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Constructed Wetland as an Alternative for Domestic Wastewater Treatment in Residential Areas

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Abstract

Domestic wastewater management in developing countries continues to face challenges due to limited sanitation infrastructure, which can pollute the environment and compromise public health. One promising solution to overcome this problem is a Constructed Wetland (CW), a vegetation-based treatment system that mimics the natural mechanism of wetlands in filtering and decomposing pollutants. This study aims to design a Domestic Wastewater Treatment Plant using Combined Wetland technology, which includes an equalisation tank, a sedimentation tank, and Subsurface Flow CW. The case study was conducted in Lam Trieng Madani Housing, Aceh Besar Regency, which lacks an adequate wastewater treatment system. The technologies selected in this study are equalisation tanks, sedimentation tanks, and CW SSF type. CW is a complex technology for processing wastewater and has aesthetic value, making it very suitable for application in rural environments. The planning stages include identifying problems, reviewing various literature studies, collecting data, processing the data, planning the design, and creating a combined CW and DWTP design. The calculation results in the form of a processing unit design drawing for the equalization tank dimensions are 1.5 m × 0.5 m × 2.3 m with a required land of 0.75 m^2, a sedimentation tank with dimensions of 2 m × 1 m × 3.5 m, a required land of 2 m^2 and SSFCW dimensions of 19 m × 5 m × 1.2 m with a required land of 95 m^2. The total land area needed for this planning is 97.75 m^2.

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1. Introduction

In Indonesia, the Regulation of the Minister of Environment and Forestry Number 68 of 2016 stipulates the threshold of pollutant parameters before wastewater can be discharged into the environment. However, many settlements still use conventional treatment systems such as septic tanks or cubluks, which are not always effective in reducing pollutant levels to meet quality standards. In addition, *grey* *water* is often directly discharged into drainage or open land, causing degradation of surface water quality and spreading pathogens that are harmful to public health. Therefore, an effective, environmentally friendly, and low-cost treatment system that does not require high technical expertise is needed.

One promising alternative technology is the Constructed Wetland (CW). This vegetation-based treatment system mimics the natural processes of wetlands, filtering and decomposing pollutants through the interaction of microorganisms, filter media, and aquatic plants. CW has been used in various wastewater treatment applications, including domestic, agricultural, industrial, and landfill leachate treatment. The advantages of CW include high effectiveness in removing organic and inorganic pollutants, ease of maintenance, and high energy efficiency. Additionally, CW can be combined with other supporting systems, such as equalisation and sedimentation tanks, to enhance pollutant removal efficiency and prevent clogging of the filter media.

Domestic wastewater management is essential, especially in developing countries with limited sanitation infrastructure. Household wastewater, including black water (from toilets) and grey water (from daily activities such as bathing and washing), can pollute the environment if not managed properly. Approximately 80-90% of wastewater in developing countries is discharged untreated, thereby increasing the risk of water pollution and the spread of diseases [1]–[3]. Various pollutants in sewage, including TSS, BOD, COD, ammonia, oil, fat, and coliform, can disrupt ecosystems and pose a threat to public health. The government has regulated wastewater quality standards through [4]–[6]. However, many settlements still use conventional systems such as septic tanks and cubluks, which are less effective in reducing pollutant levels. In some areas, greywater is directly discharged into the drainage system without treatment. Therefore, more efficient, cheap, and easy-to-implement technology is needed.

One promising solution is a *Constructed Wetland* (CW), a vegetation-based system that mimics the natural process of wetlands to filter and decompose pollutants. CW has advantages in removing both organic and inorganic contaminants, is energy-efficient, and is easy to maintain. CW is divided into Free Water Surface Constructed Wetland (FWSCW) and Subsurface Flow Constructed Wetland (SFCW) based on its water flow [7]–[10]. SFCW is more effective in reducing odour and preventing the spread of disease. Studies show that SSFCW can remove up to 97% of TSS, 59-93.3% of BOD, 50.7-95.2% of COD, and 85.4% of nitrate. Although effective, CW faces challenges such as clogging the filter media due to the accumulation of suspended particles. To overcome this, equalisation and sedimentation tanks should be used before wastewater enters the CW. The equalisation tank helps stabilise the discharge and concentration of waste, while the sedimentation tank settles suspended particles to reduce the load on the CW [11]–[14]. This combination has been proven to increase processing efficiency and extend the life of the filter media.

Domestic wastewater treatment aims to eliminate or reduce pollutant parameters in domestic wastewater to meet the quality standards permitted for release into the environment. Wastewater treatment, based on the sequence of the treatment process, is divided into primary treatment, the initial process to remove colloidal suspended solids, and neutralisation, which generally uses physical or chemical processes. Secondary treatment is the process of removing dissolved organic pollutant compounds, which typically utilise biological processes. Tertiary or advanced *treatment* is the process of producing wastewater of a higher quality as desired. Physical, chemical, and biological processes can do it, or a combination of the three processes [15]–[18].

Based on the characteristics of the wastewater treatment process, it is divided into processes involving physical, chemical, and biological methods. Physical processing methods include filtration, sedimentation, adsorption, screening, and others. Chemical processing, including sedimentation using chemicals, coagulation, chlorination, and neutralisation. Biological processing is treating wastewater by utilising the life activities of microorganisms, such as oxidation ponds and activated sludge [19]–[22].

Standard wastewater treatment technologies include conventional systems, such as activated sludge systems, membrane bioreactors, and membrane separation systems. This technology requires a significant amount of energy for its mechanical components, resulting in high operating and maintenance costs. This makes it difficult for many developing areas to invest. CW technology utilises physical, chemical, and biological processes engineered from natural wastewater treatment, namely wetland vegetation. CW is a highly sustainable technology with a large capacity suitable for treating wastewater in developing countries [23]–[26]. A comparison of wastewater treatment technologies is presented in **Table 1**.

