Evaluation and Design of Wastewater Management at Indrasari Rengat Hospital for Upgrade Program from Class C to B

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Abstract. Indrasari Rengat Hospital, a hospital owned by the Government of Indragiri Hulu Regency in Riau Province, Indonesia, was upgraded from type C hospital to type B in May 2018. This improvement program was followed by the addition of beds from 120 to 200. The production of wastewater in this hospital was around 57.6 m$^3$/day, with a water demand of 500 L/bed per day. This study aims to evaluate wastewater treatment performance and provide recommendations on wastewater management. The research was conducted by case study method, design evaluation, and redesign of the existing wastewater treatment plant (WWTP). Evaluation results showed that the WWTP would still be able to accommodate an increase in wastewater discharge due to additional beds for type B hospital. The maximum number of beds, in order that the WWTP would still be able to hold the wastewater, would be 240 beds, which is equivalent to 115.2 m$^3$/day of wastewater discharge. At this discharge, WWTP would fulfill design criteria for key parameters such as hydraulic loading rate, organic loading rate, and detention time.

Keywords: Indrasari Rengat Hospital, type enhancement, wastewater management

1. Introduction

In their daily functions, the hospital generates medical waste and non-medical waste in the form of solid waste, liquid waste, and gas waste (Arfan et al, 2012). The negative impact of hospital waste on health is very significant if not managed properly. Therefore, every hospital must treat its waste with the specified standards (Decree of the Minister of Health of the Republic of Indonesia Number 1204 of 2004). Some components of hospital waste may contain toxic materials, which can cause many diseases including cancer (Jolibois and Guebert, 2005), problematic statement and toxicity to the environment (Alrhmoun, 2014), and water-borne diseases.

Indrasari Rengat Hospital is a hospital owned by the Government of Indragiri Hulu Regency, Riau Province. Previously, this hospital was a type C hospital, with a treatment capacity of 120 beds. This hospital had a wastewater treatment plant (WWTP) to treat wastewater generated from daily activities. This wastewater comes from clinical and domestic activities. Clinical or medical waste is treated in a pretreatment unit before entering WWTP. The purpose of this pretreatment is to reduce the toxicity of medical waste. In May 2018, the Indrasari Rengat hospital obtained an increase in class from type C to type B. The minimum number of beds according to the type B hospital standard is 200 beds (Regulation of the Minister of Health of the Republic of Indonesia Number 340 of 2010).
The increase in the number of beds correlates with an increase in the amount of wastewater produced, and consequently an increase in the wastewater treatment capacity. Therefore, it was necessary to evaluate whether the existing WWTP performance could still be maintained. The results of the evaluation provided further recommendations about the overall wastewater management.

Several types of hospital wastewater treatment had been widely studied. Alrhmoun, (2014) studied the conventional activated sludge process, membrane bioreactors, attached growth biological treatment, and activated carbon adsorption for treating hospital wastewater. Hospital wastewater can also be treated with sponge membrane bioreactor coupled with ozonation process (Vo, et. al, 2019) and mixed culture of microorganisms in the treatment unit (Hegazy and Gawad, 2016). Said (2002) applied “Upflow” Biofilter System for treating hospital wastewater.

The most important result of WWTP studies is an increase in performance as indicated by high processing efficiency. Efficiency is defined as the percentage of pollutant reduction in wastewater after treatment or is expressed as the difference between the quality of wastewater before and after treatment. Hegazy and Gawad (2016) stated that the performance of a biological treatment depends on developing a suitable mixed culture of microorganisms, maintaining appropriate environmental conditions, and removing the excess sludge produced. Al Zahiri (2015) stated that performance is affected by inflow and outflow rates, outflow quality, and treatment efficiency. Characterization of the wastewater is an important step to study the performance of a WWTP. The characterization is conducted by measuring BOD, COD, TSS, TDS, NH₃, and DO for the influent and the effluent of the WWTP (Al-Zboon and Al-Ananzeh, 2008).

2. Material and Methods

The steps of this research are as follows:

1) Data Collection

Data were collected to support WWTP evaluation and redesign, including WWTP technical data and wastewater quality data. Wastewater samples were taken 3 times from influent and effluent point of the wastewater treatment plant using grab and composite sampling method. Sampling was done on a holiday, a workday, and a workday after rain. Samples were analyzed in the Laboratory of Health and Environment of Pekanbaru to measure wastewater quality with parameters of temperature, TSS, TDS, pH, BOD₅, COD, NH₃, oil and grease, and total coliform (Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 5 of 2014).

