UNIVERSITI MALAYSIA PERLIS

MODIFICATION OF LEACHATE TREATMENT PLANT COMPONENTS AND MANAGEMENT OF TREATED EFFLUENT IN RIMBA MAS SANITARY LANDFILL PERLIS

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Technical Report

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PREFACE

This report is focused on the modification of component in Rimba Mas Sanitary Landfill on-site leachate treatment plant (LTP). There are some components of this LTP that are affected by certain seasons (drought and monsoon). These components are unable to operate as it should especially during the aforementioned conditions. Rainfall volume plays a role in the volume of leachate generated as the landfill cells are not enclosed.

After a site visit and interview session with the operators of Rimba Mas Sanitary Landfill, they addressed that during drought, the generated leachate volume is insufficient for the operation of sequencing batch reactor (SBR), thus the whole LTP will come to a full stop. While during monsoon, the leachate holding pond do not have sufficient volume to store the large volume of generated leachate. This leads to a conclusion that both the SBR and leachate holding pond should be modified to ensure continuous leachate treatment regardless of the seasons.

The LTP of a sanitary landfill will still be working even long after the sanitary landfill is full and closed. The modification to these two components were designed with that in mind, where it can still be used throughout the lifespan of the LTP until the sanitary landfill fully matures and no more leachate are produced.

CHAPTER 1

INTRODUCTION

1.1 Project Introduction

Rimba Mas Sanitary Landfill is a new landfill with an estimated lifespan of 10 to 15 years with complete facilities such as administrative building, weighbridge, leachate treatment plant and waste disposal cells for domestic, garden and bulk waste. For the past 4 years the Rimba Mas landfill have been operating after the landfill at Padang Siding was closed. Waste from residential, industrial and other places around Perlis are dumped at this landfill. Generation of waste in the cell results in production of leachate.

Leachate generated are the by-products from the municipal solid wastes that formed in landfill which have their own physical, biological and chemical changes from time to time with high strength and toxicity. Leachate production in landfills can be a major problem if it is not handled properly. The composition of leachate varies depending on the degree of composition, composition of waste, extreme weather and moisture content of waste. The treated leachate is reused again as it complies with the standard parameters and guidelines by the DOE.

It is essential to control the volume of treated leachate and ensure all the leachate are treated before discharged. This affects the lifespan of landfill even after it is been closed down as the leachate production is continuous even after all the cells are closed. Thus, construction of a larger raw leachate pond, additional of tertiary treatment and pump sump are necessary.

1.2 Statement of Problem

Leachate generation from municipal solid waste (MSW) landfills have been a major problem that brings treat to surface water and groundwater (Raghab, Abd El Meguid, & Hegazi, 2013). Exposure to groundwater can affect human health and also the environment. Due to that leachate must be treated according to Department of Environment (DOE) standards and guidelines before discharging or reusing it. A proper well-equipped leachate treatment plant is necessary to treat and discharge the leachate to avoid any pollution and public health problem.

Rimba Mas is currently experiencing insufficient and over production volume of leachate during drought and monsoon season respectively. Insufficient amount of leachate leads to shutting down of leachate treatment plant which requires the whole process to start back again once there is sufficient leachate. The microbes in the SBR needs to be breed again which consumes more time and cost.

While during monsoon season the volume of leachate increases drastically due to increase in rainfall which results in excessive production of leachate for that period. The current leachate storage pond is unable to store the excess leachate which leads to accumulation of leachate in landfill cells. This may lead to alteration of leachate characteristics and cause it to be harder to treat. Other than that during this period there will be more resources used (electricity, chemical).

1.3 Statutory Requirement

The project to construct leachate treatment plant (LTP) is referred to the Malaysian Regulatory; Department of Environmental (DOE) and Environmental Quality Act of 1974 under Control of Pollution from Solid Waste Transfer Station and Landfill Regulations 2009. The design of LTP must comply the requirements and regulations which considers the environmental effects prior with designing of the plan. Sections 21, 24 and 51 under the Environmental Quality Act 1974 [Act 127] are exercised after consultation with the Environmental Quality Council to come out with the regulations to be followed:

- Operation of solid waste transfer station and landfill

An owner or occupier should strictly control noise, dust, odor, and air pollution, pollution of the soil, surface water, ground water, entry and disposal of scheduled wastes to operate a solid waste transfer and landfill.

- Monitoring of leachate discharge

An owner or occupier should ensure to monitor parameters set by the DOE at his own expense-

a) Concentration of ammoniacal nitrogen in leachate monitored on a continuous basis using online instrumentation system linked to DOE;
b) Main parameters listed in the first column of the Second Schedule for leachate discharge;
c) Install monitoring equipment, recording equipment, sampling equipment and flow-meters for monitoring purposes

- Provision of leachate treatment system

An owner or occupier shall operate a solid waste transfer station or landfill with a leachate treatment system.

- Proper operation of leachate treatment system

An owner or occupier should operate the leachate treatment system in accordance with sound engineering practice and ensure all components are in good condition. Sound engineering practice is referred to an operational characteristics which are maintained within the normal range that are commonly used.

- Performance monitoring of leachate treatment system

An owner or occupier shall monitor the compounds of leachate treatment system and fully equip the facility with relevant equipment or instruments. The monitoring should be done daily to indicate the treatment process is functional and capable to treat the leachate.

- Competent person

A competent person certified by the Director General shall be in charge in supervising the operation of leachate treatment system. The competent person shall be in duty whenever the leachate treatment system is operating and monitor acceptable conditions for leachate discharge.

- Acceptable conditions for discharge of leachate

Leachate substances concentration greater than specified in the third column of the Second Schedule shouldn’t be discharged into any soil or inland waters or Malaysian waters.

- Prohibition against leachate discharge or release through by-pass

An owner or occupier shouldn’t by-pass any discharge or released leachate into soil or inland waters or Malaysian waters. The term by-pass means intentional diversion of leachate diversion of leachate discharge from any portion of a leachate treatment system.

- Acceptable conditions for discharge of leachate

Refer Second Schedule (Regulation 13) Acceptable Conditions for Discharge of Leachate.

1.4 Project Objectives

This project needs to be complying with the following objectives:

1. Treat landfill leachate and adhere to Acceptable Conditions for Discharge of Leachate of Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 to ensure safety and health of the environment and public.

2. Identify different approach for storage of excess production of leachate to prevent retention of leachate in solid waste cells.

3. Determine alternative biological treatment method that could ensure continuous leachate treatment during minimum leachate influent flow.

1.5 Project Scope

The scope of the study is to modify the LTP components for continuous leachate treatment during extreme weather such as drought and monsoon season. The implementation of several components of LTP are necessary to replace or increase the existing equipment such as pump sump, biological process (SBR) and raw leachate holding pond to ensure LTP operates smoothly throughout the years under any condition. LTP components will be listed out into advantages, disadvantages and costing. In addition, scope of project also recommends tertiary treatment process to make zero discharge to dischargeable LTP effluent. Standard of leachate discharged from other countries like Japan and Singapore were referenced with the 29 parameters that must be in compliance to treated leachate in Malaysia. All design standards and specifications are according to the Environmental Quality Act 1974. Prior to construction, health, safety and environment assessment which are necessary are completed.

CHAPTER 2

PROJECT OPTION

2.1 Site Selection

The sanitary landfill site is located at Rimba Mas, Mukim Titi Tinggi, Perlis, Malaysia. The coordinate of the location is at 6.64 ^{0}N, 100.29 ^{0}E. The site selection for landfill chosen must be able to sustain the increase in population, expansion of service area coverage, increase in commercial activities and increase in per capita generation rate. The location of the project is surrounded by rubber plantation and located far from residential areas to prevent any odor problems and safety issues to the public due to landfill construction. The area allocated for the project is 30 hectares (74 acres) to build landfill cells, leachate treatment plant, administration building and weighing stations. The estimated population are 227,025 with 120 tonnes waste generated per day.

The location of Rimba Mas Sanitary Landfill on a map and the plan view of the location is as shown in Figure 2.1: Location map of Rimba Mas Sanitary Landfill and Figure 2.2: Specified location of Rimba Mas Sanitary Landfill respectively. The location of the leachate treatment plant (LTP) within the sanitary landfill is as shown in Figure 2.3: Specified location of LTP in Rimba Mas Sanitary Landfill.

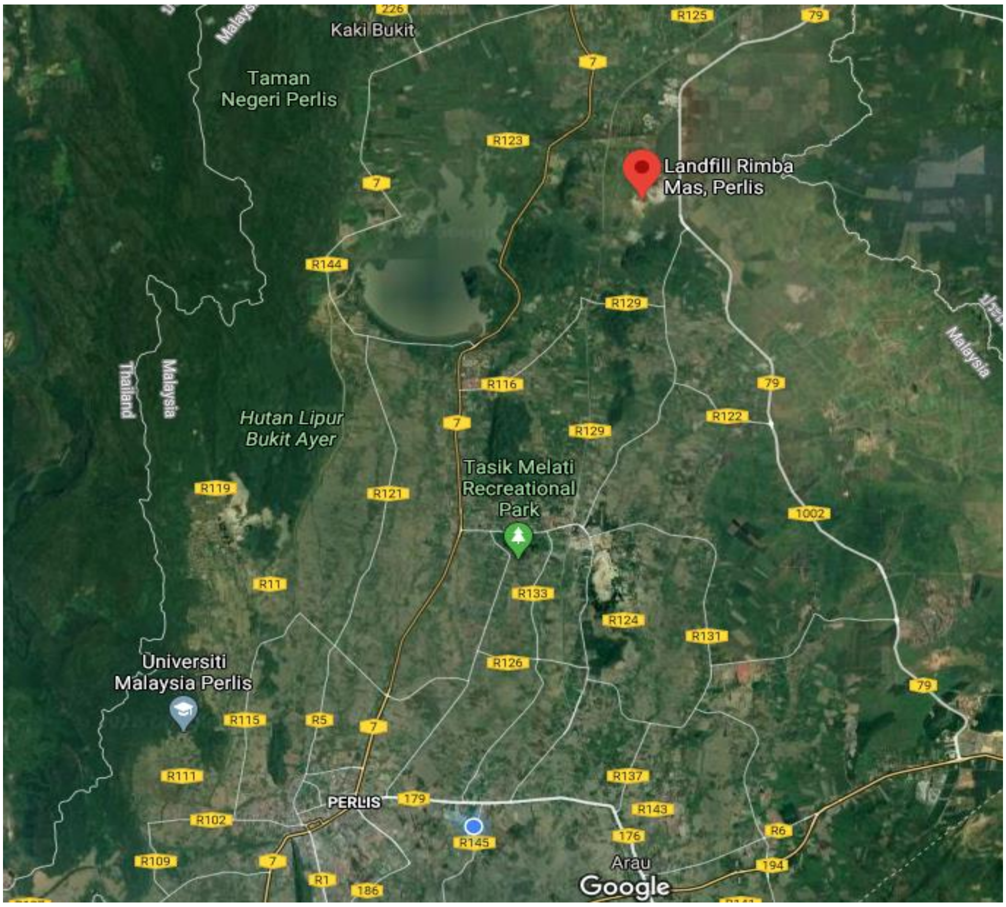


Figure 2.1: Location map of Rimba Mas Sanitary Landfill

Figure 2.2: Specified location of Rimba Mas Sanitary Landfill

Figure 2.3: Specified location of LTP in Rimba Mas Sanitary Landfill

2.2 Plan Layout

The plan layout of Rimba Mas Sanitary Landfill LTP is as shown in Figure 2.4: Plan layout below. The red line indicates the leachate movement process, which leachate is collected from municipal landfill cells and transfers to raw leachate holding pond via pump sump. Then, leachate is transported to lamella clarifier to undergo coagulation and flocculation. Leachate flows continually to SBR pond for treatment and DAF feed pond as well as DAF tank to removal of suspended matter followed by monitoring pond before sending the treated effluent to storage tank for reusable water resources within the vicinity. Blue line indicates sludge flow within the process treatment unit.

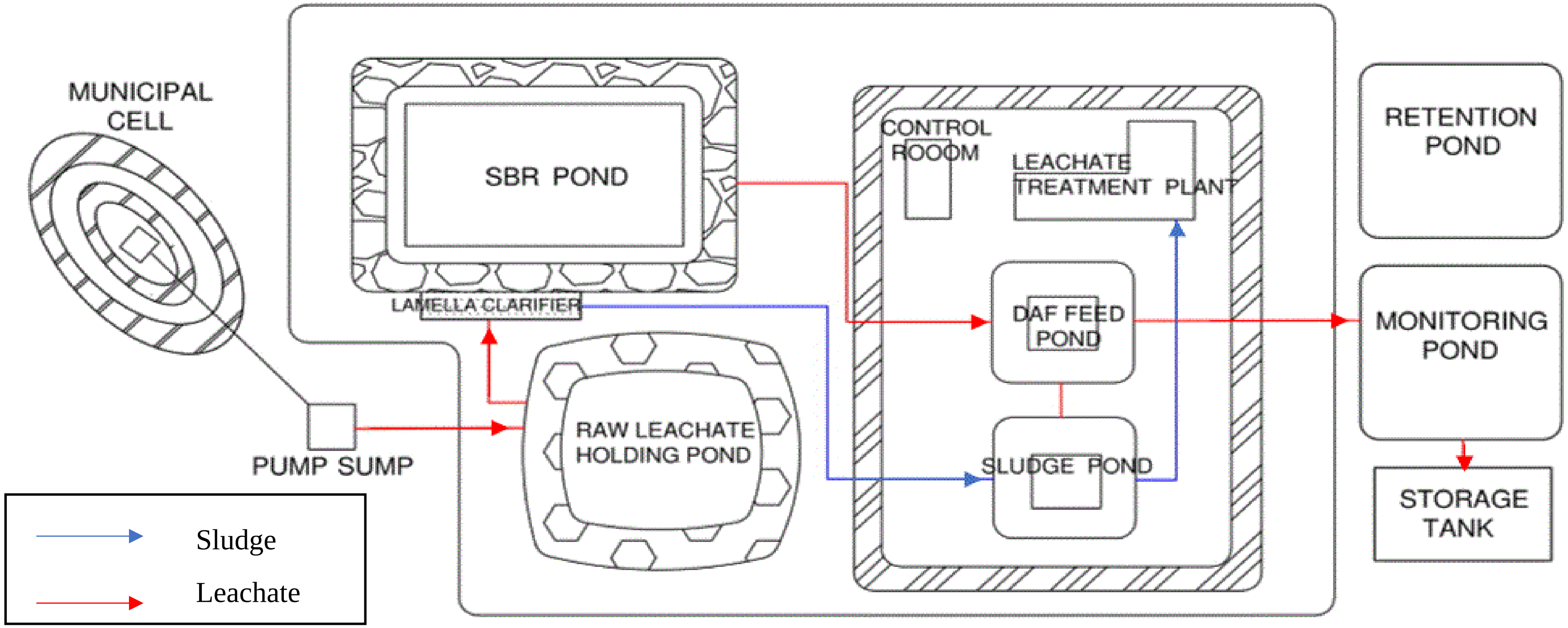


Figure 2.4: Plan layout

2.3 Process Flow Diagrams

The existing leachate treatment process flow diagram and the proposed modification to be done to the existing process flow are as shown in Figure 3.5: Process flow of existing leachate treatment plant and Figure 3.6: Process flow of modified leachate treatment plant respectively.

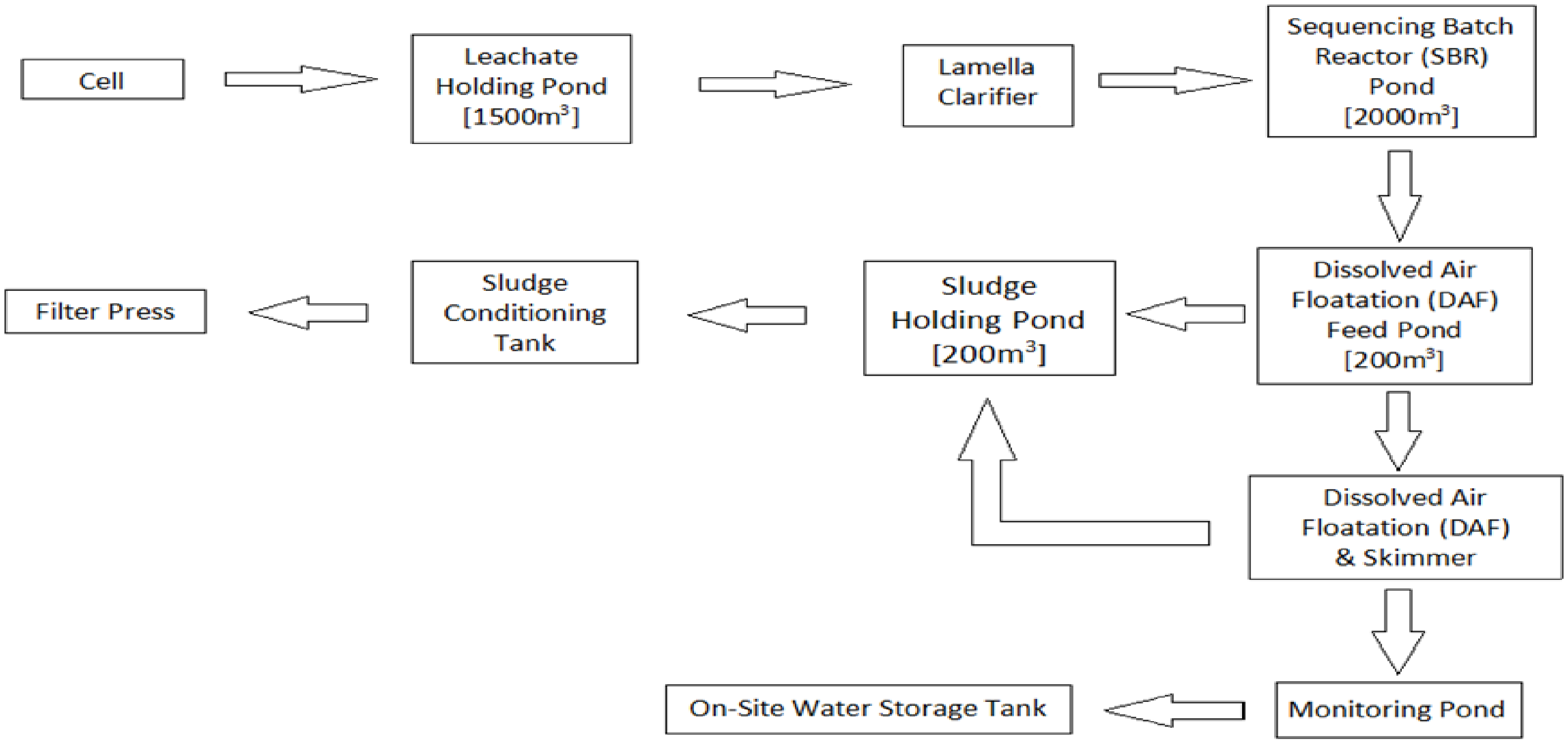


Figure 2.5: Process flow of existing leachate treatment plant

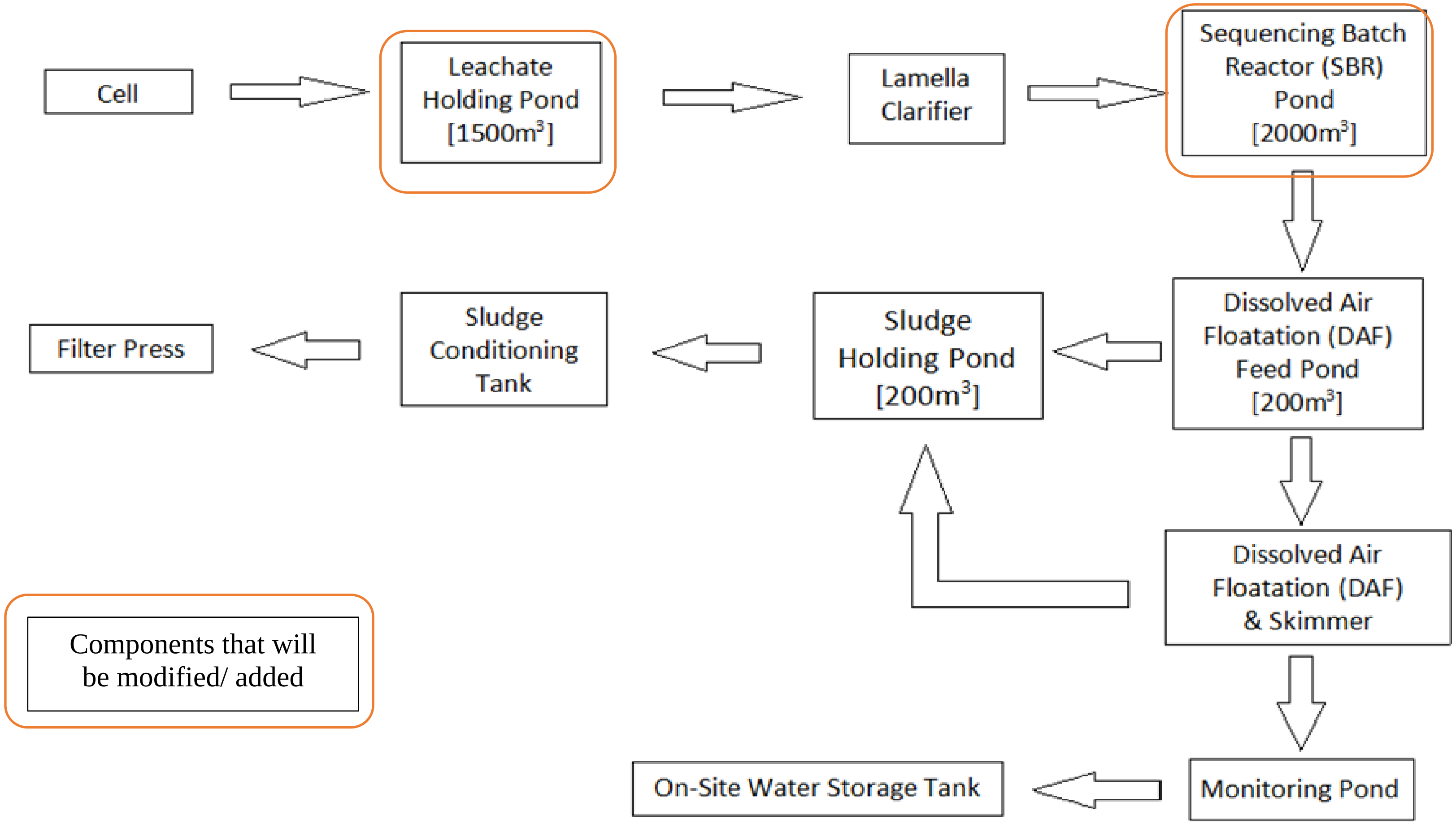


Figure 2.6: Process flow of modified leachate treatment plan

2.4 Existing Hydraulic Profile

The hydraulic profile for the Rimba Mas Sanitary Landfill current leachate treatment plant (LTP) components are as shown in Fig. 2.7: Hydraulic profile of the existing leachate treatment plant.

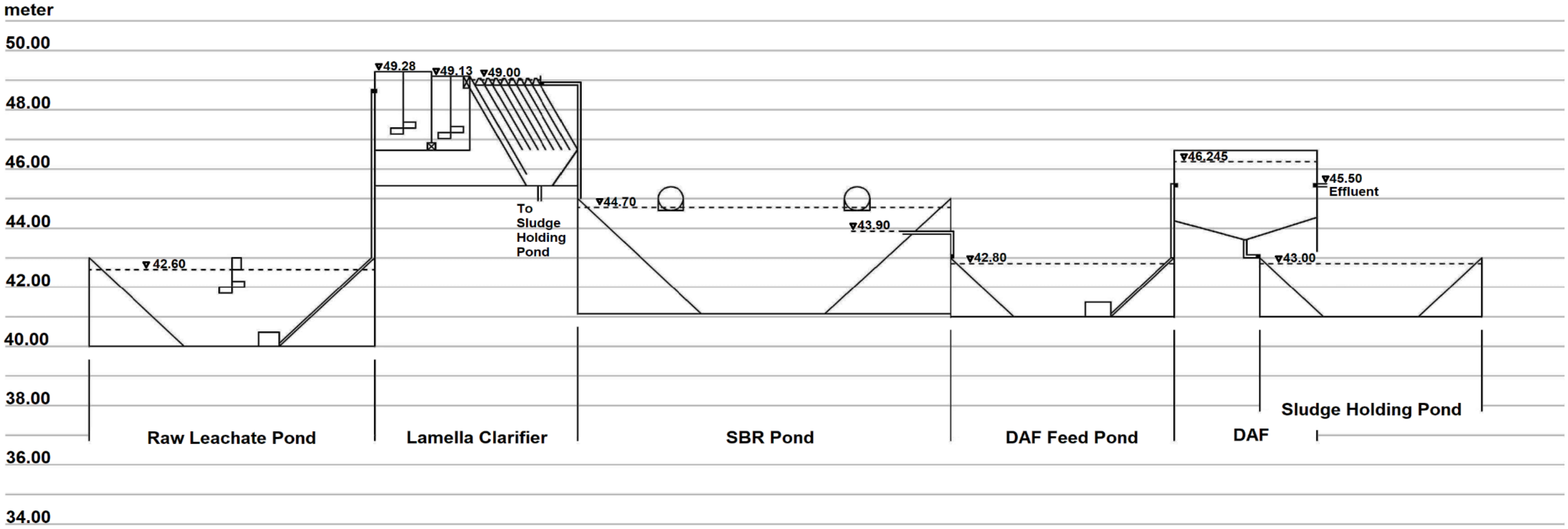


Figure 2.7: Hydraulic profile of the existing leachate treatment plant

2.5 Scope of Work

Site clearing and excavation

i. Clearing away vegetation and surface soil of construction site
ii. Warning signs and obstacles to be installed before starting excavation works
iii. Mobile equipment should only be handled by authorized person following all the safety procedures
iv. Excavation during rainy seasons are not allowed due to safety issues
v. Site to be excavated should be dry before resuming excavating works

Structural

i. Pump sump installation
ii. Biological treatment installation
iii. Raw leachate holding pond installation
iv. Tertiary treatment process installation

Monitoring and Evaluation (M&E)

i. Installation of main switch board, wiring, cables, level regulators, sensors and pumps involved in electrical work
ii. Electrical works should only be done by certified or competent person
iii. Proper PPE must be used when working
iv. Any incidents should be reported to the site supervisor immediately

2.6 Design Criteria

The design criteria of the leachate treatment plant (LTP) is to achieve goals for leachate treatment objective and design parameters that are consistent with the final disposal requirements. This design process based on site characterization studies conducted by students of Pusat Pengajian Kejuruteraan Alam Sekitar (PPKAS), UniMAP. Leachate is collected from municipal solid waste landfill located in Rimba Mas Sanitary Landfill, Perlis.

