Modification of Septic Tank for Sedimentation Optimization in the Public Toilet (Case Study at Wisdom Park UGM)

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Abstract. Septic tank with sedimentation and anaerobic processes in the same tank is commonly used as a domestic wastewater treatment technology in individual households and communal systems. Although simple to construct, such a system has some problems, such as effluent not meeting the quality requirement and blocking by trash and suspended solid before the second treatment chamber. This research aims to develop a new septic tank design that is simpler to construct and improve performance. The new design uses HDPE material, which is easier to build and standardized compared to the conventional concrete structure. The performance of the new design was compared to the conventional septic tank. The start-up process was monitored for flowrate, COD, TSS, NH₃-N, PO₄-P parameters and evaluated against effluent standards. The study was conducted at public toilet facilities at Wisdom Park UGM and Sunday Morning Market. Results from the study show that the new design effectively improves effluent quality and overcomes the trash problem.

Keywords: Public toilet facilities, sedimentation optimization, septic tank

1. Introduction

Septic tanks are used for on-site individuals, a decentralized domestic wastewater treatment system to digest wastewater in an anaerobic process and provide space for the sludge to settle [1]. A septic tank with a wastewater infiltration well has been built for a long time at Wisdom Park, Universitas Gadjah Mada (UGM), to receive effluent from public toilets in the park and a nearby office. Concern about E. Coli contamination in the surrounding resident shallow wells [2][3] as well as pollution at nearby Belik stream, a further step was taken by constructing a secondary treatment plant after the tank and deactivating the infiltration well. As the system operates, there were problems with trash and sand entering the biological reactor process in the secondary treatment plant. The trash and sand clog the aerator and submersible pump, as seen in Figure 1. Installation of a protective filter on the pump and aerator did not solve the problem. The pump has to be cleaned up every day. Other alternatives have to be found to solve the problem. In this study, a modification of the septic tank system is proposed. Since the septic tank is commonly used as individual household wastewater treatment with no central wastewater treatment system, the modified system has to be made simple and not expensive to construct in a densely populated urban area.
Figure 1. Garbage and sand problem in the secondary treatment

One of the alternative modifications of the septic tank is Anaerobic Baffle Tank Reactor (ABR). ABR is widely used as septic tank modification in communal wastewater treatment systems in Indonesia [4]. Many reviews have been conducted on this subject, although mostly on quantitative analysis of the process and performance [4][5][6]. In this research, septic tank modification was carried out by optimizing the sedimentation function based on observations of the performance of the existing septic tank system for some time. This research also considers the construction design, selection of material, construction cost, and comparing its start-up performance with the existing septic tank. It has to be noted that the observation was conducted during the COVID-19 pandemic, which affected the activity of the public park.

2. Materials and Methods

2.1. The Existing Septic Tank Location and Wastewater Type

The research is located in a domestic wastewater system that serves a public toilet at Wisdom Park UGM near the ex P4S UGM Yogyakarta (Figure 2).

Figure 2. Research location

The septic tank treats blackwater while the greywater flows directly to the secondary treatment system. The volume of the septic tank is 0.676 m³. Dimensions and design construction of the septic tank as well as the flow diagram of the greywater and blackwater treatment, are presented in Figure 3.
2.2. Septic Tank Design Method

The modification steps started from recalculating the wastewater load to be managed. The unit volume of influent wastewater per person per visit a day and the BOD$_5$ (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solids), NH$_3$, and PO$_4$-P loads for the septic tank and the modified septic tank design are based on Table 1.