2) Evaluation and Redesign

Evaluation for Indrasari Rengat Hospital WWTP included:

1. Performance of each unit of WWTP:
   a. equalization tank
   b. aerobic biofilter

2. Analysis of WWTP condition based on design criteria and standard for type C hospital. However, because of the upgrade, there might be additional flowrate and quality fluctuation, therefore the analysis had to use the standard for type B hospital.

3. Recommendation for WWTP enhancement with several alternatives including development plan based on calculation between the existing conditions and the ideal conditions.

The following are some of the equations used for WWTP evaluation and design:

1. Detention Time
   \[ td = \frac{V}{q} \]  

2. Removal Efficiency
   \[ E = \left( \frac{C_i - C_e}{C_i} \right) \times 100\% \]
3. Organic Loading Rate (OLR)

\[ OLR = \frac{Q \times C}{V} \quad (3) \]

4. Hydraulic Loading Rate (HLR)

\[ HLR = \frac{Q}{A} \quad (4) \]

5. Sludge Production

\[ PX = \frac{Q \times Y \times (So - Se)}{1 + kd \times SRT} \quad (5) \]

where \( C_i \) and \( C_e \) are respectively influent and effluent concentration (kg/m\(^3\)), \( V \) is tank volume (m\(^3\)), \( Q \) is flowrate of wastewater (m\(^3\)/sec), \( C \) is concentration of wastewater (kg/m\(^3\)), and \( A \) is surface area of tank (m\(^2\)). \( Y \) is yield coefficient, \( So \) and \( Se \) are respectively influent and effluent concentration of substrate (kg/m\(^3\)), \( k_d \) is coefficient of decay (day\(^{-1}\)), and \( SRT \) is sludge retention time (day).

3. Result and Discussion

1) Quantity and Quality of Wastewater

The flowrate of wastewater in Indrasari Rengat Hospital can be seen in Table 1, while the quality of wastewater can be seen in Table 2. Data in Table 1 were obtained from measurement of wastewater volume from the actual conditions with 27 full beds. The average flowrate was 0.55 m\(^3\)/hour. Therefore, the actual production of wastewater for each bed was 0.02 m\(^3\)/hour.

| No | Time      | Volume (m\(^3\)) |
|----|-----------|------------------|
| 1  | 06.00-07.00 | 0.86             |
| 2  | 07.00-08.00 | 0.72             |
| 3  | 08.00-09.00 | 0.65             |
| 4  | 09.00-10.00 | 0.51             |
| 5  | 10.00-11.00 | 0.70             |
| 6  | 11.00-12.00 | 0.39             |
| 7  | 12.00-13.00 | 0.72             |
| 8  | 13.00-14.00 | 0.50             |
| 9  | 14.00-15.00 | 0.33             |
| 10 | 15.00-16.00 | 0.43             |
| 11 | 16.00-17.00 | 0.38             |
| 12 | 17.00-18.00 | 0.36             |
| **Total** |           | **6.55**         |
| **Average** |            | **0.55**         |

Table 2. Quality of Wastewater Samples

| No | Parameter | Unit | Result Influent | Result Effluent | Standard |
|----|-----------|------|-----------------|-----------------|----------|
| A  | Physical  |      |                 |                 |          |
As the planned number of beds of the hospital as type B was 350 beds, the flowrate of wastewater was 8.92 m$^3$/hour. This flowrate was then used to evaluate the unit operations and unit processes of the WWTP.

2) Evaluation of Equalization Tank

There are 2 basins in the equalization tank, which are referred to as basin 1 and basin 2. An important parameter that had to be evaluated for this tank was detention time. Detention time was calculated by equation (1). At the flowrate of 8.92 m$^3$/hour, the calculated detention time for basin 1 (volume 11.37 m$^3$) was 1.27 hours, while for basin 2 (volume 3.8 m$^3$) it was 0.42 hour. Next, the results of this calculation were compared with the design criteria for equalization tanks (see Table 3) and checked whether they were qualified or unqualified.

| No | Parameter          | Design Criteria *) | Actual                   | Status     |
|----|--------------------|-------------------|--------------------------|------------|
| 1  | Detention Time     | 5-6 hours         | 1.27 (basin 1) and 0.42 (basin 2) | Unqualified |
|    | Height, m          | 2 m               | 2m (basin 1) and 2m (basin 2) | Qualified  |
| 2  | Mixer Reach        | ½ height          | -                        | Unqualified |

*) Metcalf dan Eddy, Inc. 2004

1) Evaluation of Aerobic Biofilter

The biofilter unit is made of steel, with dimensions of 6 m x 3.84 m x 1.7 m. The performance parameters analyzed included removal efficiency, HLR, and OLR, which were calculated using equation (1), (3), and (4). The removal efficiency was calculated for the parameters of chemical oxygen demand (COD) and biochemical oxygen demand (BOD). The aerobic biofilter reduced COD from 228 mg/L to 55 mg/L or with 75.8% efficiency. BOD was reduced from 141 mg/L to 31 mg/L or with 78% efficiency.