Table 1. Comparison of Wastewater Treatment Technologies [27]

Types of Technology	Excess	Lack
Constructed wetland (CW)	- Removes solids, heavy metals, and ±70% of bacteria - Low operational and maintenance costs - Capable of eliminating pathogens - Does not require skilled labour - Low energy consumption - Does not depend on imported spare parts - The resulting sludge is stable	- Requires local plants for optimal use - Requires large areas of land for large volumes of waste - Requires sedimentation units to prevent filter clogging - Process time is relatively long
Activated sludge process	- Efficient in processing - Requires less land - Suitable for small- & large-scale communities - Reduces organic matter & suspended solids (90-95%) - Produces energy from biogas	- Difficult to handle the sludge - Requires technical personnel for operation & maintenance - Low pathogen removal - Requires electricity supply - High investment & operational costs - pH fluctuations/toxicity inhibit bacterial growth
Rotating biological contractor	- Does not require expertise - Reduces volatile organic compounds (VOC) - Easy maintenance - Effective in reducing ammonia levels	- Requires energy for mechanical equipment - High investment & maintenance costs - Risk of clogging due to biomass accumulation
Waste stabilisation ponds/lagoons	- Does not require a lot of technical human resources - Low capital & operational costs - Effective in stabilising organic materials	- Requires a large area - Long processing time - Potential to cause odour - Triggers algae growth - Unstable pH & toxicity can inhibit bacteria
Membrane biological reactor	- Simple, robust & stable in operation - Requires small land - Suitable for small & large communities - Captures microbial biomass - Produces high-quality effluent	- High cost - Requires skilled labour - Spare parts are difficult to obtain - High energy consumption - Susceptible to pollutant contamination - Limited membrane life - High capital & maintenance costs
Trickling filters	- Requires less land - Easy operation - Capable of removing BOD - Less sludge produced - Easier mass transfer of pollutants - Effective in decomposing volatile pollutants	- Requires energy for mechanical equipment - High investment & operational costs - Risk of clogging due to biomass accumulation
Sequencing batch reactor	- Simple & flexible - Easy operation & maintenance - Stable effluent - Able to handle fluctuations in wastewater quality & quantity - High efficiency - Produces energy from biogas - Requires less land	- Requires time for sludge settling - Requires sludge to treat concentrated wastewater - Low pathogen removal - Requires skilled labour - Requires electricity supply - High investment & maintenance costs

Table 1 above explains the types and comparison of Wastewater Treatment technologies used in domestic wastewater treatment, often employed in c*onstructed wetlands* (CW*)*. The CW configuration of wastewater flow is divided into two main types: constructed wetlands with water (WCW) and subsurface flow-constructed wetlands (SFCW). WCW has water flowing above the surface of the media and is more susceptible to odours and the presence of disease vectors such as mosquitoes. Meanwhile, SSFCW has water flow below the surface of the filter media, which makes it more effective in reducing odour, preventing direct contact between wastewater and humans, and increasing pollutant removal efficiency. Previous studies have shown that SSFCW has a TSS removal efficiency of up to 97%, a BOD of 59.0-93.3%, a COD of 50.7-95.2%, and a nitrate removal of up to 85.4%.

This study proposes the application of *Combined CW* in Lam Trieng Madani Housing, Aceh Besar, Aceh Province, Indonesia, which currently lacks an adequate wastewater treatment system. Laboratory tests show that the location's TSS and total coliform levels exceed the established quality standards

[28]–[30]. Therefore, the combined CW-based WTP system, comprising an equalisation tank, sedimentation tank, and SFCW, is expected to be an effective and sustainable solution. With a nature-based technology approach, this study supports better wastewater management. It contributes to achieving Sustainable Development Goal (SDG) number 6: clean water and adequate sanitation.
Therefore, SFCW is a more suitable choice for residential environments. Specifically, this study aims to design a WTP system utilising CW Combination technology that aligns with the characteristics of existing wastewater. The novelty of this study lies in the combination of SFCW technology with equalisation tanks and sedimentation tanks, adapted explicitly for residential environments with limited sanitation infrastructure.

2. Methodology

The research method consisted of two main stages: identifying domestic wastewater characteristics and designing the DWTP system. This study aims to create a Domestic Wastewater Treatment Plant (DWTP) utilising Combined Constructed Wetland (CW) technology, which includes an equalisation tank, a sedimentation tank, and a *Subsurface Flow Constructed Wetland* (SFCW). The study's initial stage involved analysing domestic wastewater characteristics in Lam Trieng Madani Housing, Aceh Besar Regency. Wastewater samples were collected from household drains and analysed in the laboratory to measure water quality parameters, including *Total Suspended Solids* (TSS) and total coliform. This analysis aims to determine the extent to which these parameters exceed the threshold set in PerMenLHK No. 68 of 2016 concerning Domestic Wastewater Quality Standards. Based on the analysis results, the next stage is to design a DWTP system that follows the wastewater conditions at the research location. The proposed system comprises three main components: an equalisation tank to stabilise the flow and concentration of wastewater, a sedimentation tank to settle suspended particles, and SFCW, which serves as the primary unit that processes wastewater biologically and physically. The method of data collection is presented in **Table 1**.