The volume of wastewater for defecation and urination is assumed to be 0.012 m$^3$/person per day and 0.0045 m$^3$/day consecutively, while personal hygiene wastewater is 0.0045 m$^3$/day [7]. According to SNI 03-2399-2002 concerning Procedures for the Construction of Public MCK (bathing, washing and toilet), the use of bathing water is at least 0.02 m$^3$/person per day, washing is 0.015 m$^3$/person per day, and defecation is 0.01 m$^3$/person per day. In SNI No. 2398 of 2017, the amount of flushing water in a separate septic tank system (between bathing and defeacation/urination) is 0.02 m$^3$/person per day. Organic loads, suspended solids, and nutrients in wastewater influent from the frequency of defecation per person reach three times/day [8], urination frequency reaches seven times/day [9], while personal hygiene wastewater is assumed seven times/day. The capacity design of the existing septic tank of 0.676 m$^3$ is estimated at 25 people/day, yet the number of users is 50 people. If the design criteria for defecation wastewater volume is 0.012 m$^3$/day and urination is 0.0045 m$^3$/day, then the estimated flow

| Volume (m$^3$/person, once a day)$^a$ | Excreta (Defecation) | Urine (Urination) | Greywater |
|----------------------------------------|-----------------------|-------------------|-----------|
| Loads | (3 times/day)$^b$ | (7 times/day)$^c$ | (7 times/day) |
| BOD$_5$ (g/person/day)$^d$ | 23 | 5 | 5 |
| COD (g/person/day)$^d$ | 37 | 9 | 8 |
| TSS (g/person/day)$^d$ | 38 | 1 | 3 |
| Nitrogen (g/person/day)$^d$ | 1.6 | 7.7 | 0.3 |
| NH$_3$, 0.6 TN$^a$ | 0.96 | 4.62 | 0.18 |
| PO$_4$-P (g/person/day)$^d$ | 0.4 | 0.7 | 0.1 |

$^a$ Sperling (2007)  
$^b$ Walter, et al. (2010)  
$^c$ Colley, W (2015)  
$^d$ Boutin and Eme (2017)
design for the modified septic tank for 50 users to defecate, urinate and use hygienic water in a day is as shown in Table 2. Design criteria for the removal efficiency of a septic tank are 50% organics, and 50% suspended solids [10], while the removal efficiency of a modified septic tank as a sedimentation tank, according to several pieces of kinds of literature, ranges from 20 - 40% organics and 50-70% TSS at Hydraulic Retention Time (HRT) of 1-3 hours [11][12]; both types of the septic tank are relatively ineffective in removing nutrients. The effluent of wastewater quality target refers to the permissible water quality standard in the Minister of the Environment and Forestry Regulation No. 68 of 2016 for BOD₅, COD, TSS, and NH₃. Dimension design of the modified septic tank was calculated by considering the material specifications available in the market, namely HDPE tanks. Flow rates or discharge and concentration of the influent on the modified septic tank and the existing septic tank as well as the complete design criteria, are presented in Table 2.

Table 2. Criteria design of the existing and the modified septic tank

|                           | Existing Septic Tank | Modified Septic Tank |
|---------------------------|----------------------|----------------------|
|                           | Defecation | Urination | Defecation | Urination | Personal Hygiene |
| User (people/day)          | 25         | 50        | 50         | 50        | 50               |
| Frequency (per day)        | 1          | 1         | 1          | 1         | 1                |
| Influent concentration     | Blackwater | Blackwater | Greywater  |           |                  |
| Flow input (m³/d)          | 0.525      | 0.825     | 0.225      |           |                  |
| BOD₅ (g/m³)                | 798        | 798       | 159        |           |                  |
| COD (g/m³)                 | 1313       | 1313      | 254        |           |                  |
| TSS (g/m³)                 | 1087       | 1087      | 95         |           |                  |
| NH₃ (g/m³)                 | 173        | 173       | 6          |           |                  |
| NH₃-N (g/m³)               | 143        | 143       |            |           |                  |
| PO₄-P (g/m³)               | 33         | 33        | 3          |           |                  |
| Removal efficiency         |            |           |            |           |                  |
| BOD₅                      | 53.5%ᵃ     | (25-40%)ᵇ; (30-40%)ᶜ |            |           |                  |
| COD                       | 53.4%ᵃ     | (25-40%)ᵇ; (30-40%)ᶜ |            |           |                  |
| TSS                       | 55%ᵃ       | (50-70%)ᵇ; (50-70%)ᶜ |            |           |                  |
| NH₃                       | -4.20%ᵃ    | (-)       |            |           |                  |
| Effluent targetᵈ          |            |           |            |           |                  |
| BOD₅ (g/m³)               | 30         | 30        | 30         |           |                  |
| COD (g/m³)                | 100        | 100       | 100        |           |                  |
| TSS (g/m³)                | 30         | 30        | 30         |           |                  |
| NH₃ (g/m³)                | 10         | 10        | 10         |           |                  |
| NH₃-N (g/m³)              | 8          | 8         |            |           |                  |
| Sludge production (m³/person/year)ᵉ | 0.025 | 0.025 |
| HRT (hours)               | 24ᵃ        | (1-3.6)ᵇ; (1-3)ᶜ |            |           |                  |

