are commonly used in hospitals in Indonesia include trickling filters or biofilter, rotating biological contactor (RBC), contact aeration/oxidation, and others (Djohan & Halim, 2014), the operation of this wastewater treatment technology generally requires many artificial resources in the form of chemicals and energy sources of fuel oil through electricity or...
generators (Mangkoedihadjo and Samudro, 2010). Also, the operational costs are high, and the complexity of the treatment of wastewater treatment plants (Zulkifli, 2014).

The research, development, and application of wastewater treatment technology based on water plant species were currently receiving attention in developed and developing countries such as America, Australia, Europe, Thailand, and Malaysia. For a long time, it has been known that wetland ecosystems have the natural ability to eliminate organic and inorganic pollution. This ability is mainly due to the presence of water plant species that act as waste processors. Constructed Wetlands technology is one example of the application of wastewater treatment systems based on water plant species that are easy to operate and eco-friendly (Khiatuddin, 2003).

According to Noor (2007), Indonesia has a tropical climate, where various types of water plant species thrive throughout the year. This potential will be useful in resolving the low current efficiency of WWTP hospitals. Because the Constructed Wetlands technology has never been explicitly applied to hospitals in Indonesia, it is essential to conduct a study of hospital wastewater treatment systems in Indonesia that adopt Constructed Wetland technology.

The efforts mentioned above will provide many benefits such as: supporting government programs in realizing environmentally friendly hospitals (Green Hospital); providing an efficient, inexpensive, easy to operate and environmentally friendly WWTP hospital; and, Constructed Wetland with Horizontal Sub Surface Flow type can be used as a hospital garden that has aesthetic value.

With the issue of the development of Constructed Wetland for hospital wastewater treatment, a preliminary study has been carried out with the first step investigating the quality of hospital wastewater during 2015-2019 by selecting two hospitals in the City of Palu in Indonesia as a sample.

This preliminary study's main objective is to obtain a description of the characteristics of hospital wastewater in Palu City, Indonesia. The results of this preliminary research will be input in the design of hospital wastewater treatment systems that adopt the Horizontal Sub Surface Flow Constructed Wetland (HSSF-CW) technology.

2. Methods
This preliminary study was conducted in December 2019 by selecting two hospitals in the city of Palu in Indonesia as the research location. Data collection of hospital wastewater characteristics was done by taking data indirectly through laboratory test results during the 2015-2019 period, which are the results of the laboratory tests of the UPT Central Sulawesi Provincial Health Laboratory and the UPTB Environmental Laboratory of Donggala Regency. Tabulating data using EXCEL software to illustrate statistics (average, minimum and maximum), then presented in the form of bar charts, interpreting according to the quality standards of the Minister of Environment RI No. 5 of 2014.

3. Results and Discussion
Wastewater Treatment Plants (WWTP) of the two hospitals, where the study was conducted, used the Aerobic Anaerobic Biofilter system.

The first hospital (RS-1) is a type B education general hospital that belongs to the city government, which has a capacity of 505 beds with an average number of inpatient visits of 27,827 patients per year. The second hospital (RS-2) is a type B education general hospital that belongs to the provincial government, which has a capacity of 357 beds with an average number of inpatient visits of 15,800 patients per year.

3.1 Characteristic of hospital wastewater
Overview of RS-1 and RS-2 inlet wastewater quality is the parameter concentration value varies. However, there are four parameters of concern because the concentration is high, namely: total coliform, total suspended solids (TSS), Ammonia Nitrogen, and Chemical Oxygen Demand (COD).
### 3.1.1 Total coliform.

The average range of total coliform concentrations of RS-1 and RS-2 inlet wastewater during 2015 - 2019 were 45,000 - 213,000 and 204,000 - 676,000 MPN/100 ml (Figure 1). The total Coliform standard for hospital wastewater is 5,000 MPN/100 ml.