Table 1: Data Collection Approach

No.	Data	Source	Method
1	Characteristics of domestic wastewater	Laboratory test results	Field sampling, laboratory testing, and calculation of average values for each sample parameter.
2	Land Conditions at Planning Location	Location survey and *Google Earth Software*	Land measurements are carried out through applications and direct observations on site, complemented by data analysis to ensure the accuracy and validity of the results.
3	Domestic wastewater quality standards	Regulation No. 68 of 2016 concerning Domestic Wastewater Quality Standards	Internet browsing involves searching for information through a global network that connects various data sources, including websites, images, videos, and more.
4	Planning literature	books and previous research	Internet browsing involves searching for information through a global network that connects various data sources, including websites, images, videos, and more.

The following is a research framework presented as a flowchart, starting with identifying the problem, searching for various literature studies related to the literature review, collecting the necessary data, processing the data, designing the plan, and creating the CW Combination WTP design. The planned WTP sequence scheme is illustrated in **Figure 2**.

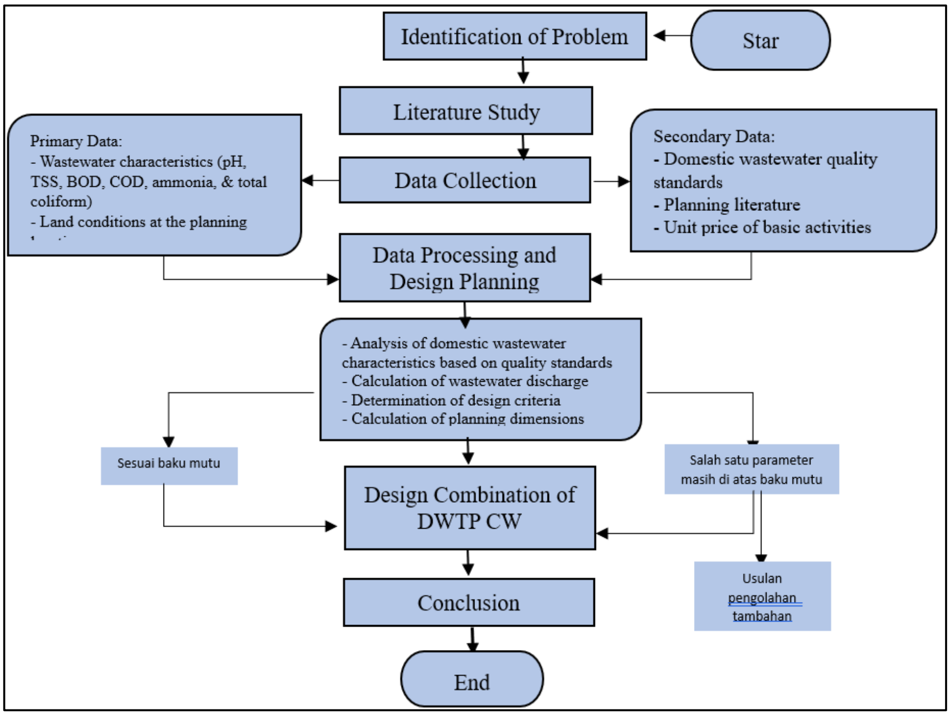


Figure 1: Research flowchart

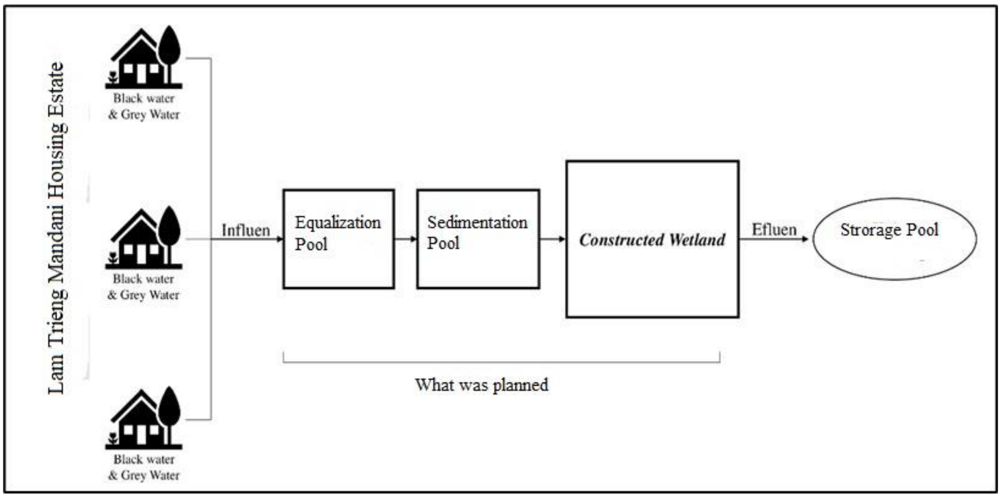


Figure 2: Planned DWTP Sequence Scheme

3. Result & Discussion

Domestic wastewater management is crucial in developing countries, including Indonesia, as inadequate sanitation infrastructure can lead to environmental pollution and health risks. Domestic wastewater, which consists of *black water* (waste from toilets) and *grey water* (waste from household activities such as bathing, washing clothes, and cooking), contains pollutants such as total suspended solids (TSS), *biochemical oxygen demand* (BOD), *chemical oxygen demand* (COD), ammonia, oil and fat, and coliform. Laboratory test results show that the quality of domestic wastewater, as indicated by the average sample test results, is characterised by the following parameters: pH 7.72, TSS 46 mg/L, BOD 15 mg/L, COD 42 mg/L, ammonia 3.87 mg/L, and total coliform count 53333/100 mL. This pollutant can disrupt aquatic ecosystems and pose a health risk if not managed properly. A 2019 United Nations (UN) report stated that around 80-90% of wastewater in developing countries is discharged directly into the environment without adequate treatment, increasing the risk of groundwater and surface water pollution.