ᵃ Nasr and Mikhaeil (2013)
ᵇ Metcalf and Eddy (2003)
ᶜ Park J K (2012)
ᵈ Regulation of LHK No.68/2016; *NH₃-N is the conversion concentration of NH₃
ᵉ Mills, et al. (2014)

2.3. Construction Method

Drawing works were done based on the results of the modified septic tank design. Then, the budget plan was calculated based on Minister of Public Works and Public Housing (PUPR) Regulation No. 28 of 2016 and the standard price of goods and services (SHBJ) of Sleman Regency in 2020. The construction process for the modified septic tank was carried out by the contractor. The authors served as the supervisors. Finally, the modified septic tank was built based on the working drawings that have been made and the estimated construction time of 2 days.

2.4. Commissioning, Start-up and Monitoring performance

The commissioning work on the modified septic tank was carried out on 11-12 October 2020 by flowing clean water through the toilet and toilet floor, monitoring the smooth water flow to the outlet, and then
stopping the clean-water flow. Monitoring the start-up process performance was carried out for three months every Tuesday and Friday at 07.00 a.m. from 12 October 2020 to 1 January 2021. The effluent flow rate measurement was carried out at the outfall point (outlet) of the wastewater treatment plant (WWTP).

The actual influent flowrate is the same as the effluent flow rate, assuming that evaporation and precipitation do not occur in the WWTP system. The measuring method flowrate accommodates the effluent in a container with a maximum volume of 0.05 m$^3$ for approximately 10 hours from 07.00 a.m. to 5.00 p.m. WIB (Western Indonesian Time). Wastewater flow rate is calculated by dividing the volume of wastewater per time:

$$ Q = \frac{V}{T} $$

which, $Q$ : effluent flowrate, m$^3$/d  
$V$ : wastewater volume, m$^3$ 
$T$ : time, d

HRT, HLRV, HLRS, COD Volumetric loading, OLRs, flow velocity, wastewater travel time, and solid retention time ($\Theta_c$) were calculated using the equation in Table 3. Monitoring the actual flow rate of the existing septic tank effluent was measured by direct observation of the number of public toilet users in one day, multiplied by water use assumed per person, and recording the duration of toilet use for seven days starting from Sunday 29 September to 5 October 2019.

**Table 3. The formula of loading performances**

| Equation | Description |
|----------|-------------|
| HRT $= \frac{V}{Q}$ | $HRT$ : hydraulic retention time, d  
$V$ : volume of tank, m$^3$  
$Q$ : flowrate, m$^3$/d |
| HLRv $= \frac{Q}{V}$ | $HLRv$ : volumetric hydraulic loading rate, (m$^3$/day)/m$^3$  
$Q$ : flowrate, m$^3$/day  
$V$ : volume of tank, m$^3$ |
| HLRS $= \frac{Q}{A}$ | $HLRS$ : surface hydraulic loading rate, (m$^3$/d)/m$^2$  
$Q$ : flowrate, m$^3$/day  
$A$ : surface area of the tank, m$^2$ |
| COD$V = \frac{Q \cdot So}{V}$ | $COD_v$ : COD volumetric loading rate, (kg/day)/m$^3$  
$Q$ : flowrate, m$^3$/d  
$So$ : COD input concentration, kg/m$^3$  
$V$ : volume of the tank, m$^3$ |
| OLRs $= \frac{Q \cdot So}{A}$ | $OLRs$ : surface organic loading rate, (kg/day)/m$^2$  
$Q$ : flowrate, m$^3$/d  
$So$ : COD input concentration, kg/m$^3$  
$A$ : surface area of the tank, m$^2$ |
| $v = \frac{HLRS}{A}$ | $v$ : velocity, m/h  
$HLRS$ : surface hydraulic loading rate, m/h |
| $t = \frac{d}{v}$ | $t$ : time, h  
$d$ : distance, m  
$v$ : velocity, m/h |
| $\Theta_c = \frac{V}{Q}$ | $\Theta_c$ : solid retention time, d  
$V$ : volume of the tank, m$^3$  
$Q$ : flowrate, m$^3$/d |