2.6.1 Characteristics of leachate

The characteristics of landfill leachate changes according to the lifespan and stage of the municipal landfill. The stages of municipal landfill are split into 5 stages, initial adjustment, transition, acid formation, methane formation and final maturation and stabilization. Rimba Mas Sanitary Landfill conduct a few batches of jar test of daily leachate before proceeding the treatment to identify the dosage of coagulant and flocculant required. They do not conduct characterization of raw leachate but the treated leachate (LTP effluent) will be collected and tested monthly.

The general characteristics of leachate according to its parameters and lifespan are shown in Table 2.1: Characteristics of leachate and Table 2.2: Landfill classification and age.

Table 2.1: Characteristics of leachate (Source: UNEP, 2005)

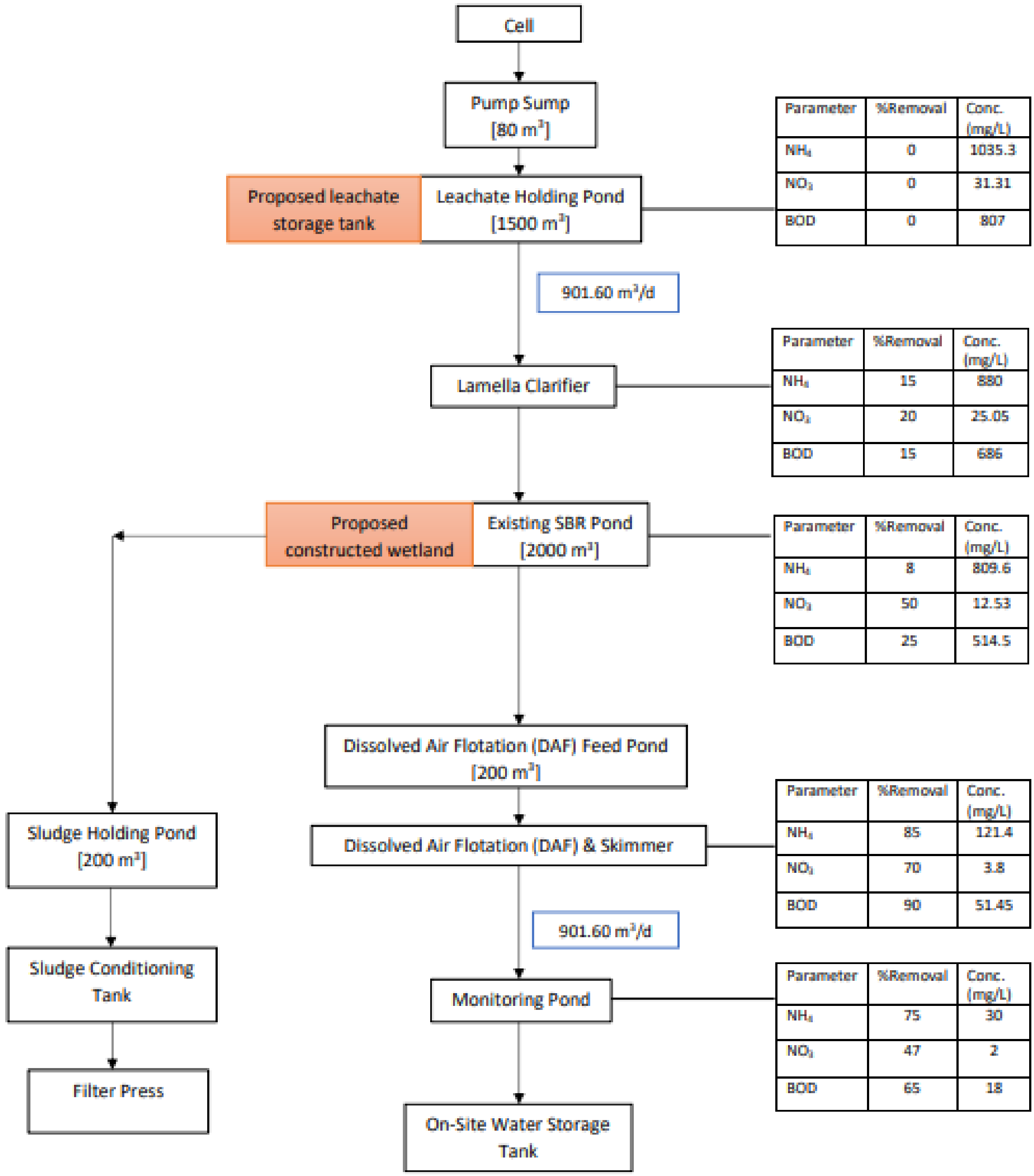
Parameter	**Range of Values (mg/L)**	**Parameter**	**Ranger of Values (mg/L)**
pH	4.5 – 9	Organic N	10 – 4250
Alkalinity ($CaCO_3$)	300 – 11500	Ammonia NH_3-N	30 – 3000
BOD_5	20 – 40000	Nitrite Nitrogen NO_2^-	0 – 25
COD	500 – 60000	Nitrite Nitrogen NO_3^-	0.1 – 50
Calcium	10 – 250	Total Nitrogen	50 – 5000
Chloride (Cl^-)	100 – 5000	Total Phosphate	0.1 – 30
Potassium	10 – 2500	Sulphate (SO_4^{2-})	20 – 1750
Sodium	50 – 4000	Manganese	0.03 – 65
Magnesium	40 – 1150	Total Iron	3 – 2100
TDS	0 – 42300	Copper	4 – 1400
TSS	6 – 2700	Lead	8 – 1020
Hardness	0 – 22800	Zinc	0.03 – 120

Table 2.2: Landfill leachate classification vs. age (Source:Ngo et al., 2008)

Parameter (mg/L)	Young leachate	Old leachate
COD	20000 – 40000	500 – 3000
BOD_5	10000 – 20000	50 – 100
TOC	9000 – 15000	100 – 1000
Volatile fatty acid	9000 – 25000	50 – 100

2.7 Existing Material Balance

Figure 2.8 is the mass balance and material balance show the remaining concentration according to the parameters of the leachate after passing through each leachate treatment plant component during the leachate treatment process.



Parameter	%Removal	Conc. (mg/L)
NH_4	0	1035.3
NO_3	0	31.31
BOD	0	807

Parameter	%Removal	Conc. (mg/L)
NH_4	15	880
NO_3	20	25.05
BOD	15	686

Parameter	%Removal	Conc. (mg/L)
NH_4	8	809.6
NO_3	50	12.53
BOD	25	514.5

Parameter	%Removal	Conc. (mg/L)
NH_4	85	121.4
NO_3	70	3.8
BOD	90	51.45

Parameter	%Removal	Conc. (mg/L)
NH_4	75	30
NO_3	47	2
BOD	65	18

Figure 2.8: Mass balance and material balance

2.8 Regulations for Landfill Leachate

In order to preserve the environmental and sustainable development aspects, this leachate treatment plant (LTP) must comply with Malaysian Regulatory, such as Environmental Quality Act (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. For this prescribed activity, Environmental Impact Assessment (EIA) is required under the Environmental Quality (Environmental Impact Assessment) Order 1987.

This act prohibits the release of waste into the atmosphere, in violation of appropriate conditions. For the effluent of the leachate, it is required to meet the following specific discharge limits as provide in Table 2.3: Second Schedule (Regulation 13): Acceptable Conditions for Discharge of Leachate.

2.8.1 Designing Leachate Treatment Plant

The design of the leachate treatment plant (LTP) will be done according to the characteristics, volume of leachate generated and regulations. The LTP components that will be added or changed will all be carried out with the 3 factors mentioned previously. The availability of land for the addition components are also taken into consideration.

The final treated effluent from the modified LTP should adhere to the discharge conditions stated in Environmental Quality Act 1974.

Table 2.3: Second Schedule (Regulation 13): Acceptable conditions for discharge of leachate (Source: Environmental Quality Act 1974)

No	Parameter	Unit	Standard
(i)	Temperature	˚C	40
(ii)	pH Value	-	6.0-9.0
(iii)	BOD5 at 20˚C	mg/L	20
(iv)	COD	mg/L	400
(v)	Suspended Solids	mg/L	50
(vi)	Ammoniacal Nitrogen	mg/L	5
(vii)	Mercury	mg/L	0.005
(viii)	Cadmium	mg/L	0.01
(ix)	Chromium, Hexavalent	mg/L	0.05
(x)	Chromium, Trivalent	mg/L	0.20
(xi)	Arsenic	mg/L	0.05
(xii)	Cyanide	mg/L	0.05
(xiii)	Lead	mg/L	0.10
(xiv)	Copper	mg/L	0.20
(xv)	Manganese	mg/L	0.20
(xvi)	Nickel	mg/L	0.20
(xvii)	Tin	mg/L	0.20
(xviii)	Zinc	mg/L	2.0
(xix)	Boron	mg/L	1.0
(xx)	Iron (Fe)	mg/L	5.0
(xxi)	Silver	mg/L	0.10
(xxii)	Selenium	mg/L	0.02
(xxiii)	Barium	mg/L	1.0
(xxiv)	Fluoride	mg/L	2.0
(xxv)	Formaldehyde	mg/L	1.0
(xxvi)	Phenol	mg/L	0.001
(xxvii)	Sulphide	mg/L	0.50
(xxiii)	Oil and Grease	mg/L	5.0
(xxix)	Colour	ADMI*	100

ADMI- American Dye Manufactures Institute

CHAPTER 3

PROJECT DESIGN

3.1 Technical Approach

3.1.1 Identifying Customer Needs

Rimba Mas sanitary landfill has been operated for more than three years with complete facilities including weighbridge, leachate treatment plant, waste disposal cells and administrative building. Leachate treatment plant in Rimba Mas sanitary landfill is to treat leachate produced from municipal cell. Although the treated leachate is compliance with the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009, there are still some issues encountered by Rimba Mas Sanitary Landfill. Due to extreme conditions in Perlis, SBR or the whole leachate treatment plant has to shut down during drought season as there is insufficient leachate whereas during rainy season leachate production is increasing which overuse the components of leachate treatment plant. In addition, make a change of the management of zero discharge in leachate treatment plant into dischargeable effluent as to contribute one or more water sources for future use. Thus, there is a need for additional modification for the components of leachate treatment plant in order to alleviate these issues.

3.1.2 Identifying Target Specifications

4 ways of leachate treatment can be combined and used for leachate treatment, these 4 ways are leachate recirculation, biological treatment, physio-chemical treatment and, natural attenuation. The summary of each leachate treatment is as in Table 3.1: Summary of Leachate Treatment Method.

Table 3.1: Summary of leachate treatment method

Leachate Treatment Method	Summary
Leachate Recirculation	Sprinkle collected leachate over landfill layers to improve the quality of leachate.
Biological Treatment	Use microbes to reduce organic and inorganic compounds.
Physio-chemical Treatment	Use chemicals that stabilize colloidal particles to form flocs.
Natural Attenuation	Uses nature's purification function. Can substitute biological treatment.

According to the Ministry of Housing and Local Government Malaysia, 2004, these 4 methods can be used together for better leachate treatment and produce a better quality treated leachate. There are 4 ways to combine these treatment methods and they are as listed below.

a. Biological treatment + physio-chemical treatment
b. Recirculation + biological treatment + physio-chemical treatment
c. Recirculation + natural attenuation
d. Recirculation + natural attenuation + physio-chemical treatment

Currently, in Rimba Mas Sanitary Landfill leachate treatment plant (LTP), they are using method A, physio-chemical treatment + biological treatment. The current biological treatment that is applied in this LTP is lagoon sequencing batch reactor (SBR). The problem that this LTP faced is that during drought, there is insufficient leachate volume to operate the lagoon SBR. Therefore changes should be done to prevent such incidents from occurring. The team has come up with an idea to either substitute the current lagoon SBR to other existing biological treatment. The plausible alternative biological treatments are, trickling filter, activated sludge or constructed wetland. Furthermore, a leachate storage tank can be installed just above the leachate holding pond as this is space-saving and act as a rain shelter for the leachate holding pond.

3.2 Leachate Production Estimation

A simple mathematical modelling from Emission estimation technique manual for municipal solid waste (MSW) landfills. The annual leachate volume was used by the Department of the Environment, Water, Heritage and the Arts as well as Australian Government (Ibrahim, Mahmood, & Othman, 2017). Estimation of leachate production can be calculated using the equation 3.1 below.

$$V = 0.15 \times R \times A \tag{3.1}$$
$$= 0.15 \times 2133 \times 10^{-3} \times 300000$$
$$= 95985 \text{ m}^3\text{/year}$$

Where,

V	=	volume of leachate discharge in a year (m^3/year)
R	=	annual rainfall (m)
A	=	surface area of the landfill (m^3)

Rimba Mas landfill with the capacity of 30 hectares (300000 m^3) and lifespan of 10 to 15 years. The annual rainfall of Perlis is 2133mm. With the received municipal solid waste of 54750 ton per year (150 ton per day), estimation of leachate over one year is 95985 m^3/year from the landfill.

Average leachate in daily production in Rimba Mas landfill will be considered as the baseline study for a full and closed landfill of Rimba Mas. Annual leachate production is 95985 m^3/year and therefore average daily leachate production is 258.02 m^3/day.

$$V = 95985 \text{ m}^3\text{/year}$$
$$= 7998.75 \text{ m}^3\text{/month}$$
$$= 258.02 \text{ m}^3\text{/day}$$

3.2.1 Maximum Leachate Production

Leachate production in Rimba Mas landfill drastically increased during monsoon season as rainfall in the municipal cell is mixed with the leachate and flow into LTP. Eventually this maximizes the leachate production.

Fig. 3.1 indicates the maximum rainfall amount in 2019 which is taken as a reference to predict the daily maximum leachate production in order to predict the measurement of components of Leachate Treatment Plant (LTP) that need to be modified.

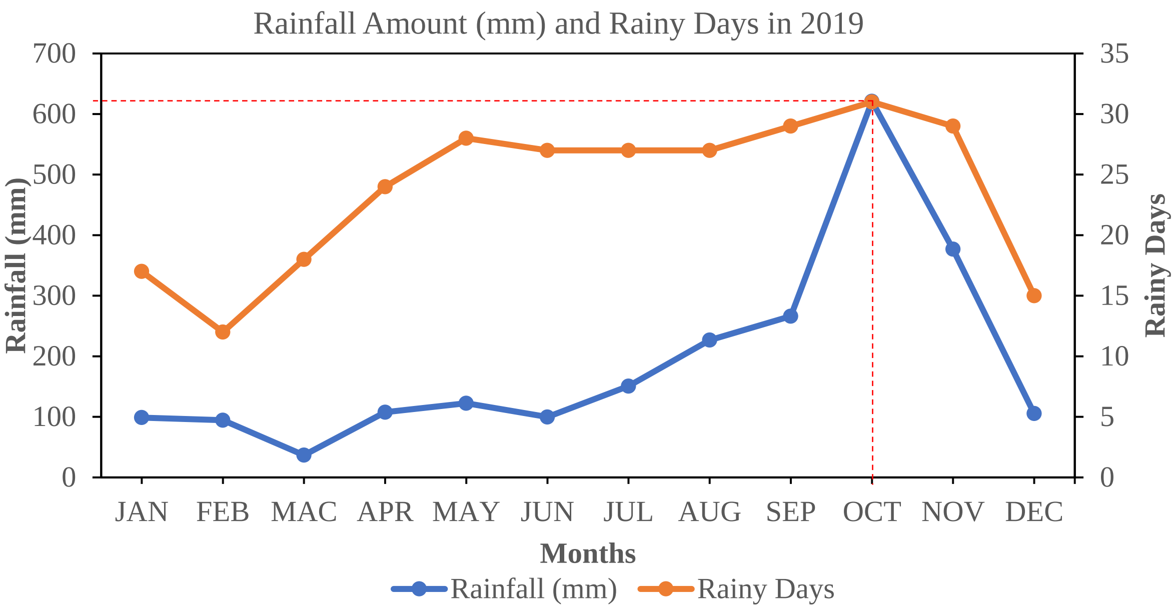


Figure 3.1: Maximum amount of rainfall (mm) and rainy days in 2019

Maximum leachate production (V) can be estimated by multiplying landfill area (A) with the maximum rainfall (R) as shown below:

$$
\begin{aligned}
V &= 0.15 \text{ x } R \text{ x } A \\
&= 0.15 \times 621.1 \times 10^{-3} \times 300000 \\
&= 27949.5 \text{ m}^3\text{/month} \\
&= 901.60 \text{ m}^3\text{/day}
\end{aligned}
$$

Where,

V	=	volume of leachate discharge in a year (m^3/year)
R	=	annual rainfall (m)
A	=	surface area of the landfill (m^3)

Daily leachate production during extreme weather from a closed and full landfill site in the future is predicted as 901.60 m^3/day. All the components of LTP are designed according to full and closed landfill site with maximum daily amount of leachate generation.

3.2.2 Minimum Leachate Production

Leachate production in Rimba Mas landfill decreased during the dry season as evaporation of moisture content from wastes occurred and unavailability of rainfall. Fig. 3.2 indicates the minimum rainfall amount in 2019 which is taken as a reference to predict the daily maximum leachate production in order to predict the measurement of components of Leachate Treatment Plant (LTP) that need to be modified.

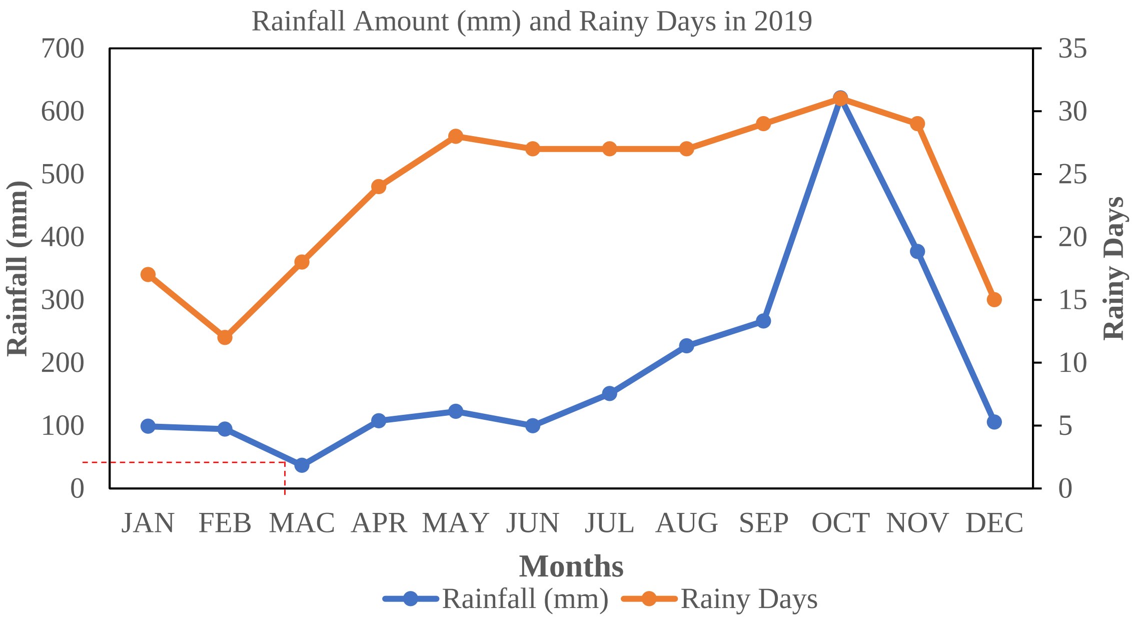


Figure 3.2: Minimum amount of rainfall (mm) and rainy days in 2019

Minimum leachate production (V) can be estimated by multiplying landfill area (A) with the maximum rainfall (R) as shown below:

$$\begin{aligned} V &= 0.15 \text{ x } R \text{ x } A \\ &= 0.15 \times 36.7 \times 10^{-3} \times 300000 \\ &= 1651.5 \text{ m}^3\text{/month} \\ &= 53.27 \text{ m}^3\text{/day} \end{aligned}$$

Where,

V	=	volume of leachate discharge in a year (m^3/year)
R	=	annual rainfall (m)
A	=	surface area of the landfill (m^3)

Daily leachate production during extreme weather from a closed and full landfill site in the future is predicted as 53.27 m^3/day. The mount of leachate in March caused the LTP to shut-down due to insufficient volume for leachate treatment.

3.3 Insufficient Storage for Leachate

During monsoon season, the current leachate storage pond is unable to store the produced leachate. During monsoon seasons, the maximum leachate produced is 901.6m^3/day. The current volume of leachate storage pond is 1500m^3. The leachate that are produced in the solid waste cell would be pumped and stored in the leachate storage pond. The new leachate will homogenise with the old leachate before it can be treated.

With the continuous leachate production for more than 1 day, the leachate storage pond will overflow as illustrated in Figure 3.3: Leachate storage pond with leachate level. In order to prevent this, the leachate will be left in the solid waste cell and pumped into the leachate storage pond when the level decreases. The characteristics of the leachate that are stored in the solid waste cell will alter and cause the leachate to be harder to treat. With the added rainwater, this will also further alter the characteristics of the leachate.

Therefore, the installation of an additional leachate storage pond is suggested to overcome this problem.

Dimension of Leachate Storage Pond (LSP): W=18m, L=20m, D=4m

$Maximum\ leachate\ produced = 901.6 \approx 905m^3/day$

905 = D×18×20

$D = 2.51 \approx 2.55m$

Depth of leachate in LSP = 2.55m (Day 1)

Depth of leachate in LSP = 5.10m (Day 2)

During max leachate produced = 901.6m^3/day

Leachate volume (Day 1)

Leachate volume (Day 2)

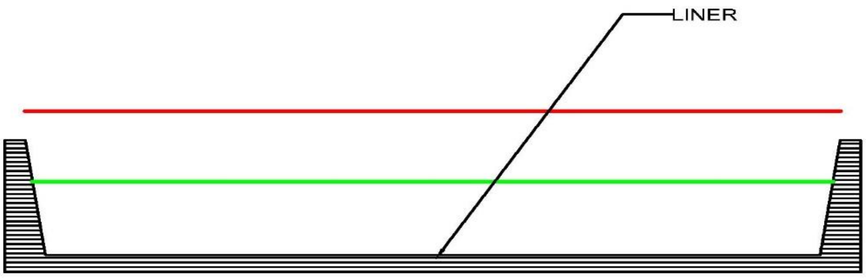


Figure 3.3: Leachate storage pond with leachate level

3.3.1 Unable to operate Sequencing Batch Reactor (SBR)

Dimension of SBR: W=20m, L=25m, D=3.5m

Max Leachate Volume Production (Monsoon) = 901.6m^3/day

905 = D×20×25

$D = 1.81 \approx 2m$

Depth of leachate in SBR = 2m

Average Leachate Volume Production (Normal conditions) = 258.02 m^3/day

260 = D×20×25

$D = 0.52 \approx 0.6m$

Depth of leachate in SBR = 0.6m

Min Leachate Volume Production (Drought) = 53.27m^3/day

55 = D×20×25

$D = 0.11 \approx 0.15m$

Depth of leachate in CAS = 0.15m

Leachate volume during monsoon

Leachate volume during normal conditions

Leachate volume during drought

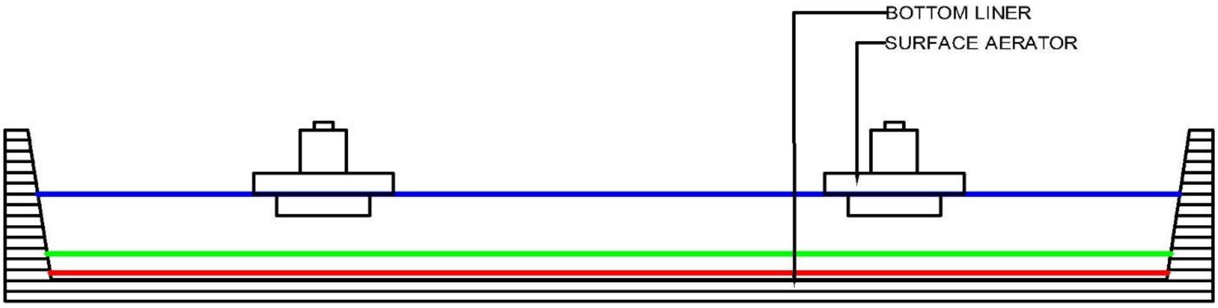


Figure 3.4: SBR during different leachate level

The current situation for the SBR in this leachate treatment plant, during drought, the volume of leachate produced is insufficient to operate the SBR. The floating aerator will be close to the bottom liner, this will cause a tear in the liner and leads to seepage of untreated leachate into the underground water.

The operators will shut down the leachate treatment plant when this happens. When the leachate volume is sufficient, they will restart the treatment plant and re-cultivate the microbes in the SBR. Therefore, this system requires to be modified for continuous leachate treatment.