Wastewater Discharge Calculation

Domestic wastewater discharge is calculated based on the assumption of the number of residents obtained and multiplied by the standard clean water requirement of 60 litres/person/day. The standard clean water requirement taken is based on the Directorate General of Human Settlements module of the Ministry of Public Works of the Republic of Indonesia, 2018, based on the category of villages with a population of <20,000 people, with a clean water requirement of 60-80 L/L/person/day. Calculation of clean water requirements for Lam Trieng Madani housing, namely:

Clean water requirement = 60 litres/person/day

$$\begin{aligned} Q_{\text{air bersih}} &= \text{Population} \times Q_{\text{clean water}} \\ &= 325 \text{ people} \times 60 \text{ litres/person/day} \\ &= 19500 \text{ litres/day} \\ &= 19.5 \text{ m}^3\text{/day} \end{aligned}$$

Calculation of wastewater discharge using a population approach with a percentage of domestic wastewater of 80% of the clean water needs of Lam Trieng Madani Housing. Calculation of domestic wastewater discharge using the equation

$$Q_{\text{waste water}} = (60\text{-}80\%) \times Q_{\text{clean water}}$$

The percentage of domestic wastewater = 80% of the clean water needs

$$\begin{aligned} Q_{\text{air limbah}} &= (60\text{-}80\%) \times Q_{\text{clean water}} \\ &= 80\% \times 19500 \text{ litres/day} \\ &= 15600 \text{ litres/day} \\ &= 15.6 \text{ m}^3\text{/day} \end{aligned}$$

The domestic wastewater discharge for this planning is at peak times. When calculating domestic wastewater discharge at peak times, first calculate the peak factor using the Ten-State Standard method. The calculation of peak time discharge using Equations 2 and 3 is as follows.

$$\begin{aligned} PF &= \frac{18+\sqrt{P/1000}}{4+\sqrt{P/1000}} \\ &= \frac{18+\sqrt{325/1000}}{4+\sqrt{325/1000}} \\ &= \frac{18,57}{4,57} \\ &= 4.06 \end{aligned}$$

$$\begin{aligned} Q_{\text{Puncak}} &= Q_{\text{rata-rata}} \times PF \\ &= 15600 \text{ litres/day} \times 4.06 \\ &= 63336 \text{ litres/day} \\ &= 63{,}336 \text{ m}^3\text{/day} \end{aligned}$$

Based on these calculations, the domestic wastewater discharge of Lam Trieng Madani Housing is 15,600 litres/day, and the domestic wastewater discharge at peak times is 63,336 litres/day.

Equalization Tank

The equalisation tank is designed to temporarily store wastewater, stabilising discharge and pollutant concentration fluctuations before it enters the next treatment unit. The primary function of this tank is to equalise the pollutant load, allowing the subsequent treatment process to run more effectively. According to Sandra (2022), the equalisation tank effectively reduces fluctuations in the pollutant load entering the CW.

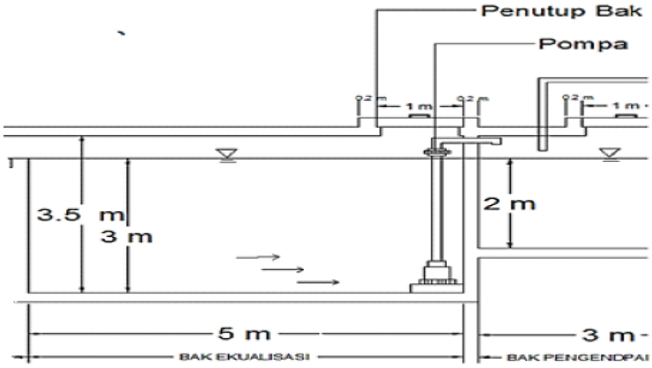


Figure 3: Equalisation Tank

When planning the equalisation tank, the HRT of the planned unit must be considered. The HRT of the equalisation tank should not exceed 30 minutes to prevent sedimentation. When cleaning the equalisation tank, domestic wastewater is diverted directly to the sedimentation tank, bypassing the equalisation tank. The calculation of the equalisation tank follows the planned design criteria.

Minimum water depth, H_{air}	= 2 m
Slope ratio	= 3:1
Length: Width ratio	= 3:1
Freeboard	= 0.3 m
HRT	= 25 minutes ≈ , 0.417 hours

- Equalisation Tank Volume

  $V = \frac{HRT}{24\ Hours} \times Q$

  $= \frac{0{,}417\ hours}{24\ Hours} \times 63{,}336\ m^3/day$

  $= 1.1\ m^3/hour$

- Area

  $A_{ef} = \frac{V}{h}$

  $= \frac{1{,}1\ m^3/hours}{2\ m}$

  $= 0.55\ m^2/hour$

- Length: Width Ratio = 3:1

3L × L	= A_{ef}
3L2	= $0.55\ m^2$
L^2	= $0.18\ m^2$
L	= $\sqrt{0{,}18}$m
L	= 0.42 m
Length of tub	= 3 × width of tub
	= 3 × 0.42 m
	= 1.26 m

- Check Volume

  $= \frac{V_{ef}}{Q} \times 24\ Hours$

  $= \frac{1{,}1\ m^3/hours}{63{,}336\ m^3/day} \times 24\ Hours$

  = 0.417 hours

  So, HRT is stated as appropriate

- Total Height of Tank

$H_{tot} = H_{air} + Fb$
$= 2 \text{ m} + 0.3 \text{ m}$
$= 2.3 \text{ m}$

- *Surface* Loading

  $SL = \frac{Q}{P \times L}$
  $= \frac{63{,}336 \text{ m}^3/\text{day}}{1{,}26 \text{ m} \times 0{,}42 \text{ m}}$
  $= 119.7 \text{ m}^3/\text{m}^2.\text{day}$