The modified septic tank effluent water quality and flow rate or discharge were taken at the same time. The effluent sample was taken at the inlet surface of the equalization tank (Figure 4), while the existing septic tank effluent was monitored from 19 August - 5 December 2019. Water quality parameters were laboratory tested for COD, TSS, NH$_3$-N, and PO$_4$-P with the following test methods,
### Table 4. Effluent water quality test for the existing septic tank and the modified one

| Parameter | Method | Reference |
|-----------|--------|-----------|
| COD       | Titrimetric with close reflux | SNI 6989-part 73 |
| TSS       | Gravimetry | SNI 69893-2004 |
| NH₃-N, PO₄-P | Spectrophotometry with reagent kit | HACH DR2010 manual book |

The performance of both types of septic tank is calculated using the formula:

\[
E = \left(1 - \frac{C_{\text{out}}}{C_{\text{in}}}\right) \times 100\%
\]

where,

- \(E\): removal efficiency, %
- \(C_{\text{out}}\): effluent concentration, g/m³
- \(C_{\text{in}}\): influent concentration, g/m³

### 3. Result and discussion

#### 3.1. The modified Septic Tank Design and Specification

Drawing pictures of the modified septic tank consisted of 2 reactors or tanks is presented in Figure 4. It is designed to remove a large proportion of TSS and a small amount of organic material with the same existing septic tank HRT. The existing septic tank was then converted as a manhole/control tub.

![Figure 4. The layout of the modified septic tank.](image)

The specification design of the existing septic tank and the modified one is presented in Table 5.

### Table 5. Design and construction specification of the existing septic tank and the modification one

|                     | Existing Septic Tank | Modified Septic Tank |
|---------------------|----------------------|----------------------|
|                     | Sedimentation Tank 1 | Sedimentation Tank 2 |
| Material            | Concrete             | HDPE                 | HDPE                 |
| Type                | -                    | TP 110               | TP 110               |
| Volume (m³)         | 0.676                | 1.05                 | 1.05                 |
| Length (m)          | 1.05                 | -                    | -                    |
| Width (m)           | 0.7                  | -                    | -                    |
| Diameter (m)        | -                    | 1.05                 | 1.05                 |
| Height (m)          | 0.92                 | 1.32                 | 1.32                 |
| Thickness (mm)      | 150                  | 9 – 12               | 9 – 12               |
| Sludge volume (m³)  | 0.313                | 1.86                 |
| Hydraulic volume (m³)| 0.364              | 0.24                 |
| Sludge drain (year) | 0.5                  | 3                    |
3.2. **Construction, Cost and Duration**

The modified septic tank construction was carried out by five workers and one supervisor with a construction duration of 2 days. Construction work consists of excavation of soil, installation of HDPE tanks, and piping network. The budget plan for the construction of the modified septic tank is presented in Table 6, and the construction cost is presented in Table 7.