![Figure 1. Average Total Coliform of RS-1 and RS-2 Inlet Wastewater Period 2015 - 2019](image)

The results of the study at several hospitals also reported the condition of high total coliform parameters. The total coliform of wastewater from Nganjuk District Hospital in 2003 was reported to reach 240,000 MPN/100 ml (Rahmawati & Azizah, 2005). The study results at Tulehu District Hospital recorded an average total coliform of 4,186,028 MPN/100 ml (Kerubun, 2014). The wastewater from the Babol University Medical Sciences Hospital, Babol, Iran, understudy was recorded at $5.4 \times 10^8$ MPN/100 ml (Amouei et al., 2015). The total coliform content of inlet wastewater in Bitung City Hospital is 160,000 MPN/100 ml (Harlisty et al., 2016).

The coliform total in RS-1 and RS-2 inlet wastewater was confirmed to be sourced from Blackwater. The presence of fecal coliform bacteria in the aquatic environment indicates that water has been contaminated with human feces containing pathogenic bacteria. The increase of coliform total in RS-2 during 2015 - 2017 could be caused by WWTP's condition not functioning optimally because it was only operated in 2015.

Most of the digestive tract pathogens become the cause of various outbreaks of enteric diseases such as Salmonella typhi (typhoid fever), Shigella spp. (shigellosis), Salmonella paratyphi (salmonellosis), Vibrio cholerae (cholera), Campylobacter jejuni (dysentery), and pathogenic Escherichia coli (diarrhea).

### 3.1.2 TSS.

During 2015 - 2019, TSS of RS-1 inlet wastewater was higher than the standard with an average range of 59 - 147 mg/l as shown in Figure 2. TSS in RS-2 is not available. The TSS standard for hospitals is 30 mg/l.
TSS consists of precipitated components, suspended material, and suspended colloidal components. Suspended solids contain organic and inorganic substances. Suspended solids affect water turbidity and brightness. Moersidik (1993) examined hospital wastewater quality in Indonesia. TSS concentrations were in the range of 36-269 mg / l. Wangsaatmaja (1997) reported that the TSS concentration of hospital wastewater in Bangkok was 90 mg / l.

High TSS concentrations in RS-1 wastewater may be related to high COD (organic matter) and total coliform. According to Slamet (1996), organic matter can be a portion of food for bacteria to support their breeding. This bacterium is also a suspended organic substance so that the addition will add to the turbidity of the water. Turbid water is difficult to disinfect. Because these suspended substances protect microbes, this is undoubtedly dangerous for health, if microbes are pathogens.

### 3.1.3 Ammonia nitrogen.

Ammonia nitrogen concentrations of RS-1 inlet wastewater recorded high occurred in 2015, 2016, 2017, and 2018 with an average value of 3.93, 4.18, 15.46, and 2.68 mg / l. Whereas the RS-2 recorded high occurred in 2015, 2016, 2018, and 2019 with an average value of 2.00, 2.29, 2.02, and 1.05 mg / l, respectively (see Figure 3). The standard ammonia nitrogen concentration for hospital wastewater is 1 mg / l.
In another study, Djaja and Maniksulistya (2006) reported high ammonia content in the inlet wastewater in Hospital X Jakarta, 35.5 mg / l. Kolibu and Tewal (2011) also reported high ammonia levels in the inlet wastewater of the GMIM Hospital Bethesda Tomohon, 28.25 mg / l.

Aquatic organisms are susceptible to ammonia-nitrogen, and also eutrophication occurs because of the high load of nitrogen in wastewater. The lethal concentration of ammonia-N for fish is 0.44 mg / l (Yadu et al., 2018).

High concentrations of NH$_4^+$-N in RS-1 and RS-2 wastewater may be caused by detergents, drugs, and urine, as reported from several previous studies. Seiler et al., (1999) reported that the use of detergents in laundry services and drugs contributed significantly to nitrate waste. For example, these drugs (such as chlorpropamide, phensuximide dan carbamazepine) are known to be excreted in the urine in an unmetabolized form. They, therefore, survive in the environment after channeling it into any body of water. Amanfo, Nyarko and Jaime (2014) report that nitrate content in hospital waste is sourced from detergents used in cleaning floors. Liquid floor cleaners generally use the necessary ingredients of a detergent type that contains SLES (sodium lauryl ether sulfate) or better known by the trade names texapone and NI (Nitrate). Beler-Baykal et al. (2004) revealed that the main components of nitrogen in human urine are ammonia and urea, which in turn are converted into ammonia itself.