  Surface load during peak hours: 2 x surface load

  $SL_{peak} = 2 \times SL$
  $= 2 \times 119.7 \text{ m}^3/\text{m}^2.\text{day}$
  $= 239.4 \text{ m}^3/\text{m}^2.\text{day}$

- Peak Hours Stay Time

  Assuming the amount of waste is 2x the average amount of waste:

  $HRT_{peak} = ½ \times HRT$
  $= ½ \times 0.417 \text{ hours}$
  $= 0.21 \text{ hours}$

Based on these calculations, the planned dimensions of the equalisation tank are as follows.

- Length of the tub = 1.26 m ≈ 1.5 m
- Width of tub = 0.42 m ≈ , 0.5 m
- Tank depth = 2 m
- The total depth of the tank = 2.3 m

Sedimentation Tank

After passing through the equalisation tank, the wastewater flows into the sedimentation tank. Here, the remaining suspended particles are deposited through gravity, reducing the TSS load entering the CW unit. The Ministry of Public Works and Public Housing (2018) stated that the sedimentation tank plays a vital role in depositing suspended particles, thereby significantly reducing the TSS load entering the CW.

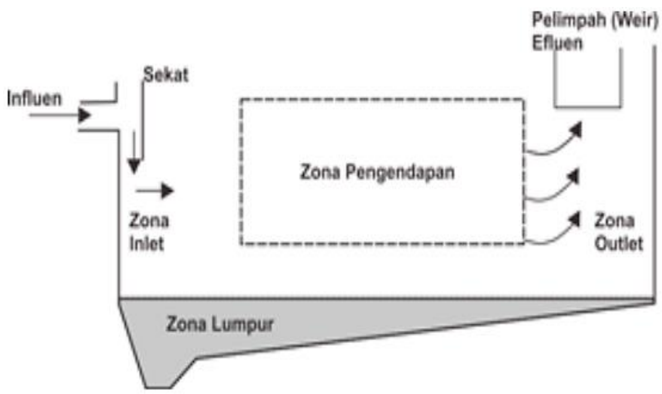


Figure 4: Sedimentation Tank *(Source: Ministry of PUPR, 2018)*

The calculation of the sedimentation tank according to the planned design criteria and assumptions is as follows:

Tank depth = 3 m
Length: Width Ratio = 2:1
Surface load = 35 $\text{m}^3/\text{m}^2.\text{day}$

Freeboard = 0.5 m
HRT = 2 hours ≈ , 0.08 days

TSS concentration = 46 mg/L ≈ 0.046 Kg/m ^{3}

- Sedimentation Tank Volume
  $V = Q \times HRT$
  $= 63{,}336\ m^3/day \times 0.08\ days$
  $= 5.1\ m^3$
- Surface area
  $area = \frac{V}{h}$
  $= \frac{5{,}1\ m^3}{3\ m}$
  $= 1.7\ m^2$
- Total Height
  $H_{tot} = H_{air} + Fb$
  $= 3\ m + 0.5\ m$
  $= 3.5\ m$
- Length: Width Ratio = 2:1
  $2L \times L$ = Surface area
  $2L^2 = 1.7\ m^2$
  $L^2 = 0.85\ m^2$
  $L = \sqrt{0{,}85} m$
  $L = 0.92\ m$
  Length of tub = 2 × width of tub
  = 2 × 0.92 m
  = 1.84 m
- HRT Suitability
  $HRT = \frac{V}{Q}$
  $= \frac{5{,}1\ m^3}{63{,}336\ m^3\ /day}$
  = 0.08 days

So, HRT is stated as appropriate

- Sludge Production
  = TSS concentration × $Q_{Air\ limbah}$ × TSS removal efficiency
  = 0.046 kg/m ^{3} × 63.336 m ^{3} /day × 60%
  = 1.75 kg/day

The production of sludge in the sedimentation tank is 1.75 kg/day. Therefore, in one year, the total output is 1.75 kg/day × 365 days, which equals 638.75 kg/year.

- BOD Set Aside
  = BOD concentration × BOD removal efficiency
  = 15 mg/L × 32%
  = 4.8 mg/L
  Effluent BOD = Inlet BOD - Removed BOD
  = 15 mg/L - 4.8 mg/L
  = 10.2 mg/L

Based on these calculations, the dimensions of the planned sedimentation tank are as follows.

- Length of tub = 1.84 m ≈ 2 m
- Width of the tub = 0.92 m ≈ 1 m
- Tank depth = 3 m

- The total depth of the tank = 3.5 m

Subsurface Flow Constructed Wetland (SSFCW)

The last unit in the system is the SSFCW, which is designed with water flowing below the surface of the filter media. The SSFCW was chosen because it reduces odour, prevents direct contact between wastewater and humans, and increases pollutant removal efficiency. Loshinta et al. (2020) stated that SSFCW is more effective in reducing odour, preventing direct contact between wastewater and humans, and increasing pollutant removal efficiency.