| Tabel 6. The construction budget cost of the modified septic tank |
|---|---|---|---|---|
| No | Work List | Unit Price | Qty | Unit | Cost |
| 1 | Land clearance | Rp17,160.00 | 18.2 | m² | Rp313,770.60 |
| 2 | Disludging | Rp100,000.00 | 9 | tub | Rp900,000.00 |
| 3 | Soil excavation >1 m | Rp99,198.00 | 2.64 | m³ | Rp261,882.72 |
| 4 | Soil backfill | Rp38,623.00 | 2.06 | m³ | Rp79,563.38 |
| 5 | TB 110 tank and installment | Rp2,816,982.00 | 2 | tank | Rp5,633,964.00 |
| 6 | PVC pipe dia 4” (D) Rucika and installment | Rp65,984.00 | 4 | m | Rp263,936.00 |
| 7 | Elbow 4” (D) Rucika | Rp34,500.00 | 4 | piece | Rp138,000.00 |
| 8 | Cap. 4” | Rp29,900.00 | 1 | piece | Rp29,900.00 |
| **Total Cost** | | | | | Rp6,821,016.70 |

| Tabel 7. Actual construction cost of the modified septic tank |
|---|---|---|---|
| No | Work List | Unit Price | Qty | Cost |
| 1 | Mobilize -demobilization | Rp775,000.00 | 1 | Rp775,000.00 |
| 2 | TB 110 Tank and install | Rp2,850,000.00 | 2 | Rp5,700,000.00 |
| 3 | PVC pipe and installment | Rp450,000.00 | 1 | Rp450,000.00 |
| 4 | Land clearance | Rp550,000.00 | 1 | Rp550,000.00 |
| **Total Cost** | | | | Rp7,475,000.00 |

3.3. **The Existing and The Modified Septic Tank Performances**

The flow rate of the existing septic tank and the modified septic tank are presented in Figure 5. A comparison of the actual performance and design characteristics of the existing septic tank and its modifications can be seen in Table 8. The results of the wastewater quality effluent test for the concentrations of COD, TSS, NH₃-N, PO₄-P, respectively, are presented in Figures 6, 7, 8, and 9, then compared to the allowable quality standard values. The recapitulation of the mean flow rate and mean wastewater quality of the influent and effluent monitoring results are presented in Table 9.

![Figure 5](image-url)
Table 8. Design capacity and actual performance of the existing and the modified septic tank

| Unit                        | Existing Septic Tank | Modified Septic Tank |
|-----------------------------|----------------------|----------------------|
|                             | Design   | Actual   | Design     | Actual     | Design     | Actual     |
| Flowrate (m³/d)             | 0.525    | 0.531    | 0.825      | 0.123      | 1.050      | 0.123      |
| HRT (h)                     | 30.90    | 30.55    | 30.55      | 24.00      | 24.00      | 24.00      |
| HLRv (m³/d/m²)              | 0.78     | 0.79     | 0.79       | 0.12       | 0.14       | 0.12       |
| HLRs (m³/d/m²)              | 0.71     | 0.72     | 0.95       | 0.14       | 1.21       | 0.14       |
| COD volumetric loading (kg.COD/m³.d) | 1.02 | 1.03      | 1.03       | 1.31       | 1.58       | 1.58       |
| OLRs (kg.COD/m².d)          | 0.93     | 0.94     | 1.25       | 0.19       | 1.58       | 0.19       |
| Velocity (m/d)              | 0.71     | 0.72     | 0.95       | 0.14       | 1.21       | 0.14       |
| Distance (m)                | 1.467    | 1.467    | -          | 0.45       | -          | 0.32       |
| Time (h)                    | 76.13    | 76.13    | 76.13      |            |            |            |
| SRT (ϴc) (d)                | 182.50   | 152.08   | 1095       | 9125       | 1095       | 9125       |

Figure 6. COD of wastewater quality effluent: (a) the existing septic tank, and (b) the modified one.

The visual appearance of the biological process on the secondary treatment was no solids/garbage clog at the aeration and recirculation pump equipment, as shown in Figure 10. Modification of the septic tank to optimize the sedimentation process seems to have succeeded in overcoming the problem of the existing septic tank.

Figure 7. TSS effluent concentration of: (a) the existing septic tank and (b) the modified septic tank.
It is evident from the provided data that the modified septic tank demonstrates superior performance in terms of effluent quality, particularly in terms of COD, TSS, NH$_3$-N, and PO$_4$-P concentrations. The modified tank outperforms the existing one by achieving higher removal efficiencies for these parameters, which is a testament to its improved design and the implementation of more effective treatment mechanisms.