3.1.4 COD.
The high average COD concentration of RS-1 inlet wastewater recorded only occurred in 2015 with 154 mg / l. In RS-2, it occurred in 2015 and 2016 with levels of 355 and 183 mg / l (Figure 4). The COD standard for hospital wastewater is 80 mg / l.

![Figure 4](image-url)

**Figure 4.** Average COD of RS-1 and RS-2 Inlet Wastewater Period 2015 – 2019

Some other research results also report high COD concentrations in several hospitals. The COD concentration in Valiasr Hospital was 435 mg / l, Bahrami Hospital was 1362 mg / l (Mesdaghinia et al., 2009). The COD concentration of hospital raw wastewater in Thailand is 232 mg / l (Wangsaatmaja, 1997). COD concentrations of raw wastewater from 70 hospitals in Iran have been reported 527 mg / l (M. Majlesi Nasr & A.R., 2008).

The content of organic pollutants in RS-1 and RS-2 wastewater can be sourced from Domestic liquid waste, such as a bathroom, kitchen, and laundry waste; Clinical liquid waste, such as wound washing water, blood washing, and others; Laboratory liquid waste originates from the washing of laboratory equipment and material from examinations such as blood, urine, and others.
Organic waste will experience degradation and decomposition by aerobic bacteria (using oxygen in water) so that the oxygen that gets in the water will be significantly reduced over time. In the condition of reduced oxygen, only certain species of organisms that can live.

3.1.5 The other parameters.
Except for the parameters COD, TSS, ammonia nitrogen, and total coliform, the conditions of the other parameters are still in the normal range (Table 1, Table 2).

**Table 1.** Average of other Parameters for RS-1 Inlet Wastewater Period 2015 – 2019

| Parameters                        | Highest concentration | Average of Parameters |
|----------------------------------|-----------------------|-----------------------|
| Iron, dissolved (Fe)             | 5 mg/l                | 0.18                  |
| Manganese, dissolved (Mn)        | 2 mg/l                | 0.58                  |
| Copper, (Cu)                     | 2 mg/l                | 0.02                  |
| Zinc, (Zn)                       | 5 mg/l                | <0.01                 |
| Cadmium, (Cd)                    | 0.05 mg/l             | <0.01                 |
| Lead, (Pb)                       | 0.1 mg/l              | <0.01                 |
| Nickel, (Ni)                     | 0.2 mg/l              | <0.01                 |
| Cyanide, (CN)                    | 0.05 mg/l             | <0.002                |
| Sulfide, (S =)                   | 0.05 mg/l             | 0.04                  |
| Flourida, (F-)                   | 2 mg/l                | 0.10                  |
| Free chlorine, (Cl2)             | 1 mg/l                | Nol                   |
| Nitrate (NO3-N)                  | 20 mg/l               | 0.66                  |
| Nitrite (NO2-N)                  | 1 mg/l                | 0.55                  |
| MBAS                             | 5 mg/l                | 0.01                  |
| Phenol                           | 0.5 mg/l              | 0.13                  |

**Table 2.** Average of other Parameters for RS-2 Inlet Wastewater Period 2015 – 2019

| Parameters                        | Highest concentration | Average of Parameters |
|----------------------------------|-----------------------|-----------------------|
| Iron, dissolved (Fe)             | 5 mg/l                | 0.05                  |
| Manganese, dissolved (Mn)        | 2 mg/l                | <0.01                 |
| Copper, (Cu)                     | 2 mg/l                | 0.01                  |
| Zinc, (Zn)                       | 5 mg/l                | <0.01                 |
| Chrome valence six, (Cr6 +)      | 0.1 mg/l              | <0.01                 |
| Cadmium, (Cd)                    | 0.05 mg/l             | <0.01                 |
| Lead, (Pb)                       | 0.1 mg/l              | <0.01                 |
| Nickel, (Ni)                     | 0.2 mg/l              | 0.11                  |
| Cobalt, (Co)                     | 0.4 mg/l              | 0.01                  |
| Cyanide, (CN)                    | 0.05 mg/l             | <0.002                |
| Sulfide, (S =)                   | 0.05 mg/l             | <0.02                 |
| Free chlorine, (Cl2)             | 1 mg/l                | Nol                   |
| Nitrate (NO3-N)                  | 20 mg/l               | 0.19                  |
| Nitrite (NO2-N)                  | 1 mg/l                | <0.003                |
| MBAS                             | 5 mg/l                | 0.04                  |
| Phenol                           | 0.5 mg/l              | <0.025                |
According to Djohan and Halim (2014), laboratory wastewater generally contains a lot of various chemical compounds as reagents when examining blood samples and other materials, contains antiseptic agents and antibiotics that are toxic to microorganisms, and contain heavy metals. Low levels of chemical compounds and heavy metals in wastewater RS-1 and RS-2 can occur due to dilution factors. The volume of laboratory wastewater is much smaller than the volume of domestic wastewater.