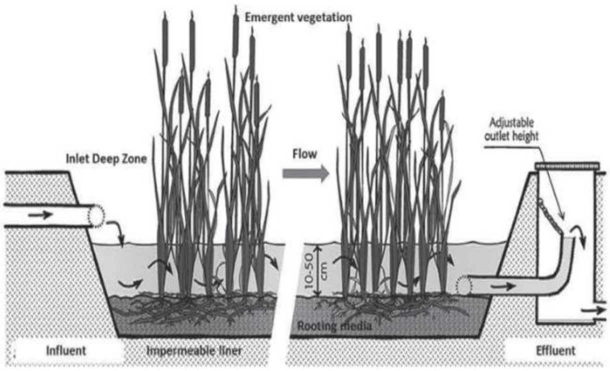
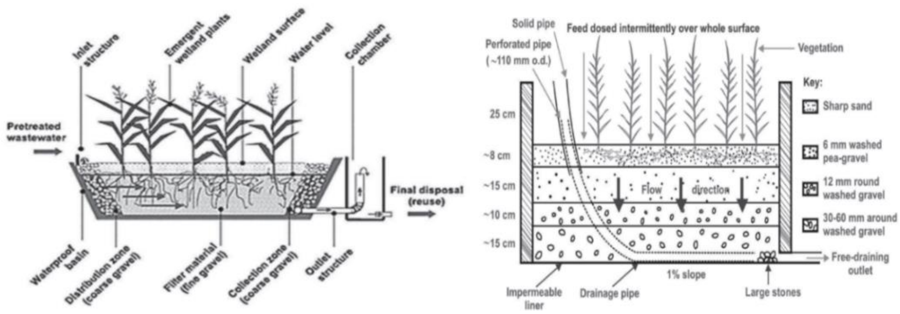


Figure 5: *Free water surface* (FWS) *(Source: Zidan and Mohammed, 2018)*



(a) (b)

Figure 6: SFCW Horizontal Flow (a) and Vertical Flow (b) *(Source: Zidan and Mohammed, 2018)*

The CW calculation follows the planned design criteria.
CW base clay layer with permeability K= 10^{-6} cm/s

Freeboard	= 30 cm
Side slope	= 4:1
Pool depth	= 0.9 m
Depth of wastewater	= 75 cm ≈ 0.75 m
Filter material	= Fine gravel Ø12-20, Coarse gravel Ø20-40 mm
Maximum BOD loading rate	= 100 kg/ha.day
Length: width ratio	= 4:1
Average water depth	= 0.15 m
Base slope ratio	= 5:1
Peak discharge	= 63,336 m^3/day
TSS concentration	= 46 mg/L
BOD concentration	= 15 mg/L
COD concentration	= 42 mg/L
Ammonia Concentration	= 3.87 mg/L
Total coliform concentration	= 53333 Number/100 mL
Water temperature, T_A	= 29 °C

a. CW Dimension Calculation

- Removal Constant Rate

Table 3. Temperature Coefficients for Rate Constants

Parameter	BOD Elimination
T_R	20
Residue (mg/L)	6
K_R (/day)	1,104
θ_R	1.06

(Source: Ministry of PUPR, 2018)

$K_T = K_R \theta_R^{(T_A - T_R)}$

$= 1.104 \times 1{,}06^{(29-20)}$

$= 1.86$ / day

- Surface Area Required

The porosity of the media (ε)used is 0.4 for gravel with a diameter of 25 mm. The BOD removal efficiency in SSFCW ranges from 59.0% to 93.3%. So,

BOD Removed = BOD Concentration × BOD Removal Efficiency
= 15 mg/L × 60%
= 9 mg/L

Effluent BOD = Inlet BOD - Removed BOD
= 15 mg/L – 9 mg/L
= 6 mg/L

$$A_{CW} = \frac{Q(\ln C_0 - \ln C_e)}{K_T y \varepsilon}$$

$$= \frac{63{,}336\ m^3/day(\ln 15 mg/L - \ln 6\ mg/L)}{1{,}86/hari \times 0{,}9\ m \times 0{,}4}$$

$$= \frac{63{,}336\ m^3/day(0{,}92)}{0{,}67\ m/day}$$

$= 86.97\ m^2$

- Length: Width Ratio = 4:1

4L × L = Surface area
4L2 = $8^6, 97\ m^2$
L^2 = 2 1, 74 m^2
L = $\sqrt{21{,}74}$ m
L = 4, 66 m
Length of the pool = 4 × width of the tub
= 4 × 4.66 m
= 1 8, 64 m

- Hydraulic Retention Time (HRT) Compliance

$$= \frac{\text{Pool surface area} \times \text{Pool depth} \times \text{Media porosity}}{\text{Debit average influence}}$$

$$= \frac{86{,}97\ m^2 \times 0{,}9\ m \times 0{,}4}{63{,}336\ m^3/hari}$$

$$= \frac{31{,}31\ m^3}{63{,}336\ m^3/hari}$$

= 0.5 days

Based on the calculation of HRT suitability, it can remove suspended pollutants in 0.5-3 days. However, it has been unable to remove dissolved pollutants, which require 5-14 days to remove.

- Hydraulic Load Rate (HLR) Compliance

$$= \frac{\text{Debit average influence}}{\text{Surface area of the pool}}$$

$= \frac{63{,}336 \text{ m}^3/\text{day}}{86{,}97 \text{ m}^2}$

= 0.73 m/day

b. Processing Unit Efficiency

- BOD

  Effluent BOD $= C_i \exp\left(\frac{-A_{CW} K_T y \varepsilon}{Q}\right)$

  $= 15 \text{ mg/L} \exp\left(\frac{-86{,}97 \text{ m}^2 \times 1{,}86 \text{ /day} \times 0{,}9 \text{ m} \times 0{,}4}{63{,}336 \text{ m}^3/\text{day}}\right)$