To further substantiate the effectiveness of the modified septic tank, the results of the monitoring study are presented in Table 9. The table contains detailed information on the flowrate, permissible concentrations, influent and effluent concentrations, removal efficiencies, and performance data for both the existing and modified septic tanks.

### Table 9. Monitoring Result of Average Wastewater Quality Concentration at the Influent and Effluent

|                       | Existing Septic Tank | Modified Septic Tank |
|-----------------------|----------------------|----------------------|
| **Flowrate (m$^3$/d)** | 0.298 (stdev 0.108)  | 0.082 (stdev 0.018)  |
| **COD**               | 100                  | 100                  |
| **TSS**               | 30                   | 30                   |
| **NH$_3$-N**          | 8                    | 8                    |
| **PO$_4$-P**          | -                    | -                    |
| **Permissible concentration standard (g/m$^3$)** | | |
| **Influent (g/m$^3$)** | 1313                 | 143                  |
| **Effluent (g/m$^3$)** | 607                  | 45                   |
| **Removal Efficiency** | 54%                  | 52%                  |
| **Performance data (NA)** | 100%                 | 42%                  |

* Regulation of Ministry of LHK No.68/2016, † Design, NA = Not appropriate

### 4. Result and Discussion

#### 4.1. Design and Construction Evaluation

The design specifications deferences for the existing septic tank and the modified one are shown in Table 5. The materials for the existing septic tank are made of reinforced concrete. In contrast, the modified septic tank was chosen to use a tank made of HDPE because, based on the specifications, HDPE material is strong enough, not easy to crack, waterproof/not easy to leak, while based on the construction implementation, it has several advantages, namely practicality and ease of handling as well as being widely sold/available in the market, easy installation and short construction time as well as ease of adding tanks and structuring plans/layouts for further development. The modified septic tank is designed for two tanks, capable of accepting a larger wastewater load with a large sludge chamber and a longer desludging period. The water treatment process in the modified septic tank is focused on the deposition of sand and TSS material, while further removal of organics and nutrient content is in the secondary treatment tank.

Figure 9. Effluent PO$_4$-P concentration of: (a) the existing septic tank & (b) the modification one.
Based on PUPR Regulation No. 28 of 2016 concerning Guidelines for Analysis of Unit Prices of Goods and Services in the Public Works Sector, and Governor of DIY Regulation No. 52 of 2020 concerning Standards for Regional Prices of Goods and Services in 2021, the construction costs for two circular-section sedimentation tanks made of reinforced concrete material with a total volume of 2.1 m$^3$ is ± Rp. 5.5 million, including land clearing, mobilization, and demobilization costs. The realization of the modified septic tank construction cost (Table 7) is slightly more expensive than the initial cost plan (Table 6), mainly due to the mobilization-demobilization costs, including excavation of the soil. The construction cost of 2 modified septic tanks made of HDPE is ± Rp 7.5 million, slightly more expensive than those made of reinforced concrete.

4.2. Performance Evaluation and Problem Solving

The monitoring flow rate of the existing effluent septic tank for one week in 2019 measured the number of toilet uses of defecation/urination at a maximum of 68 times/day or 0.531 m$^3$/d, a minimum of 23 times/day or 0.201 m$^3$/d, and an average of 35 times/day or 0.298 m$^3$/d (stdev 0.108 m$^3$/d) (Figure 5(a)). In the modified septic tank, the measured flowrate at the WWTP outlet for 30 days is a maximum of only 0.123 m$^3$/d, a minimum of 0.038 m$^3$/d, an average of 0.082 m$^3$/d (stdev 0.018 m$^3$/d) (Figure 5(b)). The Covid-19 pandemic condition caused the wastewater load into public toilets to drop to almost 0.25 times the average normal condition caused by a decline in Wisdom Park visitors and the closing of the Sunday Morning Market. Public toilets then were only used by Wisdom Park workers and some sports visitors.