3.2 WWTP hospitals existing

The performance of WWTP RS-1 and RS-2 was generally low in the removal of Total Coliform, TSS, and Ammonia Nitrogen, except COD. Total coliform removal efficiency is generally quite high, in the range of 54% - 97%, but its effect on the removal of total coliform is still above the quality standard. It may be caused by the total coliform burden that is too large than the hospital WWTP capacity.

The efficiency of WWTP RS-1 on TSS removal is low, with a range of 21% - 53%, resulting in TSS outlet levels still above the quality standard. Also, the efficiency of WWTP RS-1 and RS-2 on NH3-N removal is generally low, with a range of 7% - 62%, so that NH3-N outlet levels are still above the quality standard.

Table 3. Efficiency of WWTP RS-1 and RS-2 on Removal of Total Coliform, TSS, Ammonia Nitrogen, and COD Period 2015 - 2019

| Parameters | 2015 | 2016 | 2017 | 2018 | 2019 |
|------------|------|------|------|------|------|
| **Inlet (MPN/100ml)** | | | | | |
| Coliform | | | | | |
| RS-1 | 130,808 | 140,183 | 213,333 | 45,045 | 216,375 |
| RS-2 | 340,000 | 413,583 | 676,083 | 300,218 | 204,400 |
| **Outlet (MPN/100ml)** | | | | | |
| Eff iciency | 79% | 70% | 95% | 84% | 97% |
| Std (MPN/100ml) | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 |
| Indication | over | over | over | over | over |
| **Inlet (mg/l)** | | | | | |
| TSS | 126 | - | 59 | - | 85 |
| Outlet (mg/l) | 100 | - | 31 | - | 40 |
| Efficiency | 21% | - | 48% | - | 53% |
| Std (mg/l) | 30 | - | 30 | - | 30 |
| Indication | over | over | over | over | over |
| **Inlet (mg/l)** | | | | | |
| NH3-N | 3.93 | 4.18 | 15.46 | 2.68 | 0.45 |
| Outlet (mg/l) | 0.78 | 1.57 | 14.42 | 2.10 | 0.13 |
| Efficiency | 80% | 62% | 7% | 22% | 72% |
| Std (mg/l) | 1 | 1 | 1 | 1 | 1 |
| Indication | low | low | low | low | low |
| **Inlet (mg/l)** | | | | | |
| COD | 154 | 75 | 183 | 44 | 32 |
| Outlet (mg/l) | 52 | 42 | 37 | 31 | 26 |
| Efficiency | 67% | 44% | 14% | 21% | 15% |
| Std (mg/l) | 80 | 80 | 80 | 80 | 80 |
| Indication | low | low | low | low | low |

3.3 Overview of constructed wetlands with HSSF

The Vymazal study (2019) indicate that Horizontal Sub Surface Flow Constructed Wetlands (HSSF-CWs) can provide a sustainably excellent treatment performance for 20+ years despite being designed according to a simple formula used in the early 1990s. The present study evaluated treatment performance of 114 Czech HSSF-CWs with special attention to 17 systems that have been in operation for at least 20 years. The study clearly revealed that if the HSSF-CWs are properly loaded, their treatment performance is very steady with outflow concentrations < 15 mg l^{-1} of BOD5 and TSS and < 50 mg l^{-1} COD. The removal efficiency of 17 systems that have been in operation for at least 20 years amounted to 91.7%, 82.9% and 88.3% for BOD5, COD and TSS, respectively during the last five years of operation. Removal of both organics and TSS does not depend on the season.