  $= 15 \text{ mg/L} \exp(-0{,}92)$

  = 15 mg/L × 0.398

  = 5.97 mg/L

  Elimination efficiency $= \frac{\text{Influent concentration} - \text{Effluent concentration}}{\text{Concentration of influence}} \times 100\%$

  $= \frac{15 \text{ mg/L} - 5{,}97 \text{ mg/L}}{15 \text{ mg/L}} \times 100\%$

  = 60%

- COD

  Estimated elimination = 95%

  Effluent COD = C_i – 95%

  = 42 mg/L - 95%

  = 2.1 mg/L

- TSS

  TSS effluent $= C_i\,(0{,}1058 + 0{,}0011 \text{ HLR})$

  $= 46 \text{ mg/L}\,[0{,}1058 + (0{,}0011 \times 0{,}73 \text{ m/hari})]$

  = 4, 9 mg/L

  Elimination efficiency $= \frac{\text{Influent concentration} - \text{Effluent concentration}}{\text{Concentration of influence}} \times 100\%$

  $= \frac{46 \text{ mg/L} - 4{,}9 \text{ mg/L}}{46 \text{ mg/L}} \times 100\%$

  = 89%

- Ammonia

  ammonia $= C_i \exp\,[-0.126(1.008)^{T-20}\,\text{HRT}]$

  $= 3.87 \text{ mg/L} \exp\,[-0.126(1.008)^{29-20}\,(0.5 \text{ days})]$

  = 3.87 mg/L exp (-0.068)

  = 3.87 mg/L × 0.934

  = 3.6 mg/L

  Elimination efficiency $= \frac{\text{Influent concentration} - \text{Effluent concentration}}{\text{Influent concentration}} \times 100\%$

  $= \frac{3{,}87 \text{ mg/L} - 3{,}6 \text{ mg/L}}{3{,}87 \text{ mg/L}} \times 100\%$

  = 7%

- *Total coliform*

  Effluent concentration $= \frac{C_i}{[1 + (\text{HRT} \times K_T)]^n}$

  $= \frac{53333 \text{ Total/100 mL}}{[1 + (0{,}5 \text{ day} \times 1{,}86/\text{day})]^1}$

  $= \frac{53333 \text{ Total/100 mL}}{1{,}93}$

  = 27 633.7 Amount/100mL (does not meet quality standards)

  Elimination efficiency $= \frac{\text{Influent concentration} - \text{Effluent concentration}}{\text{Influent concentration}} \times 100\%$

$$= \frac{53333 \text{ Total/100 mL} - 27633{,}7 \text{ Total/100 mL}}{53333 \text{ Total/100 mL}} \times 100\%$$

$= 48\%$

Total elimination *of coliforms at HRT 0.5 days has not been able to meet the quality standards according to Regulation of the* Ministry No. 68 of 2016 concerning Domestic Wastewater Quality Standards. Therefore, a recalculation was performed to determine the total coliform removal at different HRTs.

- Surface Area Required to Achieve *Total Removal Process Coliform*

$$= \frac{\text{HRT} \times \text{average influent discharge}}{\text{pond depth} \times \text{media porosity}}$$

$$= \frac{10 \text{ day} \times 63{,}336 \text{ m}^3/\text{day}}{0{,}9 \text{ m} \times 0{,}4}$$

$$= \frac{633{,}36 \text{ m}^3}{0{,}36 \text{ m}}$$

$= 1759, 3 \text{ m}^2$

- Length: Width Ratio = 4:1

$4L \times L$ = Surface area

$4L^2 = 1759, 3 \text{ m}^2$

$L2 = 439.8 \text{ m}^2$

$L = \sqrt{439{,}8} \text{ m}$

$L = 20.97 \text{ m}$

Length of tub = 4 × width of tub

= 4 × 20.97 m

= 83.88 m

- Hydraulic Retention Time (HRT) Compliance

$$= \frac{\text{Pool surface area} \times \text{Pool depth} \times \text{Media porosity}}{\text{Average influent discharge}}$$

$$= \frac{1759{,}3 \text{ m}^2 \times 0{,}9 \text{ m} \times 0{,}4}{63{,}336 \text{ m}^3/\text{day}}$$

$$= \frac{633{,}34 \text{ m}^3}{63{,}336 \text{ m}^3/\text{day}}$$

= 10 days (appropriate, can remove dissolved pollutants 5-14 days)

- Hydraulic Load Rate (HLR) Compliance

$$= \frac{\text{Average influent discharge}}{\text{Surface area of the pool}}$$

$$= \frac{63{,}336 \text{ m}^3/\text{day}}{1759{,}3 \text{ m}^2}$$

= 0.04 m/day (corresponding, 0.01-0.05 m/day)

So, the *total coliform removal*,

$$\text{Effluent concentration} = \frac{C_i}{[1+(\text{HRT} \times K_T)]^n}$$

$$= \frac{53333 \text{ Total/100 mL}}{[1+(10 \text{ day} \times 1{,}86 \text{ /day})]^1}$$

$$= \frac{53333 \text{ day/100 mL}}{19{,}6}$$

= 27 21, 1 Amount/100 mL (already meets quality standards)

$$\text{Elimination efficiency} = \frac{\text{Influent concentration} - \text{Effluent concentration}}{\text{Influent concentration}} \times 100\%$$

$$= \frac{53333 \text{ Total/100 mL} - 2721{,}1 \text{ Total/100 mL}}{53333 \text{ Total/100 mL}} \times 100\%$$