The actual low influent flowrate to the modified septic tank (Table 8) has an impact on the actual high HRT (Hydraulic Retention Time) and SRT (Sludge Retention Time), as well as the low actual loading rate (Volumetric Hydraulic Loading Rate/HLRv, Surface Hydraulic Loading Rate/HLRs, Incoming COD Volumetric Loading Rate/OLRv, COD Surface Loading Rate/OLRs). All performance parameters at actual load during the Covid19 Pandemic in late October 2020 to January 2021, almost 1/7 times the normal design capacity. At a 0.25 times the normal capacity load, the modified septic tank performance act as a sedimentation tank has a very high TSS removal efficiency of 99%, even COD, NH$_3$-N removal efficiency can reach 94% and 58% (Table 9), higher than the initial target design (Table 2.) based on existing references. Good performance is indicated by 0% TSS effluent data that does not meet the quality standard, but 42% of COD effluent data and 88% of NH$_3$-N data still does not meet the allowable wastewater quality standard (Figure 6b., Figure 7b., Figure 8b.). Further research is still needed to prove the modified septic tank with its installed capacity is able to properly remove not only TSS, but also organics and nutrient removal with effluent quality that meets the permissible effluent of wastewater quality standard with an HRT design of ± 24-30 hours for normal wastewater loads. The 2.1 m$^3$ volume design of 2 tanks will have a maximum mud chamber of 1.86 m$^3$ (Table 5.), the frequency of desludging is once in 3 years at 2 hours HRT when the mud chamber is full.

The existing septic tank under normal conditions in 2019 had a wastewater load of almost four times the load during the Covid19 pandemic with a performance at HRT of ± 30 hours capable of achieving the target removal efficiency of COD, TSS, and NH$_3$-N of 54%, 96%, 69 %, respectively, exceeded the target removal efficiency research results, Nasr and Mikhaeil (2013) (Table 2.) [10], Lesmana (2018)
which is only 24-40% COD removal efficiency [5], Lohani et al. (2015) 30-50% COD removal and 60% TSS removal efficiency [13]. The frequency of desludging is once in 0.5 years because the available mud space is only ± 0.312 m³. The effectiveness of deposition, hydrolysis of organic COD molecules, and nitrification/denitrification of nutrient NH₃-N compounds is quite high in the septic tank in Wisdom Park. Unfortunately, 100% of the data on the quality of the effluent water (Table 9 and Figure 6 a., Figure 7a., Figure 8a.) still requires further processing in order to meet quality standards suitable for discharge to the environment. Despite its performance weaknesses, conventional septic tanks are superior in terms of methane gas energy sources that can be used further [14], reduction of sludge and waste volume up to 40% [10], low construction operation and maintenance costs and relatively small construction area needed when compared to other reactor technologies.

Minister of the Environment and Forestry Regulation (PerMenLHK) No. 68 of 2016 pointed out that effluent of domestic wastewater quality standard only requires NH₃ standards; it does not require a standard for PO₄-P effluent water quality parameters. In this study, the concentration of NH₃ was converted to NH₃-N because the NH₃-N laboratory analysis method was used to measure the effluent and influent. In the existing septic tank and its modifications, the NH₃-N removal performance is not effective, and it is suspected that the PO₄-P parameter also occurs. This research proves again that both the septic tank and the modification in which there is an anaerobic process still require further processing of the nutrients (PO₄-P, NH₃-N, and other Nitrogen nutrient compounds) [11], so that the effluent does not pollute the environment.

The sedimentation process with a good TSS removal efficiency in the modified septic tank (Figure 4.) confirmed that the tanks have succeeded in overcoming the main problem (Figure 1.). Another problem that is often found in septic tanks is that 1) the effluent pipe is clogged with excreta due to, 2) the dimensions of the septic tank do not meet the requirements, 3) there are no ventilation pipes and access holes to drain the sludge, 4) the location of the effluent flow is too close to the influent, 5) there is no barrier between influent and effluent [6]. The problem of wastewater leakage from septic tanks and soil/groundwater pollution in Bandung City and Denpasar City septic tanks was that they have never been dislodged in the last 5 years [15]; construction design errors [16], as well as design errors in the construction of the septic tank manhole on collection pipes in communal WWTP system in Yogyakarta [17] and surface water pollution due to the effluent quality from an inadequate environmental sanitation system [18].