3.4 Generating Design Concepts

Option 1: Trickling Filter

Trickling filter, also known as biological filter or trickling biofilter, is an aerobic treatment process. It is containing a fixed or packed bed of filter medium (crushed stones or synthetic resins) that allowing the leachate sprayed or trickled continuously to flow through the filter. Then, the organic substances in the leachate will be adsorbed and degraded by the slime layer or biofilm which is formed by attachment of microorganisms on the medium.

Sloughing process will be occurred as the time past, the thicken biofilm layer will falls off the granular material medium due to the thickness of film is increasing continuously and reducing the ability to adhere to the medium. The solid sloughing off from the medium will be removed to the clarifier by the underdrain system.

Trickling filter is suitable to the variation of quality and quantity of leachate, and the operation and maintenance is easy. There is a research on evaluation of the trickling filter as a leachate treatment method. Table 3.2 shows the removal efficiency of trickling filter in the research. However, double trickling filter is needed to improve the removal rate, prevent the filter clogged by the suspended solids and prevent shutting down the whole treatment system during the maintenance.

By adding a dome cover, the trickling filter can withstand under the extreme weather by preventing the dilution in secondary process from rain water in monsoon season and decreasing the rate of evaporation in dry season. Compared to the SBR, trickling filter does not require to regenerate the microbes because it does not affect by the water level that will stop the operation of aerator in SBR during the dry season.

The design criteria of trickling filter process is based on BOD removal efficiency, type of packing, ventilation, hydraulic loading, organic loading, recirculation ratio, depth and effluent quality which is shown in Table 3.3.

The advantages of trickling filter are as follows:

- Simple wastewater treatment process
- Small land size required
- Enable to treat high amount of organics
- Suitable for small and medium sized communities
- Effective to reduce BOD_5
- Efficient nitrification units
- High durability
- Required low electricity
- System is easy to manage and operate
- Cost effective due to simpler process, lesser material, chemical and energy used

Table 3.2: Removal efficiency of trickling filter in leachate treatment

Source: (Aluko & Sridhar, 2013)

Parameters	**Removal Efficiency (%)**	**Parameters**	**Removal Efficiency (%)**
pH	3.59	COD (mg/l)	48.50
Colour (HU)	13.69	Ammonia (mg/l)	59.50
Turbidity (FTU)	71.96	Nitrate (mg/l)	123.59
Conductivity (µs/cm)	18.05	Sulphate (mg/l)	0.30
Total Solids (mg/l)	55.09	Phosphate (mg/l)	56.30
SS (mg/l)	73.17	Lead (mg/l)	72.52
TDS (mg/l)	54.48	Nickle (mg/l)	74.17
Alkalinity (mg/l)	18.84	Cadmium (mg/l)	76.22
Chloride (mg/l)	10.49	Iron (mg/l)	82.61
DO (mg/l)	147.37	Manganese (mg/l)	75.08
BOD (mg/l)	76.69	Zinc (mg/l)	56.18

Table 3.3: Trickling filter design parameter

(Source: Metcalf & Eddy Inc., Tchobanoglous, Burton, & Stensel, 2003)

Design parameter	**Unit**	**Low rate BOD removal**	**High rate BOD removal**	**High rate BOD removal**	**BOD removal and nitrification**	**Partial BOD removal**
BOD removal efficiency	%	80 – 90	80 – 90	70 – 90	85 – 90	40 – 70
Type of packing	Type	Rock	Rock	Plastic	Plastic/ Rock	Plastic
Ventilation	Type	Natural	Forced air	Forced air	Forced air	Forced air
Organic loading	kg BOD/ m^3.d	0.08 – 0.3	0.6 – 1.6	0.6 – 2.4	0.08 – 0.4	1.6 – 3.5
Hydraulic loading	m^3/ m^2.d	1 – 4	4 – 40	15 – 75	5 – 16	40 – 100
Recirculation ratio	Qr/Q	0 – 1	1 – 2	1 – 2	1 – 2	0 – 2
Depth	m	1 – 2.5	1 – 2.5	3 – 12	Plastic 3 – 12 Rock 1 – 2.5	0.9 – 6
Effluent quality	BOD, mg/L	< 30	< 30	< 30	< 20	>30
	NH_4-N, mg/L	< 5	>5	>5	<3	

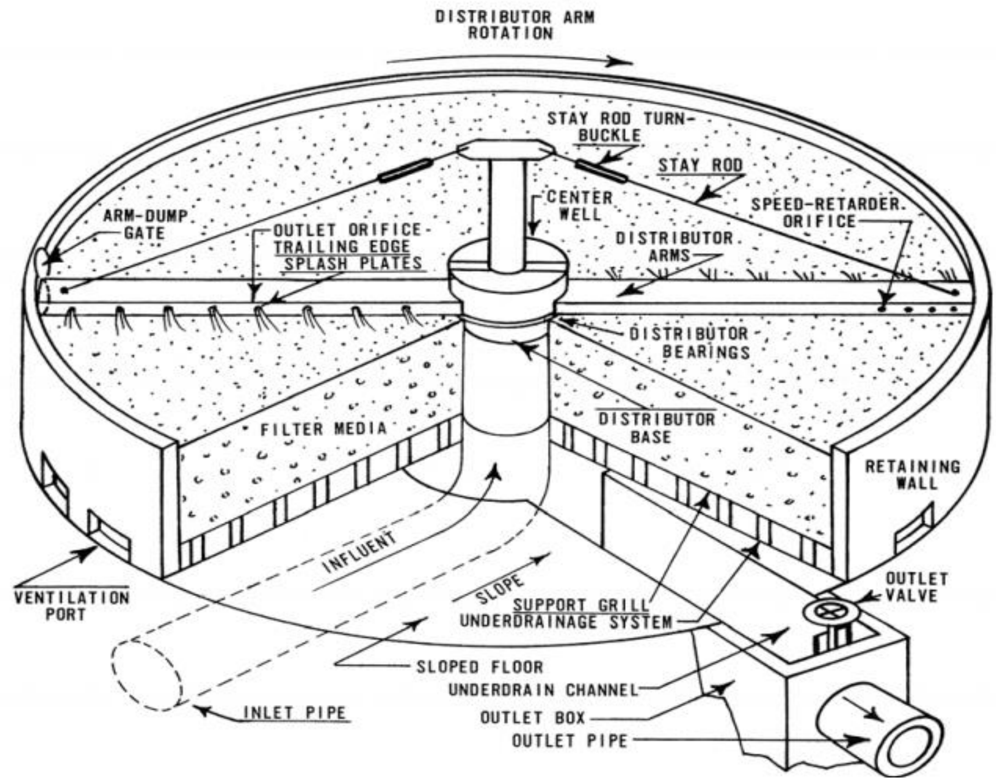


Figure 3.5: Trickling filter process

The main problem of SBR with aerators is due to the extreme weather that causes the influent overflow and insufficient influent to operate the system. Hence, the design is based on the maximum flow during the Monsoon season to withstand the highest leachate level. The volume of trickling filter calculated for maximum flow is 27.048m³ with 50m³ /m² d of hydraulic loading rate that is within the wetting rate. It has 32.22% of BOD removal efficiency that is more than the target of 30%. However, this design is not suitable during drought season which has the lowest flow all the year. Although it has 66.18%, a great BOD removal efficiency, but the hydraulic loading rate 2.954m³ /m² d is lower than the limit. This will cause insufficient leachate to operate the system and help the other living thing to grow such as snails. The calculation is shown in Table 3.4.

Table 3.4: Calculation for trickling filter

Single stage trickling filter	
During monsoon season	
Maximum leachate generation	$901.6m^3/d$
Influent BOD from lamella clarifier	686mg/l
Effluent BOD	480mg/l
Percent of BOD removal required	30%
BOD load applied to the filter	= flow x conc. of sewage (kg/d) = $901.6m^3/d$ x 686mg/l = 618.498 kg/d
Filter volume by NRC equation Where Recirculation factor, $Rf_1 = 1$ No circulation	$E_2 = \frac{100}{1+0.44(\frac{F_{1.BOD}}{V_1.Rf_1})^{1/2}}$ $30 = \frac{100}{1+0.44(\frac{618.498}{V_1.1})^{1/2}}$ $V_1 = 9.677m^3$
Depth of filter	1.5m
Filter area	= Volume/Depth = $9.677m^3/1.5m$ = $6.4513m^2$ = $\pi(D)^2/4$
Diameter, D	= 2.866m
Diameter OK since <60m	
Hydraulic loading rate, HLR	= Leachate flow/area = $901.6m^3/d/6.4513m^2$ = $139.755m^3/m^2d$
Hydraulic loading rate NOT OK since >60 m^3/m^2d of maximum wetting rate	
Recalculate the area by using HLR	$50m^3/m^2d$
Filter area	= Leachate flow/HLR = $901.6m^3/d$ / $50m^3/m^2d$ = $18.032m^2$

	$= \pi(D)^2/4$
Diameter	4.79m
Diameter OK since <60m	
Filter volume	= Filter area x Depth $= 18.032m^2$ x 1.5m $= 27.048m^3$
Recheck removal efficiency	$E_2 = \frac{100}{1 + 0.44(\frac{F_{1.BOD}}{V_1.Rf_1})^{1/2}}$ $E_2 = \frac{100}{1 + 0.44(\frac{618.498}{27.048m^3.1})^{1/2}}$ $E_2 = 32.22\%$
Removal efficiency OK since >30%	
During drought season	
Minimum leachate generation	$53.27m^3/d$
BOD load applied to the filter	= flow x conc. of sewage (kg/d) $= 53.27m^3/d$ x 686mg/l = 36.543kg/d
Filter volume (use maximum design)	$= 27.048m^3$
Removal efficiency	$E_2 = \frac{100}{1 + 0.44(\frac{F_{1.BOD}}{V_1.Rf_1})^{1/2}}$ $E_2 = \frac{100}{1 + 0.44(\frac{36.543}{27.048m^3.1})^{1/2}}$ $E_2 = 66.18\%$
Removal efficiency OK since >30%	

Filter area (use maximum design)	= 18.032m^2
Hydraulic loading rate, HLR	= Leachate flow/area = 53.27m^3/d/18.032m^2 = 2.954m^3/m^2d
Hydraulic loading rate NOT OK since <26 m^3/m^2d of minimum wetting rate	

Option 2: Activate Sludge

The activated sludge process is most commonly used for biological wastewater treatment technology (Mara & Horan, 2003). The process consists of two separate phases which are aeration and sludge settlement. There are different types of activated sludge process which are the conventional complete mix activated sludge process, series or plug flow system, tapered aeration, step feed activated sludge process, high rate activated sludge process, extended aeration, contact stabilization, oxidation ditch and deep shaft process. The types of process used varies according to the efficiency, required yield and effluent.

Table 3.5: Main components and functions in activated sludge process

Main components	Functions
Reactor (Aeration tank/basin)	- Can be a tank, ditch or lagoon - Content can be adequately mixed and aerated
Activated sludge	- Microbial biomass within reactor - Floculant suspension referred as mixed liquor
Aeration and mixing system	- Both combined each other in single system - Surface aeration or diffused air used
Sedimentation tank	- Final settlement by wastewater influent required - To separate microbial biomass from the treated effluent
Returned sludge	- Settled AS returned back to reactor to maintain microbial population to ensure continuous treatment at required concentration

Table 3.6: Basic requirements for activated sludge process

Basic requirements	Amount needed
F:M	95% - Bacteria 5% - Higher organism (protozoa, rotifers, invertebrates) -0.15 to 0.5 (based on BOD_5)
Designed to treat flow	10,000 and 250,000 gallons per day
SVI	50 to 150
SDI	1.0-2.5
Sludge age	Conventional activated sludge- 3 to 15 days Extended aeration- 15 to 30 days
Return activated sludge	20% to 40%
MLSS	600 to 3,000 mg/L

Table 3.7: Summarized activated sludge process and parameters

(Source: Wetlands for Water Pollution Control Book 2nd Edition)

Parameters	Activated sludge process
Capital Cost	- Low
Area of Land	- Smaller land compared to other process
Operating Cost	- High
Influence of weather	- More efficient in wet weather - Slightly worse during dry weather
Technical control	- Microbial activity needs to be controlled closely - Skilled and continuous operation required
Nature of wastewater	- Sensitive to changes in loading and toxic shock - Bulking problems may occur if trade in wastewater
Hydrostatic head	- Low pumping requirement - Suitable for site with limited hydraulic head
Nuisance	- Low odour - Noise
Final effluent quality	- Poor nitrification but low in suspended solids
Secondary sludge	- Large volume - High water content - Difficult to dewater

	- Less stabilized
Energy requirement	- High energy required for aeration, mixing, recycling sludge and maintaining sludge flocs in suspension
Synthetic detergents	- Possible foaming with diffuser in use
Robustness	- High maintenance on motor - Will not run without power

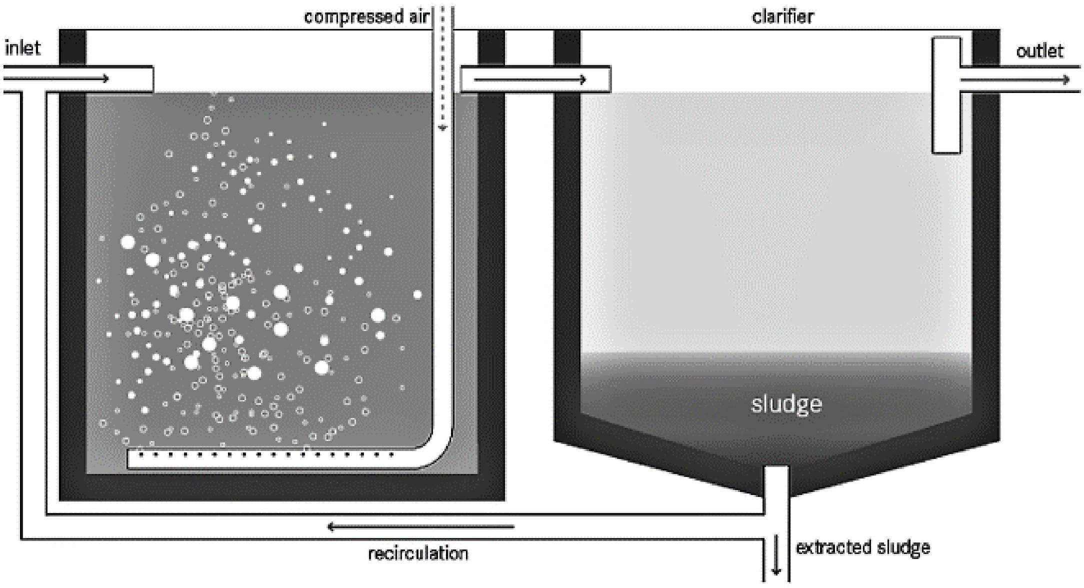


Figure 3.6: Activated sludge process

Calculations for volume of conventional activated sludge (CAS) tank:

$$F:M = \frac{Q_{max} \times BOD}{V \times MLSS}$$

$$Q_{max} = 901.6 m^3 / day$$

BOD = 0.686kg/m^3, F:M = 0.5, MLSS = 4.0kg/m^3

$$V = \frac{Q_{max} \times BOD}{(F:M) \times MLSS}$$

$$V = \frac{901.6 \times 0.686}{0.5 \times 4.0}$$

$$V = 309.25 m^3 \approx 310 m^3$$

$$\frac{L}{W} = \frac{3}{1}$$

$$L = 3W$$

D = 3m

Volume of tank = DxWxL

$$310 = 3 \times W \times 3W$$
$$W = 5.87 \approx 6m$$
$$L = 3(6) = 18m$$

$$V = 18 \times 6 \times 3.6 = 388.8 \approx 390m^3$$

Retention Time,Ɵ

$$\theta = \frac{V}{Q_{max}}$$
$$\theta = \frac{390}{901.6} = 0.433days \times 24h$$
$$\theta = 10.392hours$$

*Follows requirements of 6-16 hours.

Leachate volume during monsoon

Leachate volume during normal conditions

Leachate volume during drought

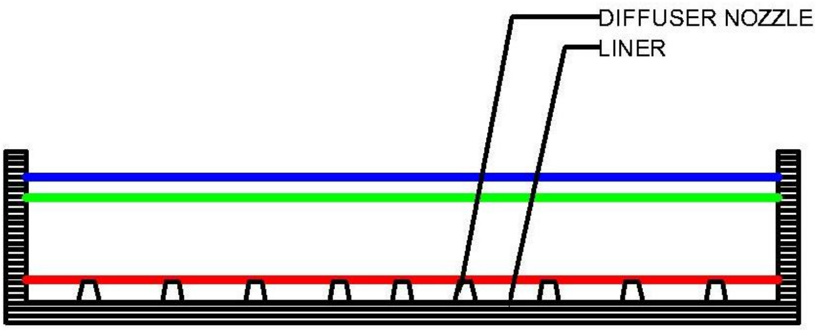


Figure 3.7: CAS tank with different leachate level

Volume of Secondary Clarifier (Rectangular)

$$\theta = \frac{V}{\left(\frac{Q_{max}}{2}\right)}$$
$$V = \theta \frac{Q_{max}}{2}$$
$$V = (0.416day)(\frac{901.6}{2}m^3 / day)$$
$$V = 187.53 \approx 190m^3$$

$$V = LWD$$
$$\frac{L}{W} = 3$$
$$L = 3W$$
$$190 = 3W \times W \times 3$$
$$W = 4.6 \approx 5m$$
$$L = 3(5) = 15m$$
$$V = 5 \times 15 \times 3.6 = 270m^3$$

Average Leachate Volume Production

$$Q_{avg} = 258.02m^3 / day$$
$$260 = D \times 6 \times 18$$
$$D = 2.41 \approx 2.5m$$

Depth of leachate in CAS =2.5m

Min Leachate Volume Production

$$Q_{min} = 53.27m^3 / day$$
$$55 = D \times 6 \times 18$$
$$D = 0.51 \approx 0.55m$$

Depth of leachate in CAS =0.55m

Conventional activated sludge could not be operated during drought (low leachate production). This is as illustrated in Figure 4.5: CAS tank with different leachate level. Therefore, CAS is not suitable to substitute the current SBR.

Option 3: Constructed Wetlands

Another option to replace SBR pond is using constructed wetlands. Constructed wetlands also classified as the biological treatment that use phytoremediation to treat wastewater. This treatment system is made by human using natural process by involving the plants, soils, microbes and wetlands hydrology. This application of constructed wetlands is to improve water quality from point and nonpoint source of water pollution.

According to (DuPoldt et al., 2000), constructed wetlands can be used for a variety of applications:

1. Municipal wastewater treatment
2. Treatment of household wastewater or greywater
3. Tertiary treatment of effluents from conventional wastewater treatment plants
4. Industrial wastewater treatment such as landfill leachate, petroleum refinery wastes, acid mine drainage, agricultural wastes, effluent from pulp and paper mills, textile mills.
5. Sludge dewatering and mineralisation of faecal sludge or sludge from settling tanks.
6. Storm water treatment and temporary storage
7. Treatment of water from swimming pools without chlorine

This on-site treatment is widely practicable on the several countries due to the advantages such as are low energy consumption, low cost implementation and operation, high efficient pollutant removal and environment friendly (Nelson, Alling, Dempster, van Thillo, & Allen, 2003). There are three type of constructed wetlands (Vymazal, 2007), surface flow wetlands, subsurface flow wetland and hybrid system which incorporate surface flow and subsurface flow to utilize specific system.

As shown in diagram below, the surface wetlands comprise a shallow containment dam system with dense vegetation cover and the subsurface wetlands consist of gravel/sand flows flowing though the network below ground. The subsurface wetlands can be divided into two group, horizontal flow and vertical flow which are used for different applications.

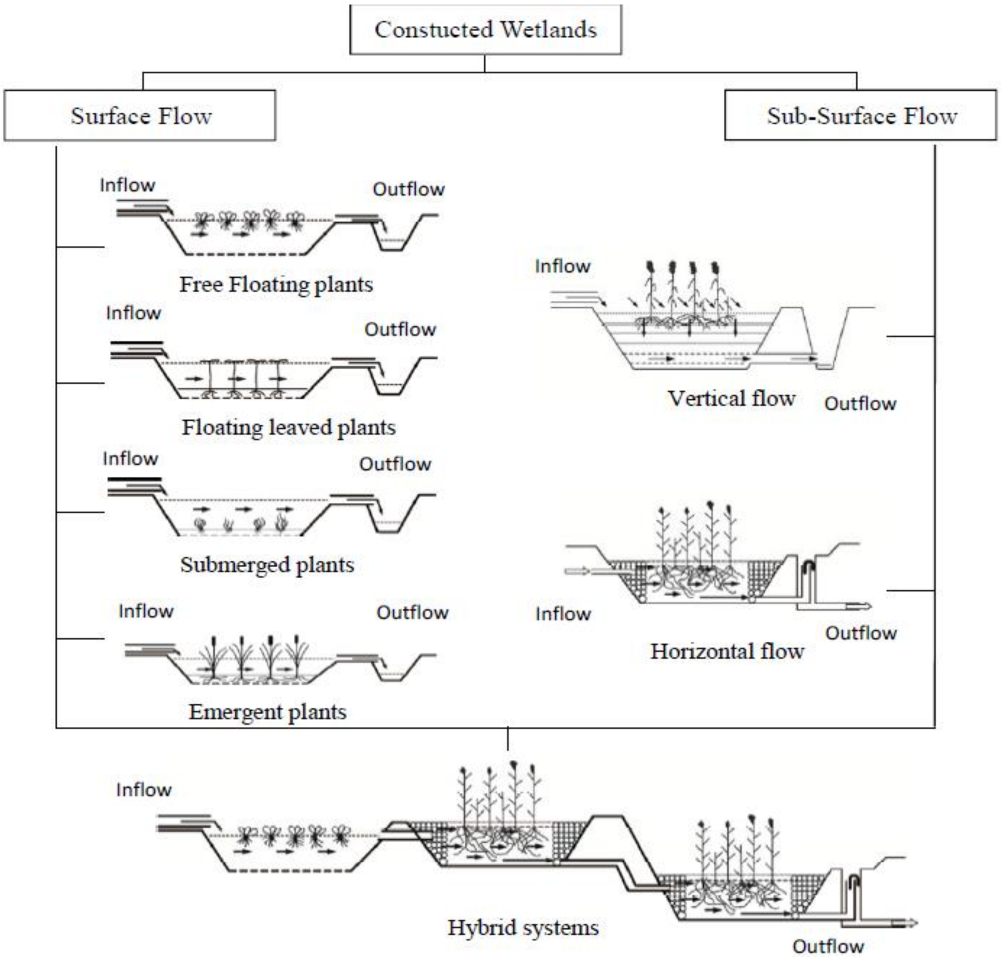


Figure 3.8: Classification of constructed wetlands

In order to evaluate the efficiency of constructed wetlands, it can be considered based on the characteristics. These characteristics are nearly same with the leachate characteristics following the parameters below. Based on journal by (Asmaliza et al., 2011), this system is considered as new method and not widely implemented in Malaysia. The author has compared the efficiency of constructed wetlands that located in USM, Nibong Tebal and Putrajaya. The tables below show the efficiency of this system. This can contribute towards to assessing the design efficiency of the developed wetland with respect to characteristics of hydrology and hydraulics for the condition of Malaysia due to the tropical climate condition.

Table 3.8: USM Nibong Tebal

Parameters	Percentage of removal, %
BOD	9.7 - 80
COD	5.7 - 62.9
DO	6.5 - 17.8
TSS	50 - 100
TP	24 - 46
TURBIDITY	21-72.3

Table 3.9: Putrajaya

Parameters	Pollutant Removal
BOD	0.38 mg/l – 1.65 mg/l
DO	0.78 mg/l -13.25 mg/l
TSS	10.25 mg/l -137.5 mg/l
TP	84.32%

Table 3.10: Advantage and disadvantage of constructed wetlands

Advantages	Disadvantages
Simple to design and construct	Require large land area– for some design and treatment capacity
Low cost compared to other treatment system (construction, operation and maintenance) Electromechanical equipment are not required (does not consume electrical energy)	Preliminary treatment needed to avoid high retention time.
High efficiency able to treat various types of pollutant	Problems with pests and mosquito breeding.
Cost effectively and environmentally friendly	Release malodour if not well kept

Other than that, there are two different configurations of constructed wetlands, horizontal and vertical construction wetlands. Materials for constructed wetland are such as pipping system, proofing and support medium. Cost of constructing horizontal subsurface wetland are lower compared to other types of constructed wetland.

This is due to differences of materials used according to allocated budget (for stuffing materials, pipping structure and excavation), initial condition of the land (geological and hydro-geological conditions) and characteristics of the soil.

Meanwhile, the maintenance and operating cost for both of this constructed wetland are observed to be the same. Maintenance expenses for both are influenced by the controls of the system such as the pre-treatment (septic tank, Imhoff tank), adjustment of water level and control flow distribution system. Cost of operational problems are due to blockage problem, distribution of inlet flow and exit collector, accumulation of mud at the stuffing material and development of weeds.

Table 3.11: Advantages and disadvantages of horizontal and vertical wetland

Type of wetland	Advantages	Disadvantages
Horizontal	• Low maintenance requirements • Intermittent flow not needed (no electricity for pump usage, good option for low gradient) • Efficient removal of organic pollutant (TSS, BOD5, COD) and nitrates	• Large surface area required • Limited oxygen transfer • Limited removal of nutrients (especially nitrogen)
Vertical	• Greater oxygen transfer capacity resulting in good nitrification • Less surface area required • Efficient removal of BOD5, COD and pathogens	• Short-term loading intervals (4 to 12 doses per day) • Requires electricity (for pump) or sufficient gradient for a siphon pulse loading system • Less efficient in soil removal (can get clogged if media selection is not correct)

The capital cost of this system is depending on the cost of sand since the bed has to be filled with the sand. The constructed wetlands typically cheaper to build for small plants and have significantly lower operation and maintenance cost compared to others biological treatment (Hoffmann, Platzer, Winker, & Münch, 2011). This system must be managed to perform well.