The organic loading rate (OLR) was calculated using equation (3), with a flowrate of 8.92 m$^3$/hour or 214.08 m$^3$/day and the volume of biofilter was 38.76 m$^3$. The OLR was 0.7 kg/m$^3$.day, qualified for the design criteria (0.5–4 kg BOD/m$^3$.day). The hydraulic loading rate (HLR) was calculated using equation (4), with length and width of tank being 6 m x 3.84 m thus the surface area was...
23.04 m². The HLR was 9.27 m³/m².day, which was not qualified for the design criteria (1-5 m³/m².day).

2) Problem Solving Alternatives for the WWTP

a. Determining maximum addition of bed

An evaluation of the design of the WWTP was carried out with a treatment capacity of wastewater generated by 350 beds. The evaluation showed that the HLR value did not meet the design criteria. Therefore, it was necessary to recalculate the maximum number of beds in the hospital wherein the wastewater generated would still be able to be treated by the WWTP capacity. By taking an HLR of 5 m³/m².day and the surface area of the biofilter remains as the existing condition, the maximum flowrate of WWTP would be 115.2 m³/day. This amount of discharge is equivalent to 240 beds. This number still meets the criteria for the number of beds for type B hospitals.

b. Modification of Equalization Tank

Basin 1 of the equalization tank needed to be modified into a settling basin. The main consideration was that the raw wastewater contained a fairly high TSS at 332 mg/L (see Table 2) which required a settling basin to remove. The dimensions of the tank did not need to be changed, which were 3.6 m x 1.58 m x 2 m. The modification would be the addition of sludge chamber at the bottom of the tank. Detention time of wastewater in the tank with a discharge of 115.2 m³/day was 2.37 hours (which meets the criteria: 1.5-2.5 hours). The overflow rate would be 20.21 m³/m².day.

A sludge chamber was designed to hold the sludge from wastewater that would have been settled for 2.37 hours, around 58.25% or as much as 22.27 kg/day dry solid. Assuming that the solid content in the sludge would be 1.5% and the sludge density would be 1.02 kg/m³, the sludge volume per day would be 1.45 m³/day. To hold this sludge, a slash-shaped sludge chamber would be needed (1.58 x 1.58) m² for upside area and (1 x 1) m² for the downside area. The design of the settling tank with a sludge chamber can be seen in Figure 1.

![Figure 1. Design of Sludge Chamber](image)

Table 4. Mass and Flow of Sludge
### Table 4. Sludge Types and Flow

| No | Sludge Type       | Dry Solid (kg/day) | Flow (m³/day) |
|----|-------------------|--------------------|---------------|
| 1  | Settling tank     | 22.27              | 1.45          |
| 2  | Aerobic biofilter | 216                | 0.1           |
|    | **TOTAL**         | **24.43**          | **1.55**      |

To hold and dry the amount of sludge as listed in Table 4, a minimum of 3 units of sludge drying bed would be required with dimensions of 2.5 m wide and 5 m long. The thickness of the sludge would be 0.3 m. The sludge drying bed would be equipped with a 50 mm-diameter underdrain pipe. The sketch of the designed sludge drying bed can be seen in Figure 2.

![Figure 2. Sketch of sludge drying bed](image)

### 4. Conclusion

Upgrading Indrasari Rengat Hospital from type C to type B hospitals would require an increase in the number of beds to a minimum of 200 beds. Consequently, wastewater that must be treated by WWTP would also increase. Based on this study’s evaluation, the existing WWTP would be able to treat the wastewater with a maximum capacity of 115.2 m³/day, so the WWTP performance would remain good and comply with the design criteria. This capacity is equivalent to 240 beds. A WWTP redesign would be needed so that WWTP performance would not be interrupted. Modifications were designed for basin 1 of the equalization unit, which would be to be converted into a settling tank. A new unit was designed, which was a sludge drying bed. To maintain a high WWTP performance, a good standard operating procedure would be required and always to be adhered to.

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