5. Conclusion

The study evaluates the design, construction, commissioning and start-up performance of a modified septic tank design for individual or communal use. The new septic tank was benchmarked against an existing conventional septic tank. The conventional septic tank with a capacity of 0.676 m³ at HRT 24-30 hours has a good removal capacity. However, all water quality parameters of the effluent do not meet the wastewater quality standard and have problems with trash entering the tank. The modified septic tank design consists of 2 HDPE tanks with a capacity of 1.05 m³ each and 24-30 hours HRT. Due to COVID19 pandemic situation, the volumetric loading rate, surface loading rate, as well as organic loading rate was lower than normal. At ¼ of normal load capacity, the modified septic tank is able to produce very good TSS removal. All TSS monitoring data of the effluent meet the quality standard. The new design also overcame the problems of disturbance of solid waste, sand, and trash in pump operation and biological processes in the secondary treatment. At HRT, almost seven times the design criteria, the performance of COD and organic matter removal are very good at 94%. However, 40% of COD data, and 88% of NH₃-N data are still above the effluent standard. Therefore secondary treatment process is still needed. The result of this study shows that the modified septic tank has a better organic and TSS removal and can overcome the trash problem to the secondary treatment compared to the conventional one. The construction cost of the HDPE tank is more expensive than the conventional reinforced concrete tank, but considering the much longer sludge drain period, it can be less expensive in the long run. Since the modified septic tank design and construction is simple and suitable for solving water
pollution problems in a densely populated urban area, we recommend the modified septic tank to be adopted into the existing standard of SNI 2398-2017.

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References
[1] Environmental Protection Agency https://www.epa.gov/septic/types-septic-systems
[2] Saraswati SP, Ardion MV, Widodo YH and Hadisusanto S 2019 J. of Civil and Environmental Forum 5 47-5
[3] Dinas Lingkungan Hidup 2020 Dokumen Amdal Pekerjaan Pembangunan Hotel-Hotel di Kota Yogyakarta
[4] Hastuti E, Nuraeni R and Darwati S 2017 Jurnal Permukiman 5 47-5
[5] Lesmana RY 2018 Media ilmiah teknik lingkungan 3 21-24
[6] Soesanto S 2000 Tangki septik dan masalahnya Media Litbang Kesehatan 10 (1)
[7] Sperling MV 2007 Wastewater Characteristic, Treatment and Disposal (Biological Wastewater Treatment Series vol 1) (New York: IWA Publishing) p 23, 57
[8] Walter SA, Kjellström L, Nyhlin H, Talley NJ and Agréus L  2010 Study Scand J. Gastroenterol 45 556-66
[9] Colley W 2015 Nursing Times 111 112 – 15
[10] Nasr FA and Mikhaeil B 2013 J. Environmental Technology 34 2337-43
[11] Metcalf and Eddy 2003 Wastewater Engineering Treatment and Reuse (4th Edition) ed Tchobanoglous G, Burton FL and Stensel HD (New York: McGraw Hill) pp 396 – 406
[12] Park JK  2012 Water and Wastewater Treatment and Disposal (Lecture Hand Out) (Wisconsin University at Madison USA)
[13] Lohani SP, Chhetri A and Khanal SN 2015 J. of Environmental Science and Technology 9 292 – 300
[14] Nadi M El, Sabry T, Hassan K, Hamdy O and Helmy M 2017 Improving wastewater effluent of septic tank using filtration membranes International Journal of Science and Engineering investigations 6 (13)
[15] Abfertiawan MS, Bao PN, Pahilda WR and Hakim MF 2019 Jurnal ilmu lingkungan 17 443-451
[16] Bao PN, Abfertiawan MS, Kumar P and Hakim MF 2020 Challenges and opportunities for septage management in the urban areas of Indonesia: case study in Bandung city J. of Engineering and Technological Science 52(4)
[17] Diavid GH, Saraswati SP and Setiawan ABN 2018 Prosiding Seminar Nasional Terapan Teknologi vol 3 pp 43-52
[18] Badan Pusat Statistik Indonesia 2019