The wetland management should focus on the most important factors in treatment performance by providing sufficiency of the water for the microbial community, assuring that flows reach all parts of the wetland by distinguish the clogging pipe, and maintaining a healthy environment for microbes maintaining a vigorous growth of vegetation. Thus, decrease energy consumption, degradation of various pollutant types, and habitat enhancement for flora and fauna are some of benefits of treating leachate in constructed wetlands system.

3.5 Selecting Design Concept

Table 3.12 shows the justification of option 1, 2 and 3 including materials, process flow, feasibility, cost, monitoring and man power.

Table 3.12: Main summary table for comparison of all process

Process	**Trickling Filter**	**Activated Sludge**	**Constructed Wetlands**
Materials	Made of stainless steel, rotary distributor central column and distributor arm to spray the wastewater, filter medium (stone or plastic).	Made of large tanks, tubes, monitoring equipment, basins, shaft and aerators.	The structure of wetlands consists of a designed basin that contains water, a substrate and vascular plant (the higher plant) or non-vascular plant (algae). Mostly, the coarse sand can be used as a substrate layer. PVC pipe is recommended to use as flow control structures. Similar materials are used for both configurations but with different length and dimension.
Process Flow	Pretreated leachate will be enter the trickling filter for secondary treatment. Then, leachate will spray by using the	The process takes advantage of aerobic micro-organisms that can digest organic matter in sewage, and clump together (by flocculation) as they do so. It thereby	As wastewaters flow through the system, suspended solids and trace metals settle and are filtered. Plants and organic material also absorb trace metals.

	distributor arm, flow through the medium and degraded by the biofilm.	produces a liquid that is relatively free from suspended solids and organic material, and flocculated particles that will readily settle out and can be removed. The general arrangement of an activated sludge process for removing carbonaceous pollution includes the following items: Aeration tank where air (or oxygen) is injected in the mixed liquor. Settling tank (usually referred to as "final clarifier" or "secondary settling tank") to allow the biological flocs (the sludge blanket) to settle, thus separating the biological sludge from the clear treated water. Treatment of nitrogenous matter or phosphate involves additional steps where the processes are managed to generate an	Organisms that live in water, on rocks, in soil, and on stems and roots of wetland plants use these organic materials and nutrients as food. Plants provide much of the oxygen needed by the organisms to live and grow. Plant roots keep the rocks or soil loose so that water can flow through easily. Only type of flow differs, process is the same.

		anoxic zone so that phosphates can be solubilized in the reducing environment and oxides of nitrogen can be reduced to ammonium ion.	
Feasibility	Trickling filter is only civil work and does not using any chemical. It is a biological treatment that is required microbial.	Requires microbes and needs to monitor nature of wastewater regularly for effective treatment.	Continuous monitoring of wastewater. Natural process including vegetation and microbes are used.
Monitoring and Manpower	Need to maintain the moisture of medium to ensure the present of microbial. Need to change or wash the medium. Manpower needed only at certain time.	Skilled and continuous operation required	Skilled manpower with less monitoring required.
Cost	Low cost for installation, operation and maintenance. Extra cost in electricity for rotary arm and changing the filter medium.	Operational cost higher than constructional cost due to high power consumption. Usage of microbes also lead to higher operational cost to maintain it.	Construction cost of horizontal wetland are more than vertical wetland. Maintenance and operating cost for both construction wetland are relatively the same.

We decided to select option 3 to implement as it is a more feasible and appropriate option compared to the other two options.

Constructed wetlands are man-made and have similar functions of a natural wetlands. Constructed wetlands are commonly used by wastewater treatment industries as a biological treatment of the wastewater. This method acts as a natural filter which improves the water quality and is being recognised world-wide due to the increased demands of reusing water. Other than that, constructed wetlands can also function as a water storage area in the water cycle as natural water storage area are slowly depleted due to urbanisation.

Constructed wetland can be categorised according to the presence of water on the subsurface or the direction of water flow (Bakhshoodeh, R., et. al., 2020). There are water on the surface of the soil for free water surface (FWS) constructed wetlands while for subsurface flow constructed wetlands, it can be differentiate according to the flow direction of the water. Constructed wetland combines physical, chemical and bio-chemical treatment process (Midhun et al., 2016).

1. Physical treatment: sedimentation, filtration
2. Chemical treatment: precipitation, adsorption
3. Bio-chemical treatment: microbial degradation

According to Bakhshoodeh, R., et. al., 2020, treatment of landfill leachate is relatively dependent on the design of the constructed wetland. Other than that, the type of plants, temperature and hydraulic retention time of the constructed wetland also plays a role on the landfill leachate treatment performance. Generally, constructed wetlands shows potential in treating wastewater that biodegrades poorly.

Currently in Malaysia, there are 3 constructed wetlands that are in use, Putrajaya, Engineering Campus and Humid Tropic Center and Universiti Sains Malaysia (USM). According to the research conducted by Sidek, L. M.,et. al., 2017, the removal efficiency of the 3 mentioned constructed wetland are as summarised in Table 4.13: Average removal efficiency for Putrajaya, Engineering Campus and Humid Tropic Center and Universiti Sains Malaysia (USM).

Table 3.13: Average removal efficiency for Putrajaya, Engineering Campus and Humid Tropic Center and Universiti Sains Malaysia (USM)

Parameters	Removal efficiency
Biological oxygen demand (BOD)	48%
Chemical oxygen demand (COD)	37%
Total phosphorus	64%
Total nitrogen	74%
Total suspended solids (TSS)	71%

There are a lot of research that is being conducted on using constructed wetland for the treatment of landfill leachate. According to a research by Białowiec, Davies, Albuquerque, & Randerson, (2012), they used willow and reed for the removal of nitrogen in landfill leachate. Willow shows the highest removal efficiency of 95% while for reed has a slightly lower efficiency. Other than that, another lab-scale research by Dan, Oka, Fujii, Soda, Ishigaki., Machimura, & Ike, (2017), demonstrated that constructed wetland have a high removal efficiency for heavy metals such as zinc, chromium, nickel, cadmium, iron and lead.

The landfill leachate characteristics in Rimba Mas Sanitary Landfill shows lower levels of BOD, COD, heavy metals and nitrogen when compared to the other landfill leachate that was conducted in the 2 before mentioned research. This shows that constructed wetland has a high potential to treat the produced landfill leachate at a higher efficiency than the currently used sequencing batch reactor (SBR) and aesthetically, constructed wetland is more pleasing when compared to SBR.

According to a research conducted by Gunes, et. al. (2011), constructed wetland as a wastewater treatment alternative is in preference by those in rural areas. This is due to the fact that it is lower in operational costs than other conventional wastewater treatment methods. As mentioned before there are 2 different flow direction for subsurface constructed wetland, vertical flow and horizontal flow. When compared, subsurface vertical flow is more preferred in rural areas compared to subsurface horizontal flow.

When both of subsurface vertical and horizontal flow treatment efficiency are compared among each other, it is concluded that subsurface vertical flow constructed wetland is better. This is proven by a research conducted by Bakhshoodeh, et. al. (2020), in a lab scale constructed wetland, they compared different constructed wetland designs among each other, subsurface vertical flow constructed wetland has a more concentrated landfill leachate and the chemical oxygen demand (COD) removal efficiency is similar to other constructed wetland. For the removal of organic matters in landfill leachate especially for ammonia nitrogen, the use of subsurface vertical flow constructed wetland is more efficient when compared to subsurface horizontal flow constructed wetlands (A., & Ugurlu, A., 2009). In another research, when there is sufficient aeration to the subsurface horizontal flow constructed wetland, the biological oxygen demand (BOD) and ammoniacal nitrogen (NH_4N) removal efficiency is above 90%, while for COD is about 60% removal efficiency (Nivala, J., et. al., 2007).

Compared to the current SBR, subsurface vertical flow constructed wetland requires a significantly lower operational cost as there is little to no use of electric and chemical. There are no mechanical parts that are required for maintenance, the only maintenance required is to tend to the vegetation to prevent overgrowing. Constructed wetland is more flexible when it comes to climate conditions. The extreme weather that leads to low leachate volume will not affect the operation of constructed wetland in the treatment of leachate while SBR is unable to operate when there is low volume of leachate. In conclusion, subsurface vertical flow constructed wetland is most suited to be constructed in Rimba Mas Sanitary Landfill LTP as a better alternative than the current SBR.

CHAPTER 4

DESIGN FORMULATION AND CALCULATION

4.1 Leachate Storage Tank

Current leachate holding pond volume = 1500 m^3 (20 m×25 m×3 m)

Maximum volume of leachate generated during monsoon = 901.6 m^3/d ≈ 905 m^3/d

Estimate maximum generation volume in a week = 905 m^3/d × 7 days = 6335 m^3

Approximate volume of leachate holding pond required = 6500 m^3

Additional required volume of leachate holding pond = (6500-1500) m^3 = 5000 m^3

Extension of leachate holding pond wall by 10 m height is required.

4.2 Pipe Selection

High-density polyethylene pipe (HDPE) is chosen in the pipeline of constructed wetland as shown in Figure . It is made of thermoplastic that provides flexible and durable which can withstand the harsh environment such as high pressure and high corrosive in landfill. The advantages of HDPE are included corrosion resistance, fatigue resistance, extended service life, leak-free joints and its adaptability. Friction loss is one of the factor that will affect the flow rate, velocity and pressure which decreasing the operational efficiency in piping systems. Hence, determination of friction loss in pipe is important in constructed wetland. Friction loss of HDPE in this project is calculated based on the size selected in Table 4.1.

Figure 4.1: HDPE pipes

1. Volumetric flow rate of leachate

$$Q = 901.6\ \frac{m^3}{d} \times \frac{d}{86400s}$$

$$Q = 0.0104\ \frac{m^3}{s} \times \frac{15850.32314\ gpm}{1\frac{m^3}{s}}$$

$$Q = 164.8434\ gpm$$

Table 4.1: HDPE pipe size with flowrate

Head Loss / 100 Feet Pipe Due to Friction (C = 150)														
C = 150 for High Density Polyethylene Pipe (HDPE)														
Flow (GPM)	Pipe Diameter (Inch)													
	½"	¾"	1"	1-¼"	1-½"	2"	2-½"	3"	4"	5"	6"	8"	10"	12"
0.5	0.8	0.1												
1	2.9	0.4	0.1											
2	10.5	1.5	0.4	0.1										
3	22.2	3.1	0.8	0.3	0.1									
4	37.9	5.3	1.3	0.4	0.2									
5	57.2	7.9	2.0	0.7	0.3	0.1								
10		28.6	7.1	2.4	1.0	0.2	0.1							
15		60.6	14.9	5.0	2.1	0.5	0.2	0.1						
20			25.4	8.6	3.5	0.9	0.3	0.1						
30			53.8	18.2	7.5	1.8	0.6	0.3	0.1					
40			91.7	30.9	12.7	3.1	1.1	0.4	0.1					
50				46.7	19.2	4.7	1.6	0.7	0.2	0.1				
60				65.5	26.9	6.6	2.2	0.9	0.2	0.1				
70				87.1	35.8	8.8	3.0	1.2	0.3	0.1				
80					45.9	11.3	3.8	1.6	0.4	0.1	0.1			
90					57.0	14.1	4.7	2.0	0.5	0.2	0.1			
100					69.3	17.1	5.8	2.4	0.6	0.2	0.1			
150						36.1	12.2	5.0	1.2	0.4	0.2			
200						61.6	20.8	8.5	2.1	0.7	0.3	0.1		
250						93.0	31.4	12.9	3.2	1.1	0.4	0.1		
300							44.0	18.1	4.5	1.5	0.6	0.2	0.1	
400							74.8	30.8	7.6	2.6	1.1	0.3	0.1	
500								46.5	11.5	3.9	1.6	0.4	0.1	0.1
600								65.2	16.1	5.4	2.2	0.5	0.2	0.1
700								86.7	21.4	7.2	3.0	0.7	0.2	0.1
800									27.4	9.2	3.8	0.9	0.3	0.1
900									34.0	11.5	4.7	1.2	0.4	0.2
1000									41.3	13.9	5.7	1.4	0.5	0.2
1200									57.9	19.5	8.0	2.0	0.7	0.3
1500									87.5	29.5	12.1	3.0	1.0	0.4
2000										50.3	20.7	5.1	1.7	0.7
3000											43.8	10.8	3.6	1.5
4000											74.6	18.4	6.2	2.6
5000												27.8	9.4	3.9

From Table 4.1, 4-inch HDPE is selected to withstand the maximum volume of leachate during Monson season.

$$D = 4\ inch \times \frac{0.0254m}{1inch} = 0.1016m$$

2. Velocity of leachate in HDPE pipe

$$V = \frac{4Q}{\pi D^2}$$

$$V = \frac{4\left(0.0104\frac{m^3}{s}\right)}{\pi(0.1016m)^2}$$

$$V = 1.2828\frac{m}{s}$$

3. Reynolds Number

$$R_e = \frac{VD\rho}{\mu}$$

Where,

R_e = Reynold's number

V = Average velocity

D= Pipe diameter

ρ=Leachate density

μ= Dynamic viscosity

$$R_e = \frac{1.2828\frac{m}{s} \times 0.1016m \times 999.33\frac{kg}{m^3}}{7.55405 \times 10^{-4}\frac{kg}{ms}}$$

$$R_e = 1.72 \times 10^5$$

Since R_e = 1.72 x 10^5 is more than 2 x 10^3. Therefore, the flow of the leachate entering the outlet pipe is turbulent.

4. Friction loss

Table 4.2: Typical roughness of the pipe materials

Material	**ε (mm)**
Concrete	0.3 – 3.0
Cast Iron	0.26
Galvanized Iron	0.15
Asphalted Cast Iron	0.12
Commercial or Welded Steel	0.045
PVC, Glass, Other Drawn Tubing	0.0015

Based on Table 4.2, the HDPE pipe roughness is ε = 0.0015mm

Relative pipe roughness

$$\frac{\varepsilon}{D} = \frac{0.0000015m}{0.1016m}$$

$$\frac{\varepsilon}{D} = 1.4764 \times 10^{-5}$$

From Fig. 5.2, friction factor is approximately, f = 0.016.

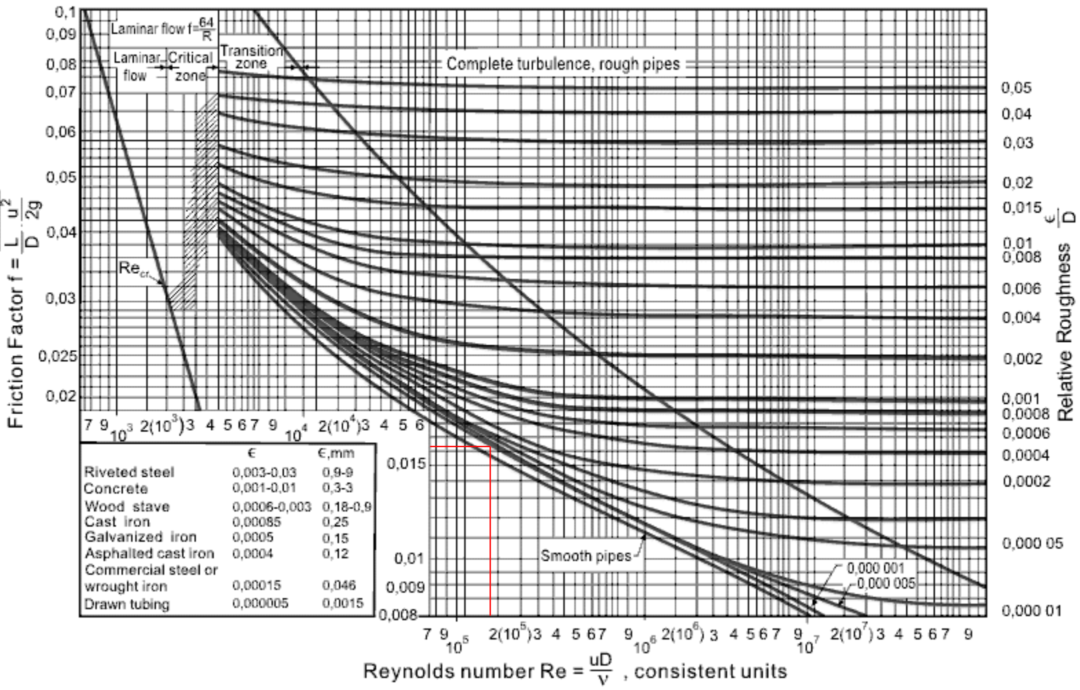


Figure 4.2: Moody diagram

5. Headloss in pipes

Headloss in pipes per meter is calculated by using Hazen-Williams equation.

$$\frac{H}{L} = 10.65\,\frac{Q^{1.85}}{C^{1.85}D^{4.87}}$$

Where,

H = Headloss, m

Q = Flow rate, m^3/s

L = Length of pipe, m

D = Diameter of pipe, m

C = Hazen-William’s coefficient

$$\frac{H}{L} = 10.65\,\frac{0.0104^{1.85}}{150^{1.85}0.1016^{4.87}}$$

$$\frac{H}{L} = 0.0148 = 0.015$$

Every 1m of outlet pipe is consisting of 0.015m of headloss.

4.3 Valve Selection

The main function of valve in leachate treatment plant is to control, modulate and on/off the leachate flow. Due to the composition of waste collected in landfill, the daily pH of leachate produced is fluctuated that causing corrosive at acidic and alkali condition. Hence, nature of fluid is one of the consideration in valve selection in order to function well for more than 10 years. In this project, butterfly valve shown in Fig. 4.3 is selected as a modulating and controlling valve because it has a lighter weight which can easy to operate, suitable for large valve application and lower maintenance cost. The selection also referred to Table 4.3 which is showing butterfly valve is suitable in most of the fluid nature.

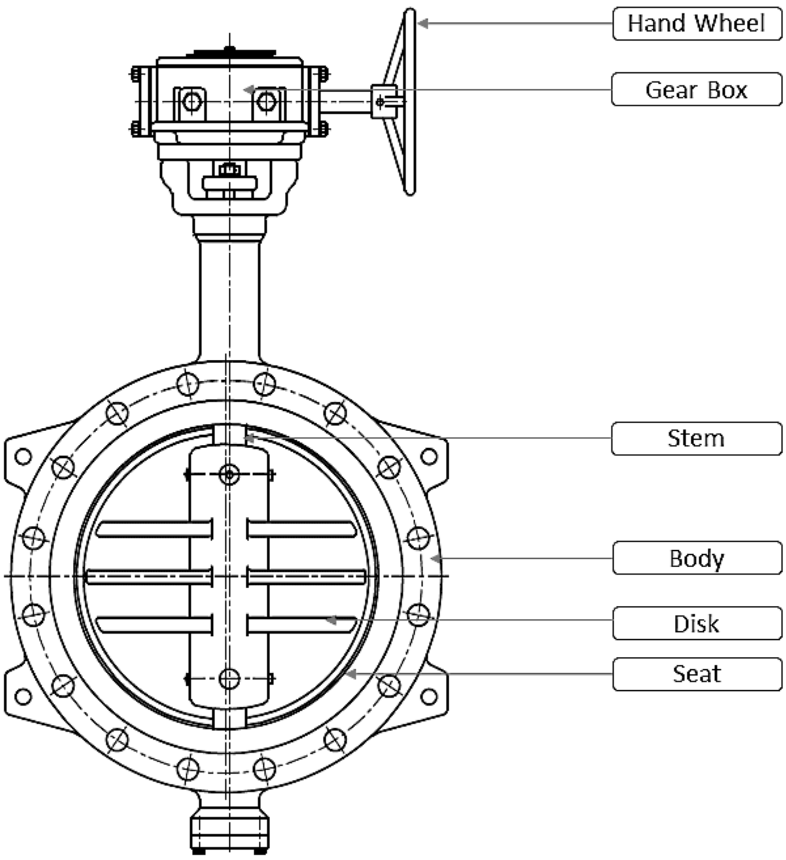


Figure 4.3: Component of butterfly valve

Table 4.3: Type of valve

Conveyed Fluid	Nature of Fluid	Valve Function	Type of Disc
Liquid	Neutral (Water, Oil, etc)	On/ Off	Gate
			Rotary ball
			Plug
			Diaphragm
			Butterfly
			Plug gate
		Control valve, modulating	Globe
			Butterfly
			Plug gate
			Diaphragm
			Needle
	Corrosive (Acid, alkaline, etc)	On/ Off	Gate
			Plug gate
			Rotary ball
			Plug
			Diaphragm
			Butterfly
		Control valve, modulating	Globe
			Diaphragm
			Butterfly
			Plug gate
	Hygienic (Food, beverages, drugs etc)	On/ Off	Butterfly
			Diaphragm
		Control valve, modulating	Butterfly
			Diaphragm
			Squeeze
			Pinch
	Slurry	On/ Off	Rotary ball
			Butterfly
			Diaphragm
			Plug

			Pinch
			Squeeze
		Control valve, modulating	Butterfly
			Diaphragm
			Squeeze
			Pinch
			Gate
	Fibrous Suspensions	On/ Off Control valve, Modulating	Gate
			Diaphragm
			Squeeze
			Pinch

4.4 Dimension of Vertical Constructed Wetland

Table 4.4: Design parameters for surface flow constructed wetland (EPA, 1999)

Parameter	Design Criteria
Influent quality	BOD ≤ 20 to 30 mg L^{-1} TSS ≤ 20 to 30 mg L^{-1}
Pre-treatment	Oxidation basins
Design flows	Q_{max} (maximum monthly flow) Q_{ave}(average flow)
Maximum BOD loading	20 mg L^{-1} : 45 kg ha^{-1} day^{-1} 30 mg L^{-1} : 50 kg ha^{-1} day^{-1}
Maximum TSS loading	20 mg L^{-1} : 45 kg ha^{-1} day^{-1} 30 mg L^{-1} : 50 kg ha^{-1} day^{-1}
Water depth	0.6 to 0.9 m (full plant cover sections) 1.2 to 1.5 m (Open water surfaces) 1.0m (Inlet settling section)
Maximum HRT	2 days (full plant cover sections) 2 to 3 days (Open water surfaces)
Basin geometry	Optimum 3:1 to 5:1
Inlet settling section	In case of failed pretreatment in settling

Inlet	Uniform influent distribution in inlet
Outlet	Uniform effluent collection in outlet

Table 4.5: Design parameter for sub-surface flow constructed wetlands (EPA, 1999)

Parameter	Design Criteria
BOD	6 g m^{-2} to 30 mg L^{-1} for inlet
TSS	20 g m^{-2} day-1 to 30 mg L^{-1} for inlet
Depth	Substrate: 0.5 to 0.6m Water: 0.4 to 0.5m
Length	Minimum 15 m
Width	Maximum 61m
Bed bottom slope	0.5 to 1%
Bed surface slope	Flat or almost flat
Hydraulic conductivity	1000m day^{-1} for the first 30% of length 10000m day^{-1} for the last 70% of length
Substrate	Inlet section: 40-80mm Process section: 20-30mm Outlet section: 40-80mm Planting section: 5-20mm

Table 4.6: Media used and characteristics

Media type	Porosity, n	Hydraulic conductivity, k_s, m^3/m^{2-} d
Gravel (fine)	0.28	3×10^{-2}
Sand (fine)	0.33	2×10^{-4}
Gravel (medium)	0.24	3×10^{-2}

Volume required for maximum leachate:

Assume:

Design flow rate, Q = 901.60 m^3/day

BOD_5 , Ci = 686 mg/L

Temperature >20 ℃

Effluent requirements (after biological treatment):

BOD_5 , Co <480 mg/L

Table 4.7: Volume required for maximum leachate

Requirements	Calculations
1. Cross sectional area of the bed, $A_c = Q \div k_s S$; k_s = Hydraulic conductivity = total hydraulic conductivity ÷ total number of media × [1/86400 d] ; S = Slope (0.01) fixed value	A_c = [901.60 ÷ (0.0267) (0.01)] × [1/86400 d] = 39.0 m^2
2. Bed width, W= A_c/d ; d = media depth for using phragmites australis plant is approximately 0.3 m (1ft into medium)	W = 39.08 ÷ 0.3 = 130.0 m
3. Surface area required, As = Q ln(C_i ÷ Co) ÷ [(k)(d_w)(n)] ; k =BOD removal-rate constant = $0.678 \times 1.06^{(T-20)}$; d_w = depth of flow, m ; n = porosity of the bed = total porosity ÷ total number of media ; T = Temperature, ℃ = 26 ℃	K = $0.678 \times 1.06^{(T-20)}$ = 0.962 As = 901.60 ln (686 ÷ 480) ÷ [(0.962) (1.1) (0.2825)] = 1073.2 m^2 = 0.107 ha
4. Bed length	L = 1073.20 ÷ 130.00