$= 95\%$

Based on these calculations, the pond's surface area required to remove total coliforms to meet the quality standards necessitates an extensive land area of 1759.3 m². In this planning, the land area is quite limited. Hence, the land area used for CW planning is 86.97 m^2. With HRT at 0.5 days, TSS parameters can be removed with a percentage of 89% below the quality standard, and total coliforms at 48%. However, it has not yet met the quality standard.
The dimension design of each component is based on the wastewater characteristic data and applicable design standards. The volume of the equalisation tank is determined based on the daily discharge fluctuation of wastewater, while the sedimentation tank is designed to provide sufficient residence time for particles, as shown in the following Figure:

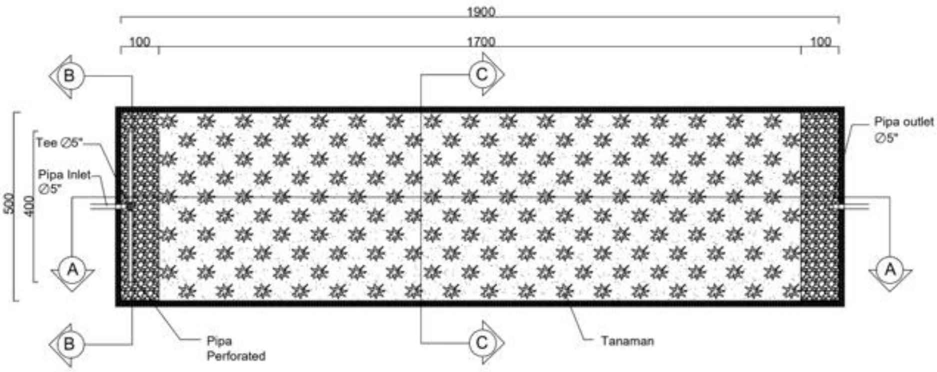


Figure 7: *Constructed Wetland (CW) plan*

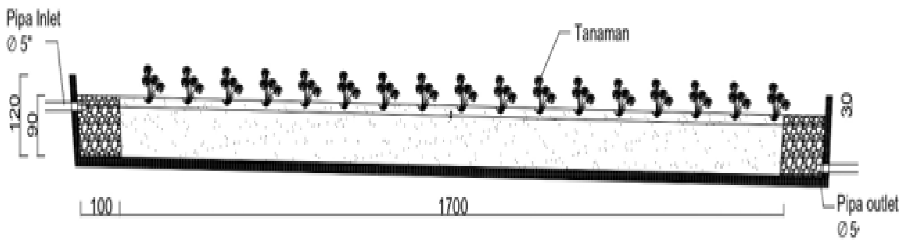


Figure 8: Section of AA Constructed Wetland (CW)

Figures 7 and **8** are the plans for a Constructed Wetland (CW), a wastewater treatment system based on artificial wetlands that utilises plant media to enhance water quality. The elements in the plan of the building are:

1. System Dimensions
    - Total length: 1900 mm (1.9 m)
    - Main area length: 1700 mm (1.7 m)
    - System width: 500 mm (0.5 m)
    - Inlet and outlet space: 100 mm on each side
2. Main Components
    - Inlet Pipe (Ø5”):
        - Functions as an inlet for wastewater into the system.
        - There is *a tee joint* (Tee Ø5”) for the initial wastewater distribution.
    - Perforated Pipe:
        - This pipe helps to spread wastewater evenly into the substrate media.
        - Usually planted in a layer of sand or gravel to improve filtration.
    - Plant:
        - Spread throughout the wetland media.
        - Plays a role in absorbing pollutants and assisting in the phytoremediation process.
    - Outlet Pipe (Ø5”):
        - The place where water comes out after filtration and purification by plants and substrate media.
3. Processing Process in CW

- Wastewater entry through inlet pipe: Wastewater starts entering the system through the Ø5" pipe and is distributed through the *tee joint*.
- Distribution through perforated pipes: Wastewater flows slowly in the substrate media, which consists of gravel and sand.
- Purification process by plants:
  - Plants absorb organic matter and excess nutrients such as nitrogen and phosphorus.
  - Microorganisms present in the substrate media aid in the decomposition of pollutants.
- Cleaner water exits through the outlet pipe after passing through the entire system.

This image shows a *Subsurface Flow Constructed Wetland* (SSF-CW) system where water flows beneath the surface of the soil/media, thereby reducing odour and direct human contact.

4. Conclusion

Laboratory tests, the results of the TSS and *total coliform parameter tests* exceeded the maximum levels of domestic wastewater based on PerMenLHK No. 68 of 2016 concerning Domestic Wastewater Quality Standards, which states that domestic wastewater produced from households, businesses or activities has the potential to pollute the environment, so wastewater treatment is needed before being discharged into the environmental media. Based on this, domestic wastewater treatment using a combination of CW is required to reduce the parameter values so that they do not exceed the maximum levels of domestic wastewater quality standards set and are safe if released into the environment.

1. The peak discharge of domestic wastewater at Lam Trieng Madani Housing is 63,336 m^3/day. The quality of domestic wastewater, as indicated by the average sample test results, is as follows: pH 7.72, TSS 46 mg/L, BOD 15 mg/L, COD 42 mg/L, ammonia 3.87 mg/L, and total coliform count 53333/100 mL. Based on PerMenLHK No. 68 of 2016 concerning Domestic Wastewater Quality Standards, two parameters exceed the quality standards: TSS and *total coliform.*
2. IPALD dimensions with CW technology Combination for equalization tank dimensions of 1.5 m × 0.5 m × 2.3 m with a required land area of 0.75 m^2, sedimentation tank with dimensions of 2 m × 1 m × 3.5 m land area required 2 m^2 and SFCW dimensions of 19 m × 5 m × 1.2 m with an area of land needed of 95 m^2. The total land area required in this planning is 97.75 m^2.

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