Haddis, Bruggen, and Smets (2020) concluded that Horizontal Sub Surface Flow Constructed Wetlands could function well under variable flow conditions and be the technology of choice in low-income countries, particularly in tropical climates. Two selected plant species, i.e., Cyperus papyrus
(papyrus) and Scirpus Validus (bulrush), were tested using the wastewater from a dormitory at Jimma University Campus in Ethiopia. BOD$_5$ removal was 81% in papyrus, 76% in bulrush, and 48% in Control. TSS removal was 76% and 75% in papyrus and bulrush compared to 54% in the Control. COD removal showed 65% and 62% in the planted beds and 32% in the Control.

Garcia-Ávila et al. (2019) studied of the purification of domestic wastewater using HSSF-CWs with Cyperus Papyrus on a small scale received municipal wastewater with primary treatment. The results obtained in the experimental tests indicated that the HSSF-CWs with Cyperus Papyrus presented a high capacity of pollutants removals such as BOD (80.69%), COD (69.87%), ammoniacal nitrogen (69.69%), total phosphorus (50%), total coliforms (98.08%) and fecal coliforms (95.61%).

Typha with the broken brick was significantly improved (P<0.05) the treatment performance of the Horizontal Sub Surface Flow Constructed Wetland systems for the removal of TSS, BOD5, COD, TKN, NH4-N, NO3-N, and phosphate from hospital wastewater, respectively, 93.2%, 90.4%, 83.7%, 64%, 64.3%, 52.1% and 56.1% in the dry season and 89.7%, 85.8%, 82.9%, 66%, 62.7%, 56.1% and 59.5% in the rainy season (Dires, Birhanu, and Ambelu, 2019).

Dires et al. (2018) reveal that in general horizontal subsurface flow constructed wetlands could help to solve the problem of the cost-effective disposal of hospital wastewater, being a suitable treatment for reducing indicator, pathogenic, and antibiotic-resistant bacteria which is comparable to activated sludge treatment system and be promoted in a strategy to reduce water pollution in low-income countries like Ethiopia.

### Table 4 Performance of Constructed Wetlands with Horizontal Sub Surface Flow

| Parameters     | Performance (%) | Location | Reference           |
|----------------|-----------------|----------|---------------------|
| BOD$_5$        | 91.70           | Czech    | Vymazal, (2019)     |
| COD            | 82.90           |          |                     |
| TSS            | 88.30           |          |                     |
| BOD$_5$        | 81.00           | Ethiopia | Haddis, Bruggen, and Smets, (2020) |
| COD            | 65.00           |          |                     |
| TSS            | 76.00           |          |                     |
| BOD$_5$        | 80.69           |          | Garcia-Ávila et al. (2019) |
| COD            | 69.87           |          |                     |
| Amonia-N       | 69.69           |          |                     |
| Total Coliform | 98.08           |          |                     |
| Fecal Coliform | 95.61           |          |                     |
| BOD$_5$        | 90.40           | Ethiopia | Dires, Birhanu, and Ambelu, (2019) |
| COD            | 83.70           |          |                     |
| TSS            | 93.20           |          |                     |
| Amonia-N       | 64.30           |          |                     |
| TKN            | 64.00           |          |                     |
| NO3-N          | 52.10           |          |                     |
| Phosphate      | 56.10           |          |                     |

### 4. Conclusions and Recommendations

The investigation results have shown that the characteristics of wastewater hospitals inlet in Palu are variable values with four high concentration parameters: total coliform, TSS, Ammonia Nitrogen, and COD. The hospital WWTP's efficiency level in Palu is relatively low in removing pollutants such as total coliform, TSS, Ammonia Nitrogen, and COD. Some research results describe the performance of CW-HSSF in wastewater treatment in tropical areas. Therefore HSSF-CW has the opportunity to be used for hospital wastewater treatment in Indonesia.
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