$L = As \div W$	$= 8.26$ m
5. Detention time / Hydraulic Retention Time, HRT $t = Vv \div Q = LWdn \div Q$;Vv = Volume void	$t = (8.26)(130)(1.1)(0.2825) \div 901.60$ $= 0.3701$ days $= 8.88$ hours
6. Hydraulic Loading Rate, $HLR = 100 \times Q \div As$	$HLR = 100 \times Q \div As$ $= 100 \times 901.60 \div 1073.2$ $= 84.01$ cm/d
7. Total Volume, $V = L \times W \times D$	Construct 1 cell, $V = 130\text{m} \times 8.26\text{m} \times 1.1\text{m}$ $= 1181.18\ \text{m}^3$
8. For nitrification (NH_4) $As = [Q(\text{In } Co - \text{In } Ce)] \div (K_T\ d\ n)$ $\ln Ce = \ln Co - (As \times K_T\ d\ n)/Q$ where Ce = effluent NH_4, mg/L Co = influent NH_4, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d	Co = 880 mg/L $K_T = 0.2187 \times 1.048^{(26-20)}$ $K_T = 0.289745$ Effluent NH_4 $\ln Ce = \ln Co - (As \times K_T\ d\ n)/Q$ $\ln Ce = \ln 880 - (1073.15 \times 0.289745 \times 1.1 \times 0.2825)/901.6$
d = depth of flow, m n = porosity K_T = NH_4 removal-rate constant $= 0.2187 \times 1.048^{(T-20)}$	$\ln Ce = 6.6728$ Ce = 790.56 mg/L Removal efficiency = (880 – 790.56)/ 880 x 100% = 10.16 %
9. For denitrification (NO_3) $As = [Q(\text{In } Co - \text{In } Ce)] \div (K_T\ d\ n)$ $\ln Ce = \ln Co - (As \times K_T\ d\ n)/Q$ Ce = effluent NO_3, mg/L Co = influent NO_3, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d d = depth of flow, m	Co = 25.05 mg/L $K_T = 1.0 \times 1.15^{(26-20)}$ $K_T = 2.313061$ Effluent NO_3 $\ln Ce = \ln Co - (As \times K_T\ d\ n)/Q$ $\ln Ce = \ln 25.05 - (1073.15 \times 2.313061 \times 1.1 \times 0.2825)/901.6$

n = porosity K_T = NO_3 removal-rate constant = 1.0 x $1.15^{(T-20)}$	ln Ce = 2.3653 Ce = 10.65 mg/L Removal efficiency = (25.05 – 10.65)/ 25.05 x 100% = 57.49 %
10. For TSS removal Ce = Ci (0.1139 + 0.00213 HLR) Ce = effluent TSS, mg/L Co = influent TSS, mg/L HLR = hydraulic loading rate, cm/d	Co = 1353 mg/L Effluent TSS Ce = Co (0.1139 + 0.00213 HLR) Ce = 1353 (0.1139 + 0.00213 x 84.01) Ce = 396.21 mg/L Removal efficiency = (1353 – 396.21)/ 396.21 x 100% = 70.72 %
11. Hydraulic consideration where Q = average flow rate, m^3/d w = width of wetland, m v = liquid flow velocity, m/s n = Manning's coefficient, $s/m^{1/3}$ d = depth of water, m s = hydraulic gradient or slope of water surface, m/m a = resistance factor, $s.m^{1/6}$ = 0.40 for sparse vegetation and d_W > 0.396 m L = length of wetland, m	
a. Velocity	v = Q/ (L x w) v = 901.6/ (33.04 x 32.5)

	v = 0.84 m/s
b. Mannind's	$n = a/L^{1/2}$ $n = 0.40/33.04^{1/2}$ $n = 0.0696\ s/m^{1/3}$
c. Hydraulic gradient	$s = \{v / [(1/n)(L^{2/3})]\}^2$ $s = \{0.84/ [(1/0.0696)(33.04^{2/3})]\}^2$ s = 0.00003 m/m
d. Headloss	$h_L = sd$ $h_L = 0.00003 \times 1.1$ $h_L = 0.00004$ m

Volume required for minimum leachate:

Assume:

Design flow rate, Q = 53.27 m^3/day

BOD_5 , Ci = 686 mg/L

Temperature >20 ℃

Effluent requirements (after biological treatment):

BOD_5 , Co <480 mg/L

Table 4.8: Volume required for minimum leachate

Requirements	Calculations
1. Cross sectional area of the bed, Ac = Q ÷ ksS ; ks = Hydraulic conductivity = total hydraulic conductivity ÷ total number of media × [1/86400 d] ; S = Slope (0.01) fixed value	Ac = [53.27 ÷ (0.0267) (0.01)] × [1/86400 d] = 2.31 m^2
2. Bed width, W= Ac/d ; d = media depth for using phragmites australis plant is approximately 0.30 m (1ft into medium)	W = 2.31 ÷ 0.3 = 7.70 m
3. Surface area required, As = Q ln(C_i ÷ Co) ÷ [(k)(d_w)(n)] ; k =BOD removal-rate constant = $0.678 \times 1.06^{(T-20)}$; d_w = depth of flow, m ; n = porosity of the bed = total porosity ÷ total number of media ; T = Temperature, ℃ = 26 ℃	K = $0.678 \times 1.06^{(T-20)}$ = 0.962 As = 53.27 ln(686 ÷ 480) ÷ [(0.962)(1.1)(0.2825)] = 63.64 m^2 = 0.0063 ha
4. Bed length L = As ÷ W	L = 63.64 ÷ 7.70 = 8.27 m

5. Detention time / Hydraulic Retention Time, HRT $t = Vv \div Q = LWdn \div Q$;Vv = Volume void	$t = (8.27)(7.70)(1.1)(0.2825) \div 53.27$ = 0.3715 days = 8.92 hours
6. Hydraulic Loading Rate, $HLR = 100 \times Q \div As$	$HLR = 100 \times Q \div As$ $= 100 \times 53.27 \div 63.64$ = 83.71 cm/d
7. Total Volume, $V = L \times W \times D$	Construct 1 cell, $V = 8.27m \times 7.70m \times 1.1m$ $= 70.05\ m^3$
Total volume required (70.05 m^3) < Design volume (1181.18 m^3) Surface area required (63.64 m^2) < Design area (1073.2 m^2) Design volume and area is suitable during the minimum leachate generation	
By using the maximum value as a design value	
8. Hydraulic loading rate HLR = 100 x Q/As	HLR = 100 x 53.27 m^3/d / 1073.15m^2 = 4.96 cm/d
9. For BOD As = [Q (In Co - In Ce)] ÷ (K_T d n) ln Ce = ln Co – (As x K_T d n)/Q where Ce = effluent BOD, mg/L Co = influent BOD, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d d = depth of flow, m n = porosity K_T = BOD removal-rate constant	Co = 686 mg/L $K_T = 0.678\times1.06^{(26-20)}$ K_T = 0.962 Effluent BOD ln Ce = ln Co – (As x K_T d n)/Q ln Ce = ln 686 – (1073.15 x 0.962 x 1.1 x 0.2825)/53.27 ln Ce = 0.5086 Ce = 1.66 mg/L
$= 0.678\times1.06^{(T-20)}$	Removal efficiency = (686 – 1.66)/ 686 x 100% = 99.76 %
10. For nitrification (NH_4) As = [Q (In Co - In Ce)] ÷ (K_T d n)	Co = 880 mg/L $K_T = 0.2187 \times 1.048^{(26-20)}$

$\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ where Ce = effluent NH_4, mg/L Co = influent NH_4, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d d = depth of flow, m n = porosity K_T = NH_4 removal-rate constant $= 0.2187 \times 1.048^{(T-20)}$	$K_T = 0.289745$ Effluent NH_4 $\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ $\ln Ce = \ln 880 - (1073.15 \times 0.289745 \times 1.1 \times 0.2825)/53.27$ $\ln Ce = 4.9661$ $Ce = 143.46$ mg/L Removal efficiency = (880 – 143.46)/ 880 x 100% = 83.70 %
11. For denitrification (NO_3) $As = [Q (\ln Co - \ln Ce)] \div (K_T\, d\, n)$ $\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ Ce = effluent NO_3, mg/L Co = influent NO_3, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d d = depth of flow, m n = porosity K_T = NO_3 removal-rate constant $= 1.0 \times 1.15^{(T-20)}$	Co = 25.05 mg/L $K_T = 1.0 \times 1.15^{(26-20)}$ $K_T = 2.313061$ Effluent NO_3 $\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ $\ln Ce = \ln 25.05 - (1073.15 \times 2.313061 \times 1.1 \times 0.2825)/53.27$ $\ln Ce = -11.2594$ $Ce = 0.00001$ mg/L Removal efficiency = (25.05 – 0.00001)/ 25.05 x 100% = 99.99 %
12. For TSS removal $Ce = Ci (0.1139 + 0.00213\, HLR)$ Ce = effluent TSS, mg/L Co = influent TSS, mg/L HLR = hydraulic loading rate, cm/d	Co = 1353 mg/L Effluent TSS $Ce = Co (0.1139 + 0.00213\, HLR)$ $Ce = 1353 (0.1139 + 0.00213 \times 4.96)$ $Ce = 168.40$ mg/L

	Removal efficiency = (1353 – 168.40)/ 1353 x 100% = 87.55 %
13. Hydraulic consideration where Q = average flow rate, m^3/d w = width of wetland, m v = liquid flow velocity, m/s n = Manning's coefficient, $s/m^{1/3}$ d = depth of water, m s = hydraulic gradient or slope of water surface, m/m a = resistance factor, $s.m^{1/6}$ = 0.40 for sparse vegetation and d_W > 0.396 m L = length of wetland, m	
a. Velocity	v = Q/ (L x w) v = 53.27/ (33.04 x 32.5) v = 0.05 m/s
b. Mannind's	$n = a/L^{1/2}$ $n = 0.40/33.04^{1/2}$ $n = 0.0696\ s/m^{1/3}$
c. Hydraulic gradient	$s = \{v / [(1/n)(L^{2/3})]\}^2$ $s = \{0.05/ [(1/0.0696)(33.04^{2/3})]\}^2$ $s = 1.1 \times 10^{-7}$ m/m
d. Headloss	$h_L = sd$ $h_L = 1.1 \times 10^{-7} \times 1.1$ $h_L = 1.3 \times 10^{-7}$ m

Volume required for average leachate:

Assume:

Design flow rate, Q = 258.02 m^3/day

BOD_5 , Ci = 686 mg/L

Temperature>20 ℃

Effluent requirements (after biological treatment):

BOD_5 , Co <480 mg/L

Table 4.9: Volume required for average leachate

Requirements	Calculations
1. Cross sectional area of the bed, Ac = Q ÷ ksS ; ks = Hydraulic conductivity = total hydraulic conductivity ÷ total number of media × [1/86400 d] ; S = Slope (0.01) fixed value	A_c = [258.02 ÷ (0.0267) (0.01)] × [1/86400 d] = 11.19 m^2
2. Bed width, W= Ac/d ; d = media depth for using phragmites australis plant is approximately 0.30 m (1ft into medium)	W = 11.19 ÷ 0.3 = 37.30 m
3. Surface area required, As = Q ln(C_i ÷ Co) ÷ [(k)(d_w)(n)] ; k =BOD removal-rate constant = 0.678×1.06 $^{(T-20)}$; d_w = depth of flow, m ; n = porosity of the bed = total porosity ÷ total number of media ; T = Temperature, ℃ = 26 ℃	K = 0.678×1.06 $^{(T-20)}$ = 0.962 As = 258.02 ln(686 ÷ 480) ÷ [(0.962)(1.1)(0.2825)] = 308.25 m^2 = 0.0308 ha
4. Bed length L = As ÷ W	L = 308.25 ÷ 37.30 = 8.26 m

5. Detention time / Hydraulic Retention Time, HRT $t = Vv \div Q = LWdn \div Q$;Vv = Volume void	$t = (8.26)(37.30)(1.1)(0.2825) \div 258.02$ $= 0.3710$ days $= 8.90$ hours
6. Hydraulic Loading Rate, $HLR = 100 \times Q \div As$	$HLR = 100 \times Q \div As$ $= 100 \times 258.02 \div 308.25$ $= 83.71$ cm/d
7. Total Volume, $V = L \times W \times D$	Construct 1 cell, $V = 8.26m \times 37.20m \times 1.1m$ $= 338.0\ m^3$
Total volume required (338.00 m^3) < Design volume (1181.18 m^3) Surface area required (308.25 m^2) < Design area (1073.2 m^2) Design volume and area is suitable during the minimum leachate generation	
By using the maximum value as a design value	
8. Hydraulic loading rate HLR = 100 x Q/As	HLR = 100 x 258.02 m^3/d / 1073.15m^2 = 24.04 cm/d
9. For BOD As = [Q (In Co - In Ce)] ÷ (K_T d n) ln Ce = ln Co – (As x K_T d n)/Q where Ce = effluent BOD, mg/L Co = influent BOD, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d d = depth of flow, m n = porosity K_T = BOD removal-rate constant	Co = 686 mg/L $K_T = 0.678 \times 1.06^{(26-20)}$ $K_T = 0.962$ Effluent NH_4 ln Ce = ln Co – (As x K_T d n)/Q ln Ce = ln 686 – (1073.15 x 0.962 x 1.1 x 0.2825)/258.02 ln Ce = 5.2875 Ce = 197.85 mg/L
$= 0.678 \times 1.06^{(T-20)}$	Removal efficiency = (686 – 197.85)/ 686 x 100% = 71.16 %
10. For nitrification (NH_4) As = [Q (In Co - In Ce)] ÷ (K_T d n)	Co = 880 mg/L $K_T = 0.2187 \times 1.048^{(26-20)}$

$\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ where Ce = effluent NH_4, mg/L Co = influent NH_4, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d d = depth of flow, m n = porosity K_T = NH_4 removal-rate constant $= 0.2187 \times 1.048^{(T-20)}$	$K_T = 0.289745$ Effluent NH_4 $\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ $\ln Ce = \ln 880 - (1073.15 \times 0.289745 \times 1.1 \times 0.2825)/258.02$ $\ln Ce = 6.4054$ $Ce = 605.13$ mg/L Removal efficiency = (880 – 605.13)/ 880 x 100% = 31.24 %
11. For denitrification (NO_3) $As = [Q (\ln Co - \ln Ce)] \div (K_T\, d\, n)$ $\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ Ce = effluent NO_3, mg/L Co = influent NO_3, mg/L As = surface area, m^2 Q = leachate flow rate, m^3/d d = depth of flow, m n = porosity K_T = NO_3 removal-rate constant $= 1.0 \times 1.15^{(T-20)}$	Co = 25.05 mg/L $K_T = 1.0 \times 1.15^{(26-20)}$ $K_T = 2.313061$ Effluent NO_3 $\ln Ce = \ln Co - (As \times K_T\, d\, n)/Q$ $\ln Ce = \ln 25.05 - (1073.15 \times 2.313061 \times 1.1 \times 0.2825)/258.02$ $\ln Ce = 0.2313$ $Ce = 1.26$ mg/L Removal efficiency = (25.05 – 1.26)/ 25.05 x 100% = 94.97 %
12. For TSS removal Ce = Ci (0.1139 + 0.00213 HLR) Ce = effluent TSS, mg/L Co = influent TSS, mg/L HLR = hydraulic loading rate, cm/d	Co = 1353 mg/L Effluent TSS Ce = Co (0.1139 + 0.00213 HLR) Ce = 1353 (0.1139 + 0.00213 x 24.04) Ce = 223.39 mg/L

	Removal efficiency = (1353 – 223.39)/ 1353 x 100% = 83.49 %
13. Hydraulic consideration where Q = average flow rate, m^3/d w = width of wetland, m v = liquid flow velocity, m/s n = Manning's coefficient, $s/m^{1/3}$ d = depth of water, m s = hydraulic gradient or slope of water surface, m/m a = resistance factor, $s.m^{1/6}$ = 0.40 for sparse vegetation and d_W >0.396 m L = length of wetland, m	
a. Velocity	v = Q/ (L x w) v = 258.02/ (33.04 x 32.5) v = 0.24 m/s
b. Mannind's	$n = a/L^{1/2}$ $n = 0.40/33.04^{1/2}$ $n = 0.0696\ s/m^{1/3}$
c. Hydraulic gradient	$s = \{v / [(1/n)(L^{2/3})]\}^2$ $s = \{0.24/ [(1/0.0696)(33.04^{2/3})]\}^2$ s = 0.000003 m/m
d. Headloss	$h_L = sd$ h_L = 0.000003 x 1.1 h_L = 0.000003 m

Table 4.10: Removal result of proposed constructed wetland

All the design area is based on maximum leachate generation to withstand the high amount of leachate and to prevent overflow. A = 1073.2 m^2			
Maximum leachate generation = 901.6 m^3/d			
Parameter	**Influent concentration (mg/L)**	**Effluent concentration (mg/L)**	**Removal efficiency %**
BOD	686	480	30.03
NH_4	880	790.56	10.16
NO_3	25.05	10.65	57.49
TSS	1353	396.21	70.72
Minimum leachate generation = 53.27 m^3/d			
Parameter	**Influent concentration (mg/L)**	**Effluent concentration (mg/L)**	**Removal efficiency %**
BOD	686	1.66	99.76
NH_4	880	143.46	83.70
NO_3	25.05	0.00001	99.99
TSS	1353	168.40	87.55
Average leachate generation = 258.02 m^3/d			
Parameter	**Influent concentration (mg/L)**	**Effluent concentration (mg/L)**	**Removal efficiency %**
BOD	686	197.85	71.16
NH_4	880	605.13	32.24
NO_3	25.05	1.26	94.97
TSS	1353	223.39	83.49

Resizing are required to fit in the existing space of the SBR process, adjust the calculated value according to the efficiency and standards. Resizing was done according to the design criteria (EPA, 1999) for better optimization of constructed wetland. Detention time or hydraulic retention time is set based on time taken for contaminants to settle out of the water. This should preferably be 72 hours but not less than 48 hours for constructed wetland. The length to width ratio should not be less than 5:1 or 3:1 to avoid short circuit flow paths and poorly mixed regions. The desirable depth should be 0.50 m to 1.50 m depending on the desired operation and target pollutant. Table 4.11 shows the comparison between SBR and constructed wetland together with the resized dimension. Meanwhile Table 5.12 shows the summary of proposed constructed wetland.

Table 4.11: Comparison of existing SBR and designed constructed wetland

Existing dimension for SBR including liner	**Calculations for Constructed Wetland**	**Resized dimension of Constructed Wetland**
SBR width, W = 32.0 m	Bed width, W = 130.0 m	Bed width, W = 130.0 m ÷ 4 = 32.50 m
Surface area, As = 1248.0 m^2 = 0.124 ha	Surface area required, As = 1073.2 m^2 = 0.107 ha	-
SBR length, L = 39.0 m	Bed length, L = 8.26 m	Bed length, L = 8.26 m × 4 = 33.02 m
SBR depth, D = 3.5 m	Bed depth, d_w = 1.10 m	-
Detention time / Hydraulic Retention Time, HRT t = 14 to 24 hours	Detention time / Hydraulic Retention Time, HRT t = 0.3701 days = 8.88 hours	Detention time / Hydraulic Retention Time, HRT t < 48 hours
Total Volume, V = 2000 m^3	Total Volume, V = 1181.18 m^3	Total Volume, V = 1180.45 m^3

Table 4.12: Summary of proposed constructed wetland

Length	33.02 m
Width	32.50 m
Wetland surface area	1073.2 m^2
Design Inflow rate	901.60 m^3/day
Mean hydraulic retention time	24 to 48 hours
Slope of wetland	0.01
Media Depth: • Gravel • Sand	 0.40 m 0.70 m
Bed depth	1.10 m
Media	Fine gravel, fine sand, medium gravel
Vegetation	Phragmites Australis
Hydraulic conductivity	2×10^{-4} to 3×10^{-2}

4.5 Efficiency of Constructed Wetland Compared To SBR

Efficiency of constructed wetland can be proven based on the percentage of removal efficiency of pollutants compared to SBR. Table 4.13 below shows the percentage of removal efficiency of existing SBR and resized constructed wetland. Even though resizing was done to fit in the existing space of SBR, the removal efficiency will not be affected based on the manual calculations. This was further supported by the results obtained by WASDA where the proposed area is suitable for the removal efficiency. Refer to Table 4.12 for summary of surface area calculated by WASDA. These proves that there is better removal of pollutant by replacing the biological treatment system.

Table 4.13: Comparison of removal efficiency of SBR and proposed constructed wetland

Parameter	SBR (%)	Proposed constructed wetland (%)
BOD	25	30.03
NH_4	8	10.16
NO_3	50	57.49
TSS	80	70.72

4.6 Liners of Vertical Constructed Wetland

Constructed wetland required to be lined with clay or liners to prevent mixing with groundwater and natural infiltration as well as to maintain the surface water wetland conditions. In this project, liner for constructed wetland is not required. The existing SBR treatment unit is lined with 5.0 mm high-density polyethylene (HDPE), and this liner can be reused for constructed wetland.

4.7 Vegetation of Vertical Constructed Wetland

The plant presence in constructed wetland is highly important in order to improve pollutant removal efficiencies such as organic matter, nitrogen and phosphorus. The suite of plant species is dependent on two factors; The degree spread of rhizome and the development of belowground root biomass as well as depth of root penetration which improves the treatment of wastewater.

Purification process contributed by the plant species through the pumping of atmospheric oxygen to the surrounding ground portion in wetlands from the emerged part of the root system and by enhancing the active aerobic bacterial communities in the rhizosphere. This performs better oxidation of the leachate wastewater and creation of aerobic, anoxic and anaerobic environments in the vertical constructed wetland which develops various specific microorganism communities to carry out microbial activities and disappearance of the pathogens.

For tropical climate region like Malaysia, the most suitable and commonly available species is *Phragmittes* (K. Kamal et al., 2020). *Phragmites australis,* the common reed is selected for the vegetation of vertical constructed wetland in Rimba Mas leachate treatment plant at a density of 10 plant stems per m^2. The common reed is generally recommended to use in constructed wetland as it plays a useful role in wastewater management systems as reported in earlier studies (Gersberg et al., 1986; Gray and Biddlestone, 1995) for pollutants removal such as nitrogen, total suspended solids and biochemical oxygen demand in wastewater.

Phragmites australis can shoot up above 5 m above ground level from an extensive system of rhizomes and stolons which many researchers have been proven their versatility in constructed wetland. A single silky inflorescence develops at the end of each fertile stem and produces 500–2000 seeds. Roots develop from nodes of rhizomes and grow as sparse pairs which can extend from 30 cm in flooded sites down to 4 m deep where the greatly fluctuation of hydrology. The planting of *Phragmites australis* is done by hand and initially they were filled with water in order to facilitate the growth of plant and bed environment adjustment.

The adaptability, structure and physiology of *Phragmites australis* as mentioned above are fit into the conditions of vertical constructed wetland located at Rimba Mas LTP, Perlis, therefore, *Phragmites australis* (common reed) is selected as vegetation for wetland.

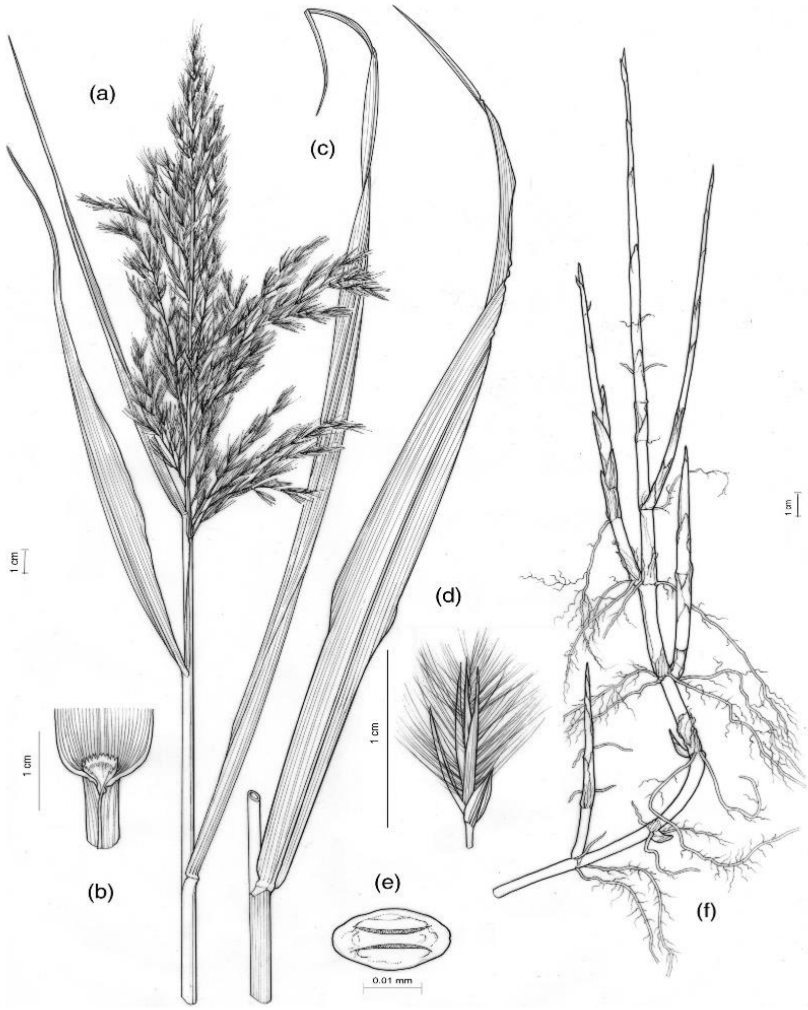


Figure 4.4: Typical morphology of *Phragmites australis* showing (a) panicle, (b) leaf sheath containing fringed ligule, (c) leaf blade, (d) spikelet, (e) stoma and (f) horizontal and vertical rhizomes with roots (British Ecological Society, 2017)

Figure 4.5: *Phragmites australis*

4.8 Media Selection

The media in constructed wetland is crucial as they are rooting material for plant, facilitate evenly distribution throughout the wetland at inlet, provide surface area for growth of microbial communities and act as filter to trap unwanted particles.

The filling media for vertical constructed wetland in Rimba Mas leachate treatment plant consists of 4 layers, there are drainage layer with 20 cm of medium gravel layer (size of gravel around 20-40 mm), a layer of 10 cm fine gravel (5 to 10 mm) and 70 cm sand (1-4 mm), and 10 cm of fine gravel on the top of the bed to ensure a proper evenly distribution over the sand layer and planting of vegetation. According to Stefanakis & Tsihrintzis (2012), an extended sand layer could enhance significantly the performance of the constructed wetland. The total height is around 110 cm.

4.9 Flow Distribution of Wetland

There are few hydraulic aspects that need to be considered for the design of vertical constructed wetland, including distribution of the influent flow and collection of the effluent flow. Structures are required to transfer water from Lamella Clarifier into the wetland and transfer the treated effluent from constructed wetland to DAF Feed Pond. There are various types of pipe materials to be chosen and the materials of pipe are depend upon the magnitude of the flow to be managed. Construction of distribution system for wastewater to distribute into the constructed wetland consisting of pipe, channels, or coarse rock beds.

The inlet device used of the distribution system to spread the entering wastewater across the wetland width is HDPE perforated pipes as these distribution pipes are short and gravity-fed. A series of perforated influent distribution pipes will be constructed on the surface of the wetland bed. Each pipe spacing is approximately two meter in order to achieve a evenly distribution of influent onto the wetland bed. According to Robert H., Scott D. (2009), there is no rational design method on the number of square meters per distribution point and volume per dose.

For outlet zone of constructed wetland, effluent flows vertically through the porous medium until it reaches the drainage system at the bottom of wetland. Outlet pipeline of the drainage system will be connected to outlet manhole prior to DAF feed pond. The function of an outlet manhole in constructed wetland is to control the water level in constructed wetland. There is only the effluent flow when the new batch of influent come in from lamella clarifier. For instance, during drought season, low amount of leachate will be produced from landfill and treated in leachate treatment plant, effluent will firstly be collected in outlet manhole then transfer to DAF Feed Pond in order to prevent dry out of wetland due to insufficient water levels for plant growth and operation of the wetlands.

4.10 Maintenance of the Vertical Constructed Wetland

For subsurface flow, deposition of plant detritus, particulate matter and biofilms of microbial function as clogging mechanisms. However, clogging in vertical wetlands in Rimba Mas sanitary landfill is less likely to occur due to treating leachate with inherently low in TSS, especially during monsoon season, rainwater dilutes the leachate produced in landfill cells. The solids form a mat on the surface of the bed before entering the wetland system as shown in Fig 4.6. This appears as a trap for future incoming solids and spares the underlying bed from clogging as well as facilitate in pollutant treatment of leachate.

According to Molle et al. (2004a), Chazarenc and Merlin (2005), the cleanout frequency for the wetland of eight to ten years was reasonable as the accumulation of solids layer on the surface of bed to be a function of the organic-loading rate and operational load-and-resting regime. Skid-steer loader can be used to remove the excessive accumulated solids if necessary.

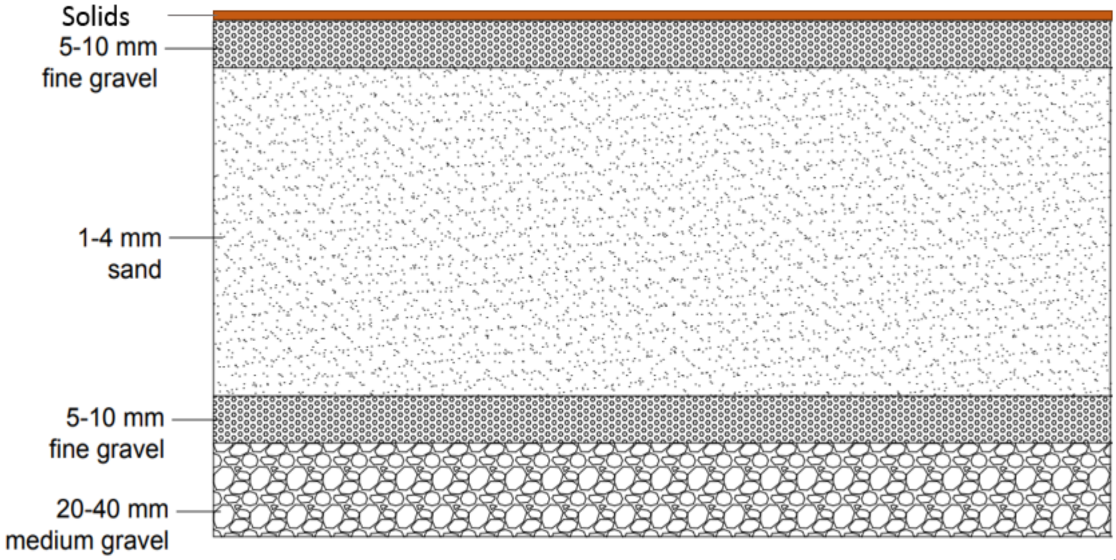


Figure 4.6: Accumulated solids on surface of wetland

For vegetation, routine maintenance measures are crucial such as mowing and structure cleaning to maintain top performance of the vertical wetland system. Vegetation management including depth management and controlled use of fire.

Despite the constructed wetland system is operator-friendly but monitoring of inflow and outflow water quality is one of the crucial aspects of the wetlands operation including routine monitoring of the internal wetland structure and analysis of data which provides a reference for correlating changes in water quality performance with system structure.

4.11 Process Control Implementation in Rimba Mas Leachate Treatment Plant

Controller and sensor are used in this LTP system to check the quality of leachate and leachate treatment if they achieve the same accuracy and reproducibility as off-line methods. This system is also well known to perform in industrial environments. For leachate treatment quality checking and analysis several parameters such as pH, DO (Dissolved Oxygen) and flow into ponds are monitored. Chemicals are also added into the coagulation and flocculation mixer automatically. As for controller, pH controller are used in several places such as flocculation mixer and SBR tank. Besides, single point capacitive sensor is used to measure pressure, temperature and fluid level at several processes in this LTP. All of the measurements and levels are showed at the control board at the panel board and recorded with the accurate time the measurement was taken.

According to the Technical Guideline for Sanitary Landfill, Design and Operation (revised draft, 2004), all the recorded parameters must be presented if required and it compulsory to take note of them. In order to fulfill this, an automatic process can be to ease the process. This also reduces manpower to avoid harmful work and move towards the industrial revolution to be increasing usage of technology. Figure 4.8 shows the feedback controller diagram of the LTP process which includes controller and sensor used. The diagram shows the flow from constructed wetland toward the monitoring pond. Leachate is proceeded in each of the stages shown below to get an output of treated leachate at the monitoring pond.

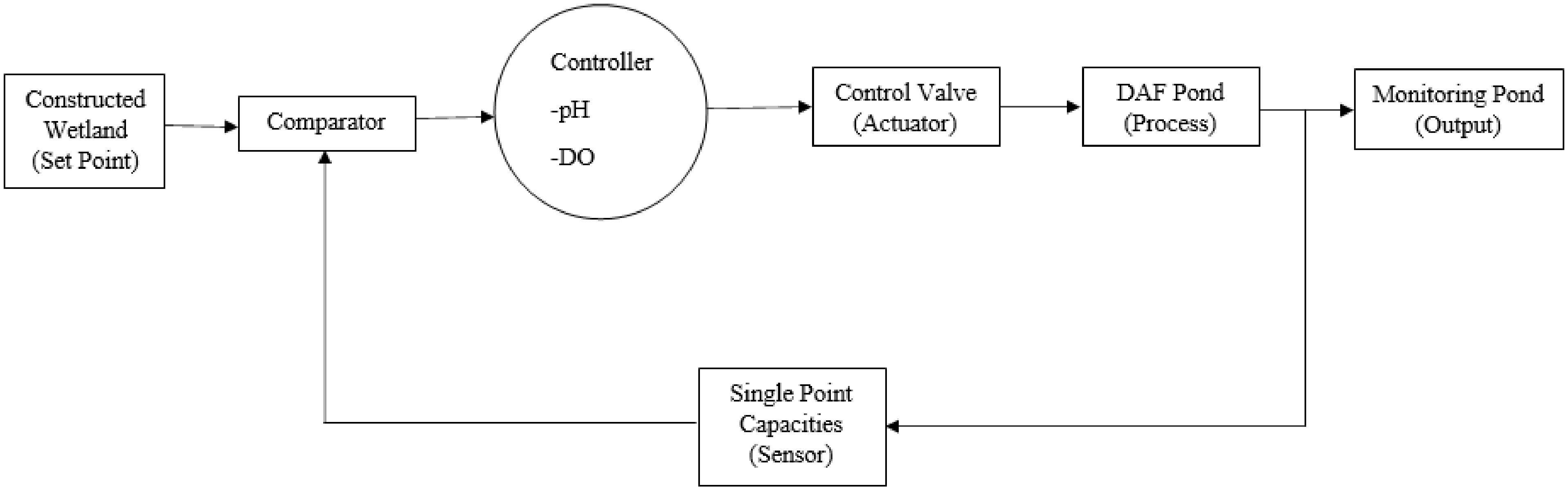
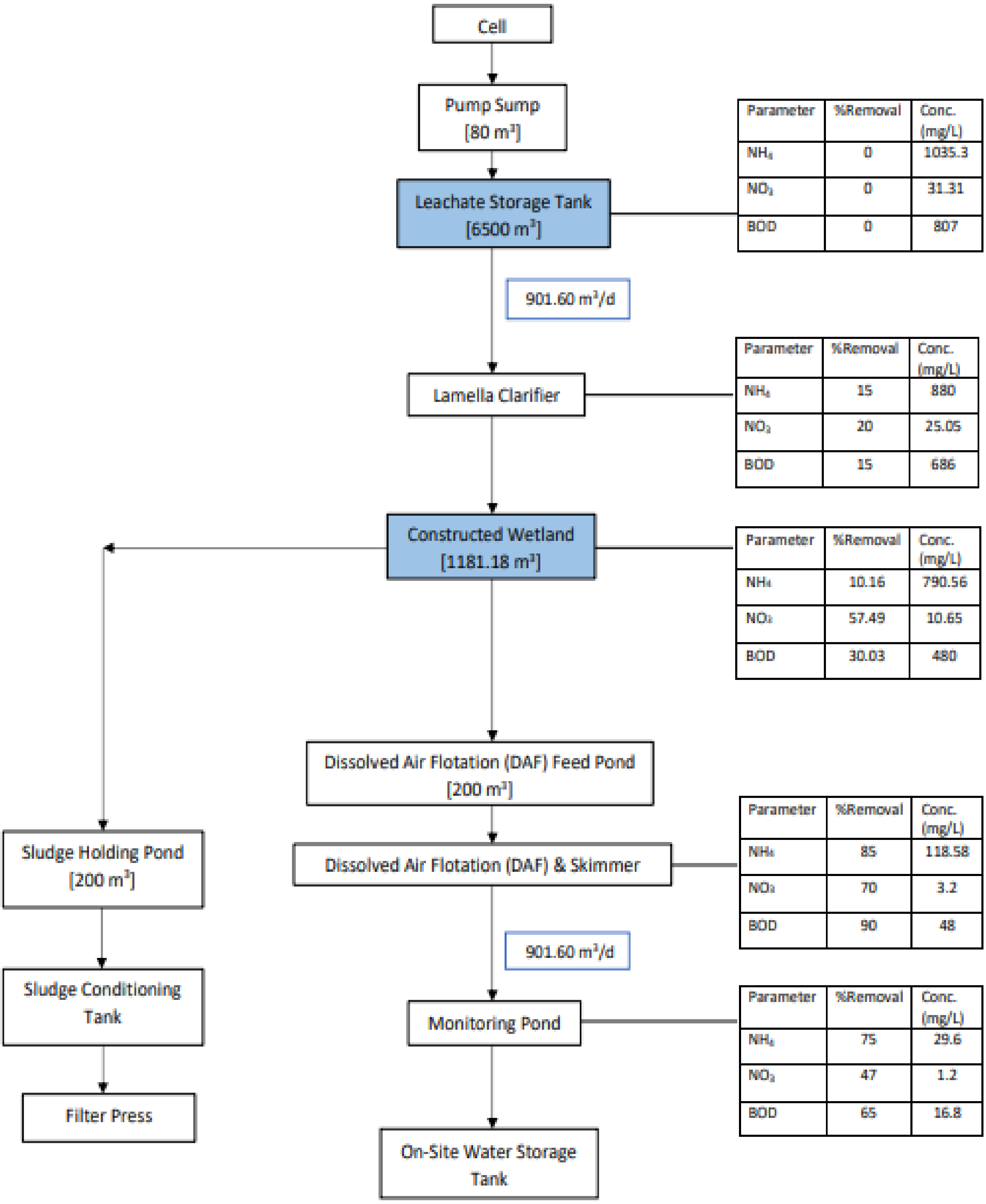


Figure 4.7: Feedback Controller Diagram of LTP system

4.12 Modified Material Balance



Parameter	%Removal	Conc. (mg/L)
NH_4	0	1035.3
NO_3	0	31.31
BOD	0	807

Parameter	%Removal	Conc. (mg/L)
NH_4	15	880
NO_3	20	25.05
BOD	15	686

Parameter	%Removal	Conc. (mg/L)
NH_4	10.16	790.56
NO_3	57.49	10.65
BOD	30.03	480

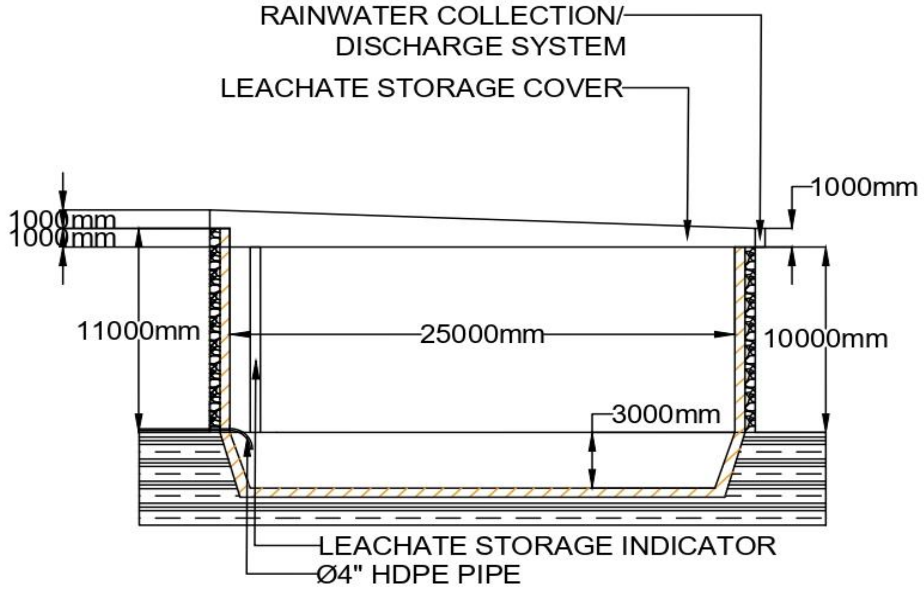
Parameter	%Removal	Conc. (mg/L)
NH_4	85	118.58
NO_3	70	3.2
BOD	90	48

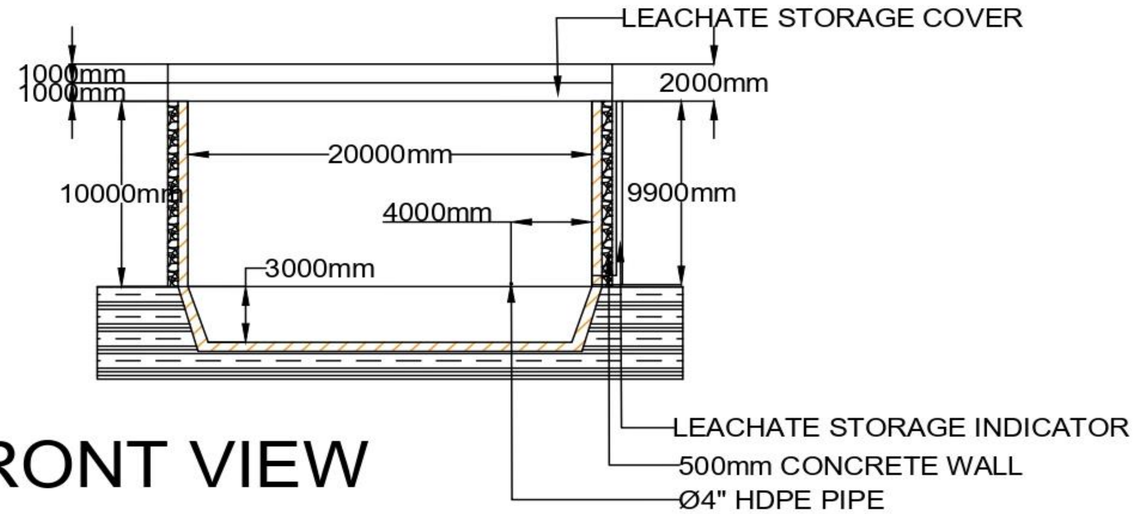
Parameter	%Removal	Conc. (mg/L)
NH_4	75	29.6
NO_3	47	1.2
BOD	65	16.8

4.13 AutoCAD Drawings

1) Extension of leachate Storage Pond
2) Constructed Wetland (Side view and front view)
3) Constructed Wetland (Top view and bottom view)
4) Constructed Wetland (Outlet Manhole)
5) Hydraulic Profile

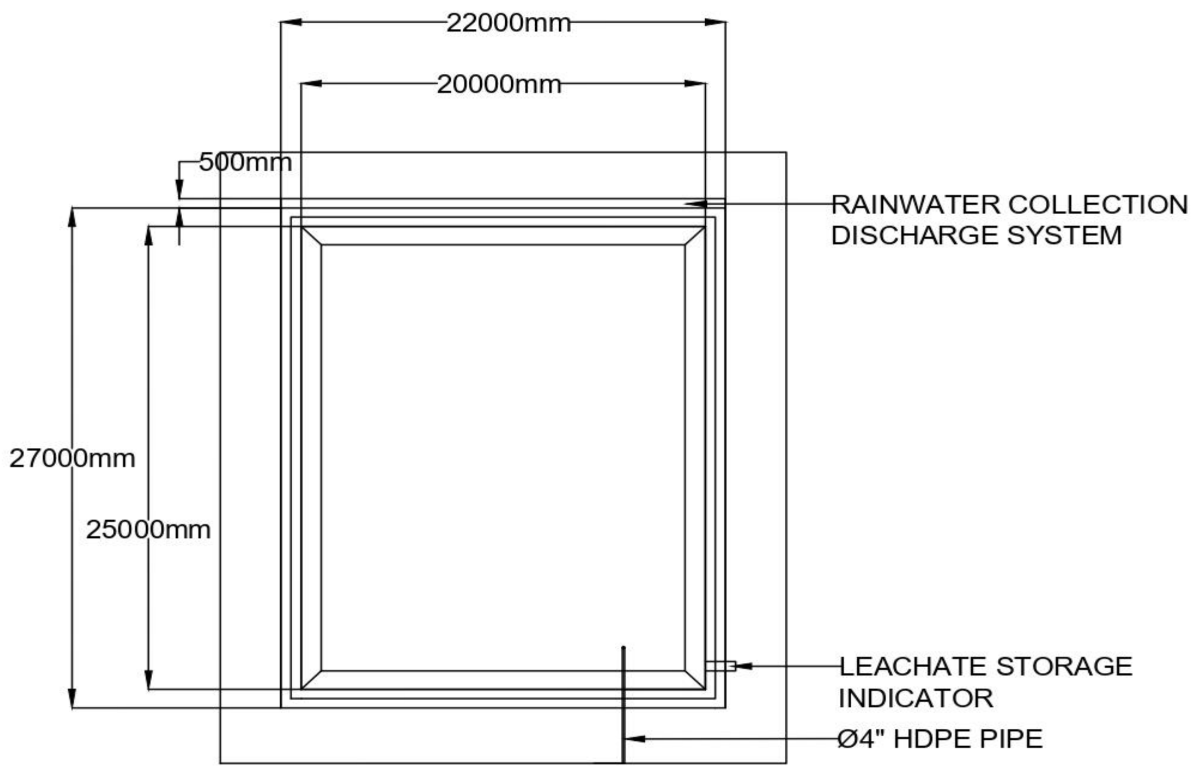
SIDE VIEW





FRONT VIEW

TOP VIEW



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LANGITBIRU SDN. BHD.
NO 6, KOMPLEKS PERNIAGAAN UTARA,
01000 KANGAR, PERLIS

SPECIALIST CONTRACTOR (1):

SPECIALIST CONTRACTOR (2):

REV	DATE	DESCRIPTION

PROJECT TITLE:
MODIFICATION OF RIMBA MAS SANITARY LANDFILL LEACHATE TREATMENT PLANT

DRAWN BY: BEBIANNA LIM CHEAN YIING

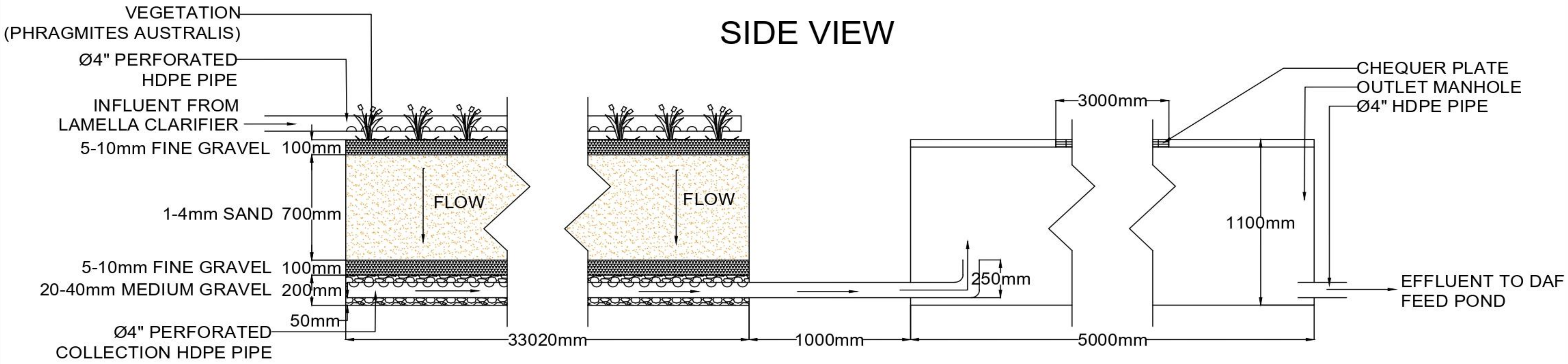
CHECKED BY:

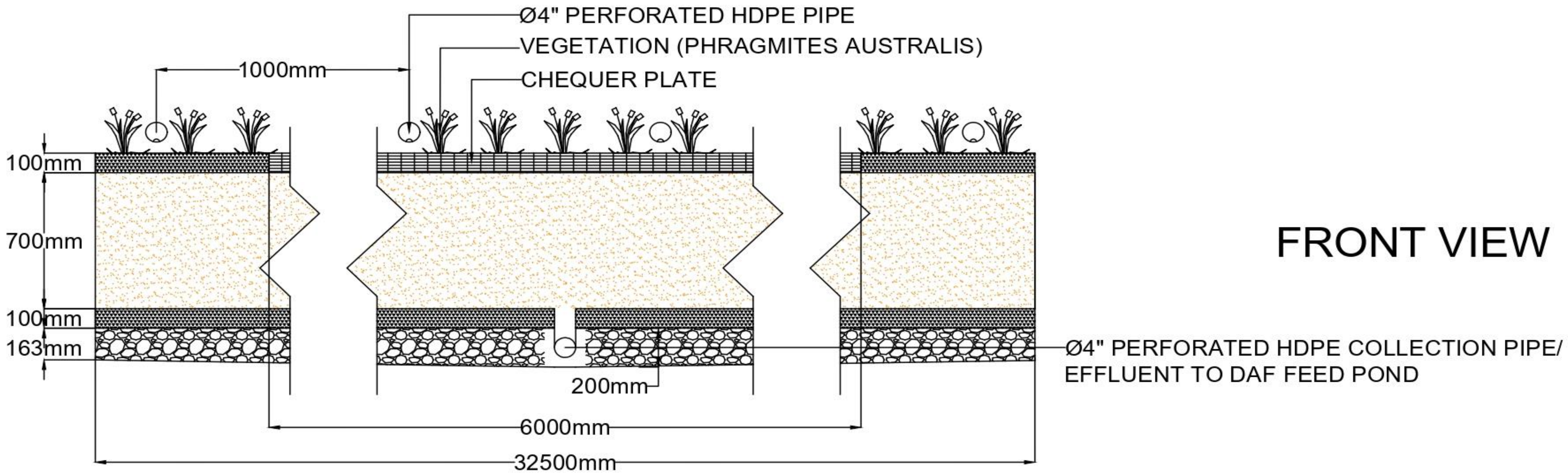
DATE: 5 MAY 2020

DRAWING TITLE: EXTENSION OF LEACHATE STORAGE POND

SCALE: 1:350

DRAWING NO: 1





MAIN CONTRACTOR:
LANGITBIRU SDN. BHD.
NO 6, KOMPLEKS PERNIAGAAN UTARA,
01000 KANGAR, PERLIS

SPECIALIST CONTRACTOR (1):

SPECIALIST CONTRACTOR (2):

REV	DATE	DESCRIPTION

PROJECT TITLE:
MODIFICATION OF RIMBA MAS SANITARY LANDFILL LEACHATE TREATMENT PLANT

DRAWN BY:
MOHAMAD YAZID BIN AHMAD NAZRI
BEBIANNA LIM CHEAN YIING

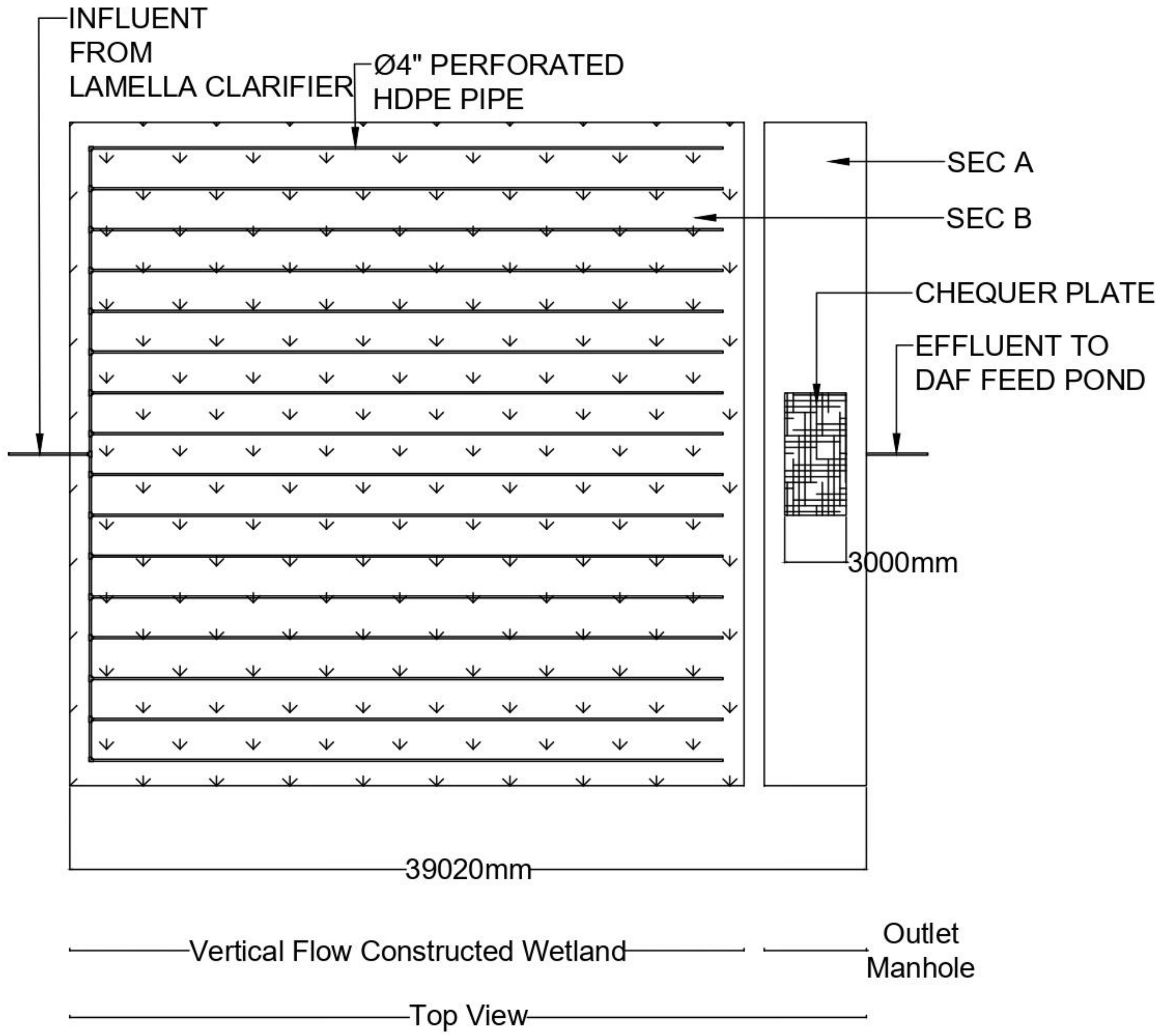
CHECKED BY:

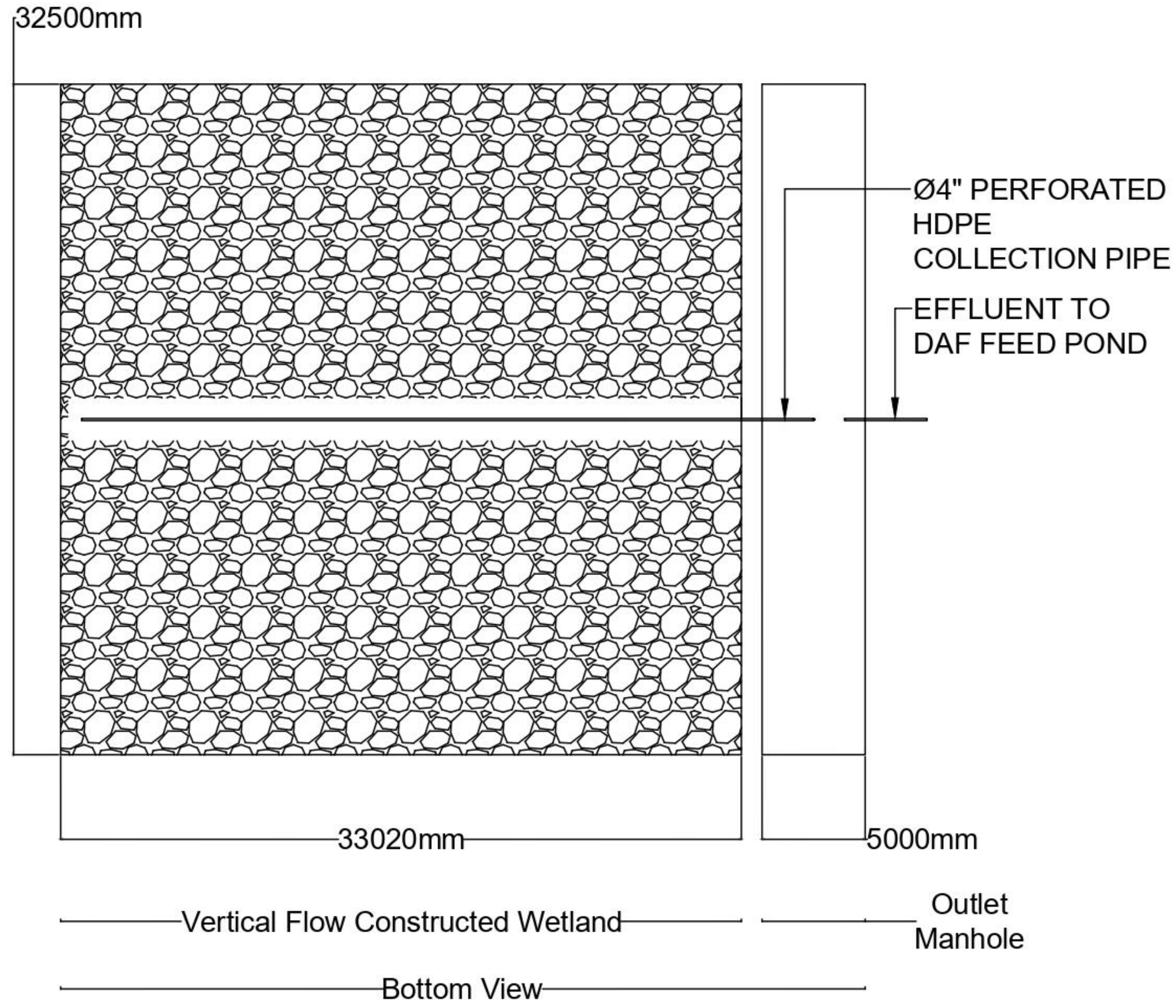
DATE: 5 MAY 2020

DRAWING TITLE: CONSTRUCTED WETLAND

SCALE: 1:350

DRAWING NO: 2





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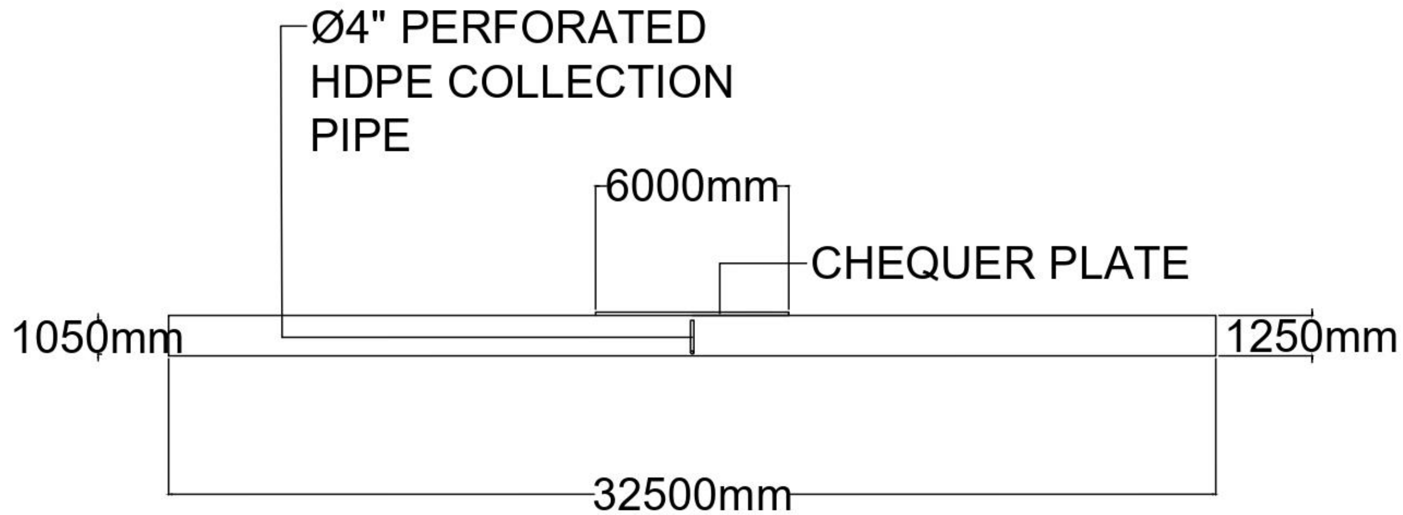
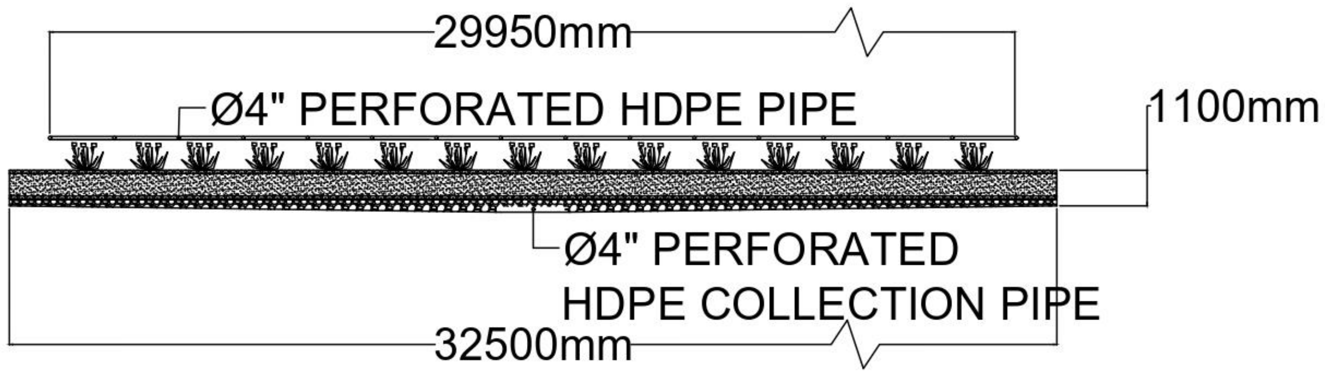
LANGITBIRU SDN. BHD. NO 6, KOMPLEKS PERNIAGAAN UTARA, 01000 KANGAR, PERLIS						MODIFICATION OF RIMBA MAS SANITARY LANDFILL LEACHATE TREATMENT PLANT	LEE CHING MEN
							CHECKED BY:
							DATE: 5 MAY 2020
						DRAWING TITLE: CONSTRUCTED WETLAND SCALE: 1:350	DRAWING NO: 3



Section A Outlet Manhole



Section B Constructed Wetland

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LANGITBIRU SDN. BHD. NO 6, KOMPLEKS PERNIAGAAN UTARA, 01000 KANGAR, PERLIS						MODIFICATION OF RIMBA MAS SANITARY LANDFILL LEACHATE TREATMENT PLANT		LEE CHING MEN
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								DATE: 5 MAY 2020
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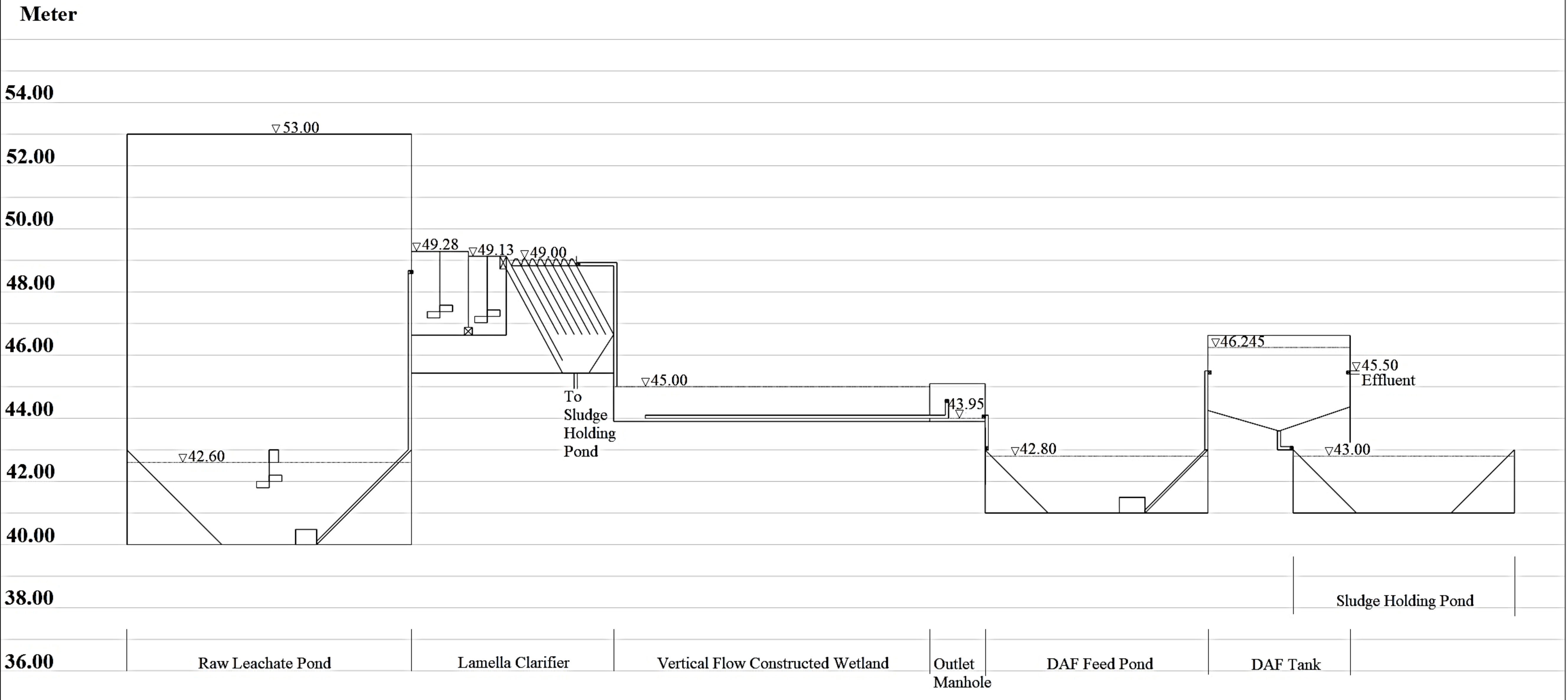

MAIN CONTRACTOR:	SPECIALIST CONTRACTOR (1):	SPECIALIST CONTRACTOR (2):	REV	DATE	DESCRIPTION	PROJECT TITLE:		DRAWN BY:
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								CHECKED BY:
								DATE: 5 MAY 2020
						DRAWING TITLE: HYDRAULIC PROFILE	SCALE:	DRAWING NO: 5

4.14 Design Simulation

Constructed wetland is not popular or widely use in Malaysia since its first impression is the process required large land area and it is a natural process. In fact, constructed wetland has a great treatment mechanism which is including bioconversion by facultative and anaerobic bacteria on plant and debris surfaces, filtration, sedimentation, nitrification, denitrification, plant uptake, volatilization and adsorption of plant roots. Besides that, modern tool is applied to ensure and prove the proposed constructed wetland is workable as a secondary treatment process.

Wastewater Treatment Plant Design Advisor (WASDA) is an assisting tool to guide engineer in decision making for wastewater treatment plant design. It is a practical and useful computation tool especially in Malaysia since the design criteria and requirements simulate in WASDA is based on Malaysian Department of Environment (DOE) and Department of Sewerage Services (DSS). In this assisting tool, the constructed wetland is categorised in the secondary treatment process which mean, the process is recognized as a secondary treatment process by DOE and DSS. This could break the traditional idea concept which is the constructed wetland only can use as a final polishing process.

In this project, WASDA is used to simulate the vertical flow constructed wetland in order to determine the area required for biochemical oxygen demand (BOD) removal, total suspended solid (TSS) removal, nitrification and denitrification by using the concentration of influent and effluent of the leachate.

414.1 Result of Design Simulation

The influent and effluent of concentration calculated in this project is applied in WASDA to determine the surface area required. The surface area of proposed constructed wetland is 1073.2 m^2 which is very close to the result determined by using WASDA which is shown in Table 4.16. The small difference of surface area may be affected by round-off error occurred either in WASDA or manual calculation. However, the result of WASDA shows the vertical flow constructed wetland with surface area of 1073.2 m^2 is suitable to treat BOD, TSS, nitrification and denitrification during extreme weathers, Monsoon season and drought season.

Table 4.14: Summary of surface area calculated by using WASDA

Proposed surface area = 1073.2 m^2	
Maximum leachate generation = 901.6 m^3/d	
Parameter	**Surface area in WASDA, m^2**
BOD	1077.25
NH_4	1073.25
NO_3	1072.86
TSS	1077.25
Minimum leachate generation = 53.27 m^3/d	
Parameter	**Surface area in WASDA, m^2**
BOD	1073.73
NH_4	1073.15
NO_3	1073.13
TSS	1073.73
Average leachate generation = 258.02 m^3/d	
Parameter	**Surface area in WASDA, m^2**
BOD	1073.44
NH_4	1073.13
NO_3	1073.23
TSS	1073.44

For maximum leachate generation:

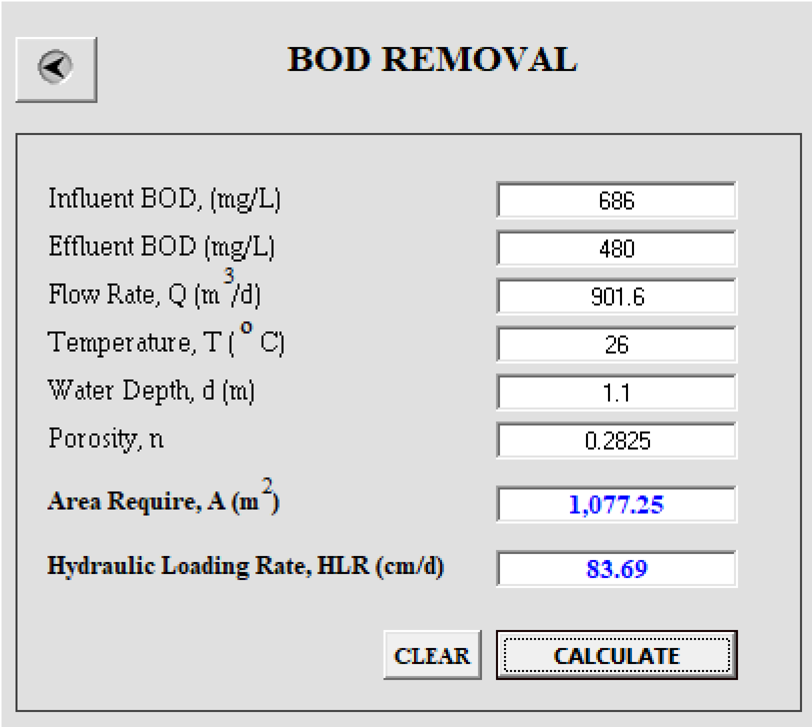

Figure 4.8: BOD removal for maximum flowrate

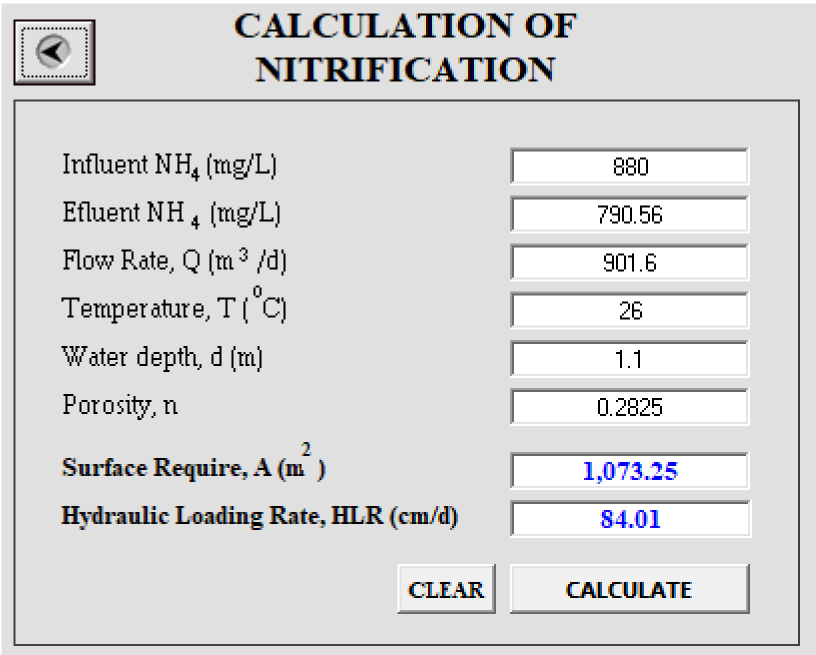

Figure 4.9: Nitrification for maximum flowrate

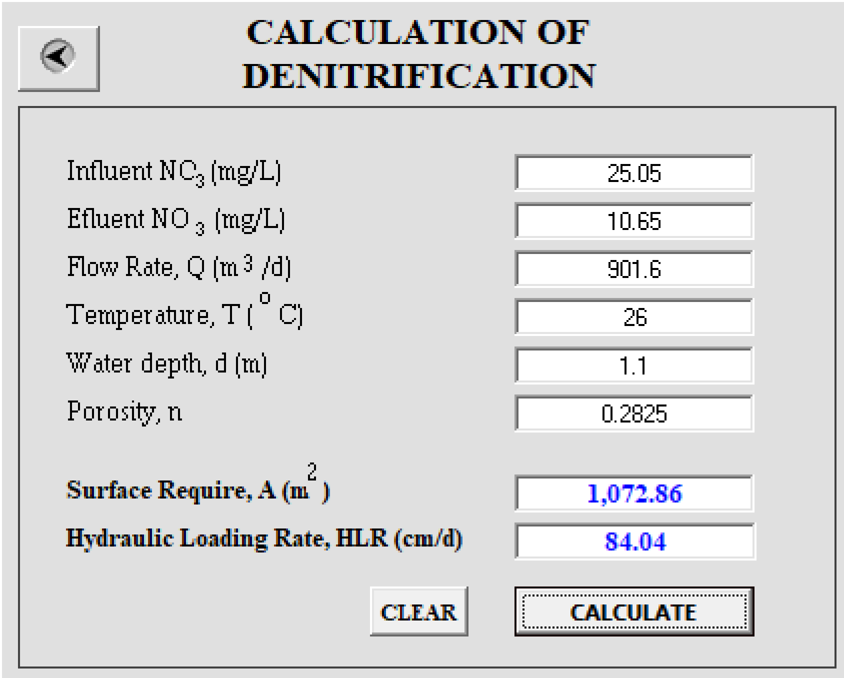

Figure 4.10: Denitrification for maximum flowrate

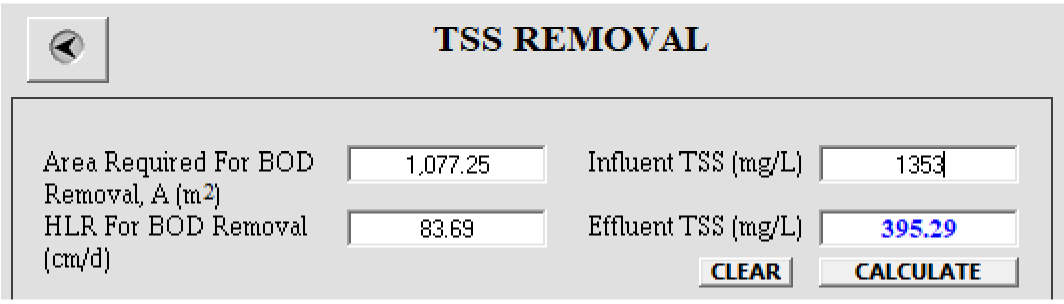

Figure 4.11: TSS removal for maximum flowrate

For minimum leachate generation:

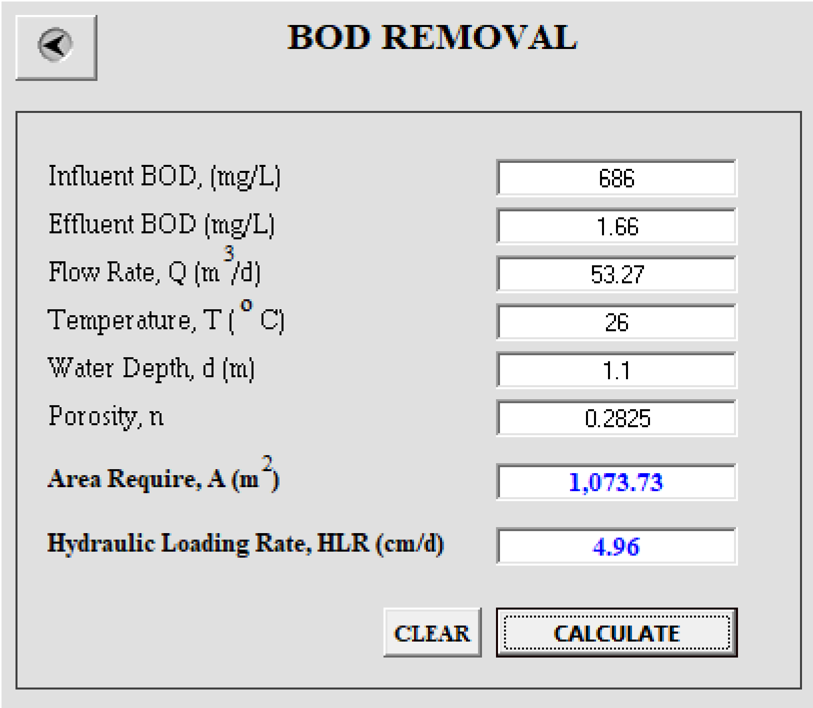

Figure 4.12: BOD removal for minimum flowrate

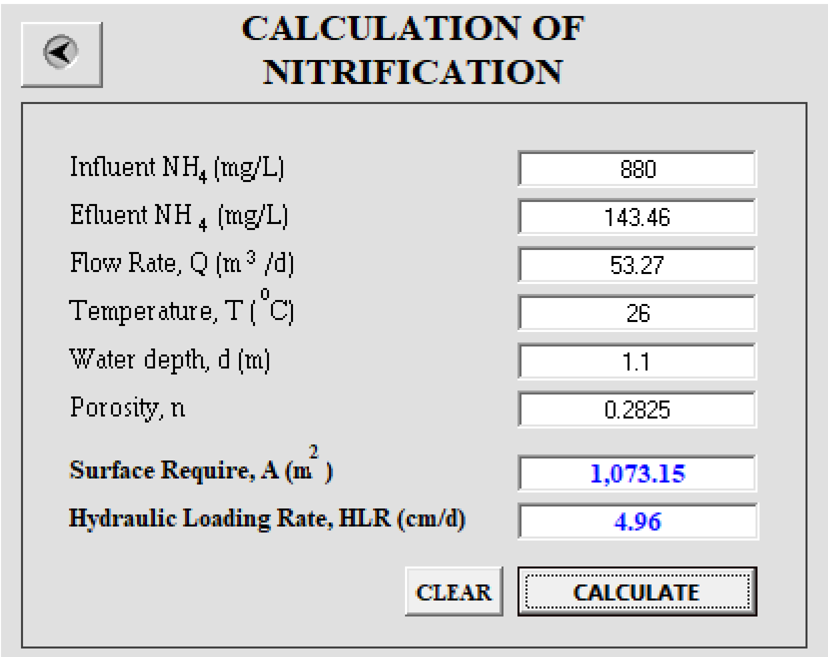

Figure 4.13: Nitrification for minimum flowrate

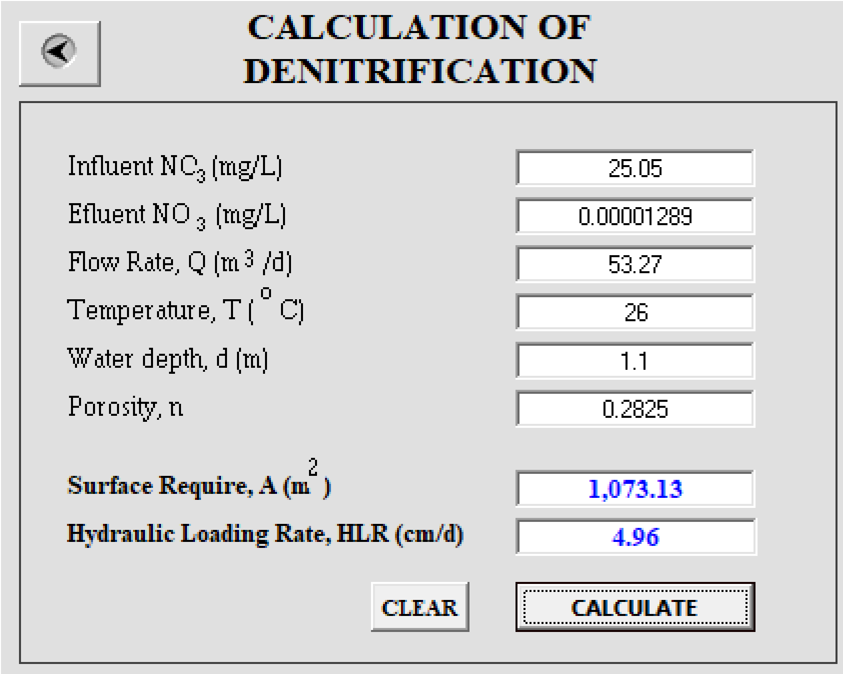

Figure 4.14: Denitrification for minimum flowrate

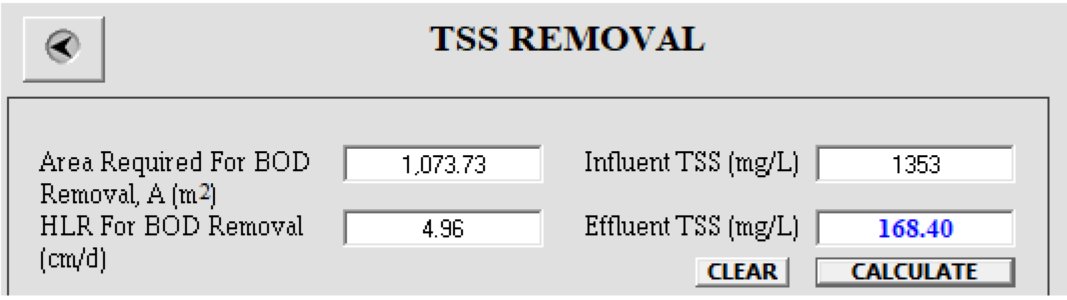

Figure 4.15: TSS removal for minimum flowrate

For average leachate generation:

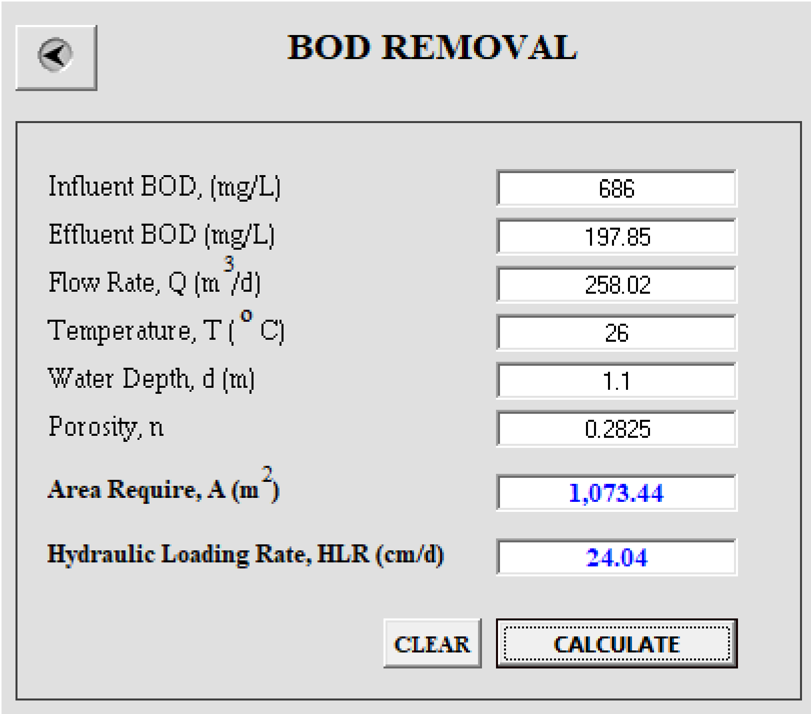

Figure 4.16: BOD removal for average flowrate

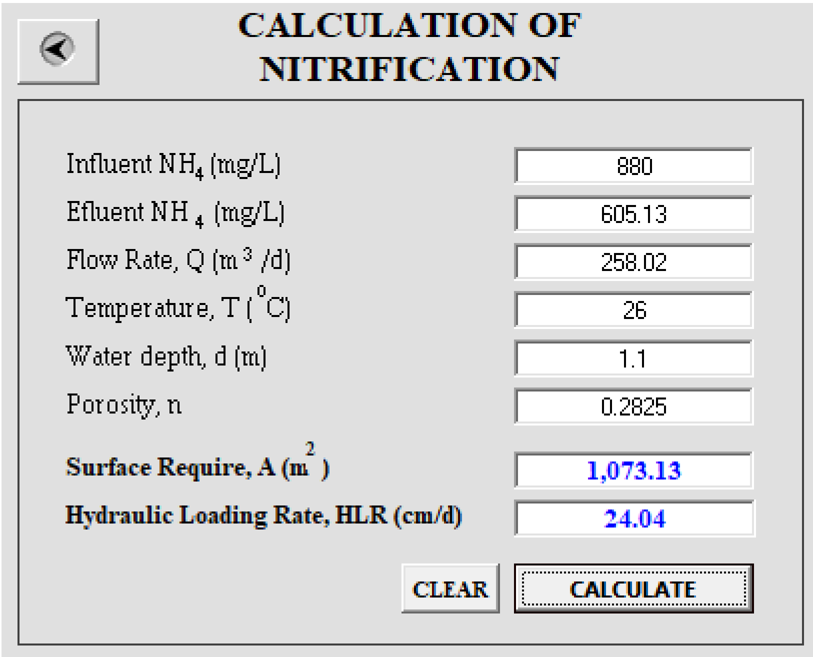

Figure 4.17: Nitrification for average flowrate

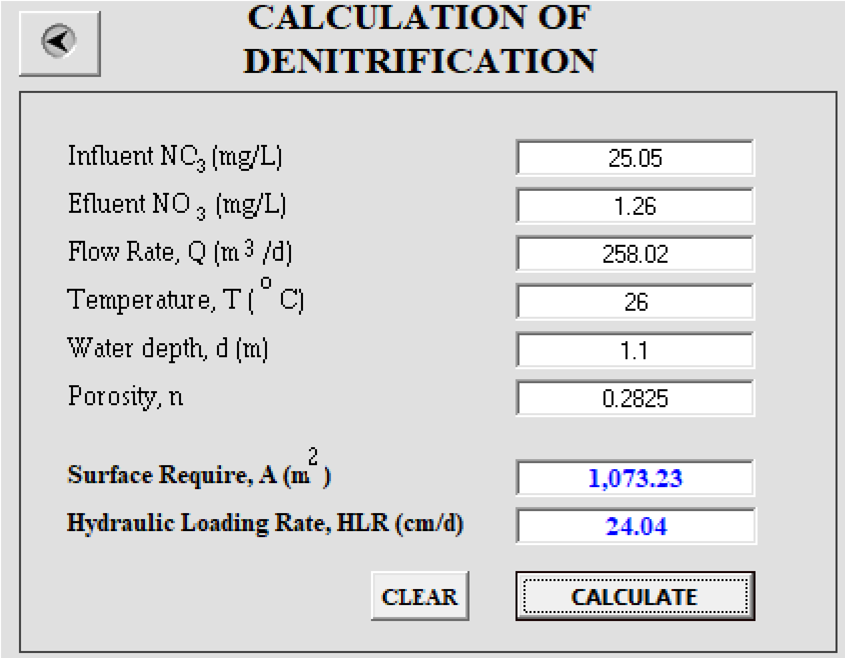

Figure 4.18: Denitrification for average flowrate

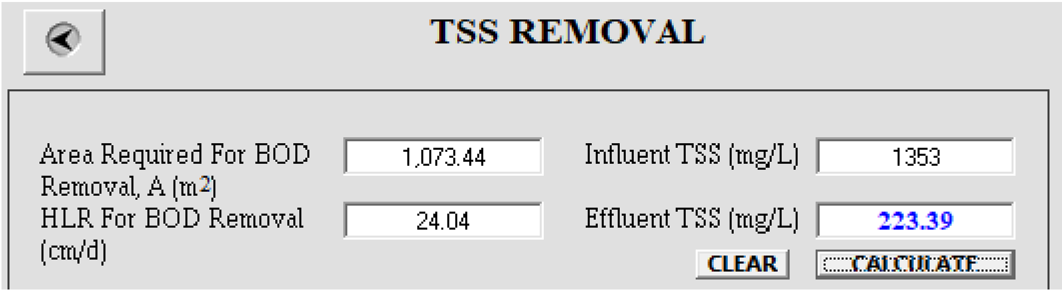

Figure 4.19: TSS removal for average flowrate

CHAPTER 5

COST EVALUATION

5.1 Cost Estimation

Production costs is crucial to estimate its construction, operation and maintenance cost as well as to conduct a financial evaluation. The purpose of conducting a financial analysis is to evaluate a budget and minimize wastage on material and cost during construction, operation and maintenance phase. Table below shows the estimated capital expenses, total indirect cost and O&M cost of a 1 ha wetland system.

PROPOSED MODIFICATION OF LEACHATE TREATMENT PLANT AT RIMBA MAS SANITARY LANDFILL

Table 5.1: Bill of preliminaries

BILL NO. 1 – PRELIMINARIES					
Item	**Description**	**Qty**	**Unit**	**Rate**	**Amount**
	Some of the condition is not needed since the construction location is a private area own by E-Idaman.				
1.1	Temporary site buildings, 20' x 8' x 8 ½' storage container	1	unit	6,500.00	6,500.00
1.2	Light and power consumption	90	day	10.00	900.00
1.3	Water consumption for site use	90	day	10.00	900.00
1.4	Fire extinguisher	1	no	200.00	200.00
1.5	Hire portable toilet	1	no	1,500.00	1,500.00
1.6	Site clearing		sum	6,000.00	6,000.00
1.7	Survey work		sum	2,000.00	2,000.00
1.8	Mobilization and demobilization		sum	2,000.00	2,000.00
1.9	Design drawing, submission approval		sum	30,000.00	30,000.00
1.10	HAZOP study		sum	20,000.00	20,000.00
	SUM (RM)				70,000.00

PROPOSED MODIFICATION OF LEACHATE TREATMENT PLANT AT RIMBA MAS SANITARY LANDFILL

Table 5.2: Bill of leachate storage pond

BILL NO. 2 – LEACHATE STORAGE POND					
Item	**Description**	**Qty**	**Unit**	**Rate**	**Amount**
2.1	Excavation for wall foundation	40	m3	15.00	600.00
2.2	Supply and erect timber formwork to wall slab	300	m2	34.23	10,269.00
2.3	Supply and cast reinforced concrete Grade 30	475	m3	247.70	123,850.00
2.4	Supply tensile steel bar exceeding 12mm diameter	38000	kg	2.33	88,540.00
2.5	Supply and install waterproofing HDPE liner	950	m2	4.50	4,275.00
2.6	Wire mesh (1”x1”x18G(WD)x3’x50’)	25	m2	58.50	6,142.50
2.7	Galvanized (GI) wire #10	20	kg	8.00	16.00
2.8	Portland cement	30	bag	17.00	510.00
	SUM (RM)				234,202.50

PROPOSED MODIFICATION OF LEACHATE TREATMENT PLANT AT RIMBA MAS SANITARY LANDFILL

Table 5.3: Bill of constructed wetlands

BILL NO. 3 – CONSTRUCTED WETLANDS					
Item	**Description**	**Qty**	**Unit**	**Rate**	**Amount**
3.1	Import the sand, filling and compact to required level	919	m3	38.12	35,032.28
3.2	Supply and erect timber formwork to wall slab	100	m2	34.23	3,423.00
3.3	Supply and cast reinforced concrete Grade 30	128	m3	247.7	31,705.60
3.4	Supply tensile steel bar exceeding 12mm diameter	10240	kg	2.33	23,859.20
3.5	Filling of substrate layer, sand 33.04 x 32.5 x 0.7	751.66	m3	92.00	69,147.20
3.6	Filling of substrate layer, medium gravel 33.04 x 32.5 x 0.2	214.76	m3	138.0	29,636.88
3.7	Filling of substrate layer, fine gravel 33.04 x 32.5 x 0.2	214.76	m3	163.0	35,005.88
3.8	Seeding and planting, *Phragmites australis*	1075	pot	4.50	4,837.50
3.9	Supply and install HDPE pipe (ø 4in)	700	m	16.80	11,760.00
3.10	Mild steel plate, 6 x 3 x 0.006m	842.4	kg	2.60	2,190.24
	SUM (RM)				246,597.78

Table 5.4: Bill of labor rates

BILL NO. 4 – LABOR RATES					
Item	**Description**	**Qty**	**Unit**	**Rate**	**Amount**
4.1	Construction manager	1	pax	10000	10,000.00
4.2	Project engineer	1	pax	6,000	6,000.00
4.3	Supervisor	1	pax	3,500	3,500.00
4.4	QS	1	pax	4,500	4,500.00
4.5	M&E coordinator	1	pax	4,500	4,500.00
4.6	General labor	90	day	60.00	4,500.00
4.7	Semi-skilled labor	90	day	75.00	6,750.00
4.8	Skilled labor	90	day	95.00	8,550.00
	SUM (RM)				48,300.00

Table 5.5: Bill of plant and equipment rates

BILL NO. 5 – PLANT & EQUIPMENT RATES					
Item	**Description**	**Qty**	**Unit**	**Rate**	**Amount**
5.1	Bar cutter machine	2	month	450	900.00
5.2	Bar bending machine	2	month	450	900.00
5.3	Welding set	2	month	900	1,800.00
5.4	Lorry with driver, 6 wheels	14	day	400	5,600.00
5.5	Excavator	2	month	7,000	14,000.00
5.6	Vibrator	1	no	270	270.00
5.7	Scaffold		Sum		2000.00
	SUM (RM)				25,470.00

Table 5.6: Bill of other

BILL NO. 6 – OTHER					
Item	**Description**	**Qty**	**Unit**	**Rate**	**Amount**
	Total amount Bill 1 – Bill 5				**624,570.28**
6.1	Construction observation		%	5	31,228.51
6.2	Start-up service		%	5	31,228.51
6.3	CIDB - Levy		%	0.125	780.71
6.4	Contractor's all risk		%	0.15	936.86
6.5	Workmen's compensation policy		%	0.075	624.57
6.6	Contract document stamping fee		%	0.1	540.80
6.7	Contingency		%	20	124,914.06
	SUM (RM)				190,254.02

Table 5.7: Bill of final summary

FINAL SUMMARY		
Item	**Description**	**Amount**
1	BILL NO. 1 – PRELIMINARIES	70,000.00
2	BILL NO. 2 – LEACHATE STORAGE TANK	234,202.50
3	BILL NO. 3 – CONSTRUCTED WETLANDS	246,597.78
4	BILL NO. 4 – LABOR RATES	48,300.00
5	BILL NO. 5 – PLANT & EQUIPMENT RATES	25,470.00
6	BILL NO. 6 – OTHER	190,254.02
	TOTAL AMOUNT (RM)	786,594.00

5.2 Comparison of Major Cost in Constructed Wetland and SBR

Construction wetland is a wastewater treatment process with lower energy consumption since the system required lesser or no electrical equipment and relies on natural process by plants, microbes and substrate layer. Hence, the major cost in constructed wetland is focusing on maintenance cost which is including inlet zone bed maintenance and vegetation. Based on Molle et al. (2004a), Chazarenc and Merlin (2005), the compost layer of accumulated solids can aid in treatment for eight to ten years. We assume Rimba Mas cleanout the compost layer with plant mowing or replanting for every 5 years. The major maintenance cost estimation in constructed wetland is shown in Table 5.8.

Table 5.8: Maintenance cost estimation of constructed wetland

MAINTENANCE OF CONSTRUCTED WETLANDS EVERY 5 YEARS					
Item	**Description**	**Qty**	**Unit**	**Rate**	**Amount**
3.5	Filling of substrate layer, sand 33.04 x 32.5 x 0.1	107.38	m3	92.00	9,878.96
3.6	Filling of substrate layer, medium gravel 33.04 x 32.5 x 0.1	107.38	m3	138.0	14,818.44
3.7	Filling of substrate layer, fine gravel 33.04 x 32.5 x 0.1	107.38	m3	163.0	17,502.94
3.8	Seeding and planting, *Phragmites australis*	1075	pot	4.50	4,837.50
3.9	Supply and install HDPE pipe (ø 4in)	700	m	16.80	11,760.00
	Backhoe with front loader and driver	7	day	800	5,600.00
	Lorry with driver, 6 wheels	7	day	400	2,800.00
	General worker	7	day	120	840.00
	SUM (RM)				68,037.84

In the existing secondary treatment system, SBR pond is functioning with 4 surface aerators. The cost for SBR to compare with the construction wetland is focusing on operating cost since the surface aerator has a high energy usage which is the major expenditure of SBR. Based on the information provided by Rimba Mas, the operating cost is calculated and shown in the Table 7.9.

Table 5.9: Operating cost of surface aerator

Equipment	Surface aerator
Number	4
Power each aerator	22 kW
Operating hour during peak hour	5 hours
Operating hour during off peak hour	13 hours
Pricing and tariff (peak hour)	36.4 sen/kWh
Pricing and tariff (off-peak hour)	22.4 sen/kWh
Total cost (peak hour)	RM 256.25
Total cost (off-peak hour)	RM 160.60
Total cost per day	RM 416.85
Total cost per month	RM 12505.68
Total cost per year	RM 150068.15

The comparison of cumulative major cost for 10 years of constructed wetland and SBR is shown in Fig 5.1. The cost of constructed wetland is calculated by using the construction cost (Table 5.7) for first year, maintenance cost (Table 5.8) for every 5 years and other estimated operating and monitoring cost for RM20,000 per year. For SBR, the major cost is electricity cost used by the aerator which is calculated in Table 5.9. The result of Fig. 5.1 shows that, the cumulative cost for electricity for aerator in SBR at 6 to 7 years is equaled to the investment cost for vertical constructed wetland. After the 6 to 7 years, the investment cost for vertical constructed wetland is lower than the SBR as the operating year is increasing. Although the constructed wetland may be clogging by the biomat formed by composting of leachate on inlet surface. However, the cost of refurbishment and maintenance is still cheaper than the electricity cost of SBR. Especially the operating year is over 20 years, the gap of the cost for vertical constructed wetland and SBR will become more obviously.

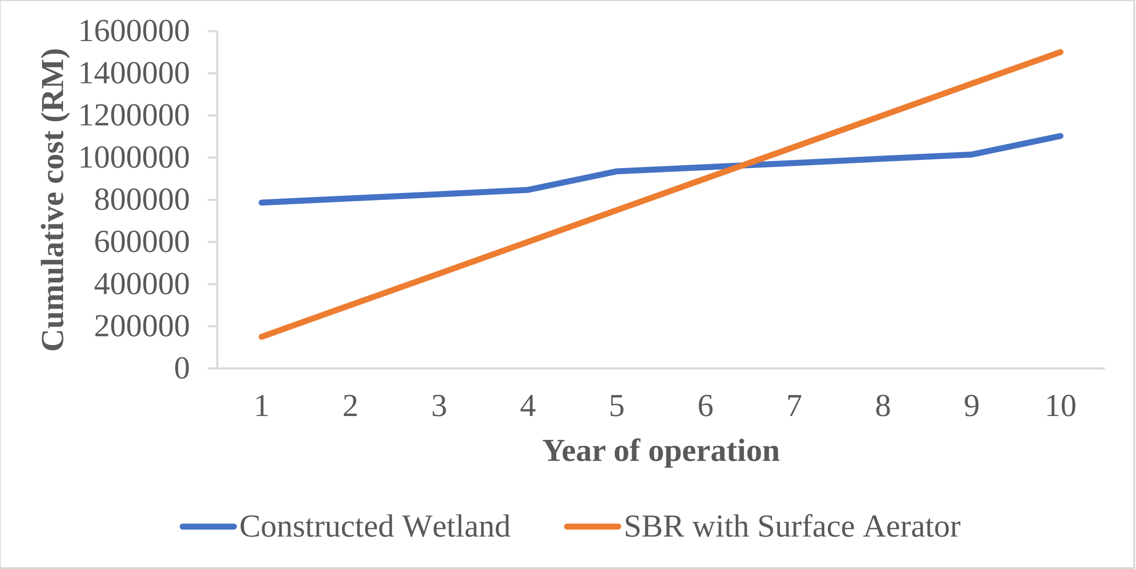

Figure 5.1: Comparison of cumulative major cost for constructed wetland and SBR

CHAPTER 6

CONCLUSION

Sanitary landfills can be constructed as an environmentally friendly means of disposal of waste, provided they are run properly. However, the production of leachate the landfills was a major problem that triggers surface water and groundwater treatment that can affect human health and also the environment. Regarding this issue, the Rimba Mas landfill is currently facing imbalance volumes of leachate during the season of drought and monsoon. Generation of waste from residential, industrial and other places around Perlis are dumped at this landfill cause the production of leachate is increase and need to expand the lifespan of this facility. Hence, this project is aim to upgrade the leachate treatment plant components and management of treated effluent of Rimba Mas landfill focusing on alternative treatment design that can effectively produce the effluent in accordance with DOE's Effluent Discharge Standards.

In this project, it involves significant construction and upgrading. The installation of an additional leachate storage pond is suggested to overcome overflow of leachate during the monsoon seasons. For the insufficient leachate volume, we proposed three alternative biological treatments options to replace SBR pond. The first design option is trickling filter, also known as biological filter or trickling biofilter which is aerobic treatment process. Next, second design option is the activated sludge, commonly used for biological wastewater treatment technology. The process consists of two separate aeration and sludge settlement phases. The process types used vary depending on the efficiency, yield required and effluent required. For the last design option, we are using the constructed wetlands that also classified as the biological treatment which uses phytoremediation to treat wastewater. This method of treatment is rendered by humans using natural process by involving hydrology of plants, soils, microbes and wetlands.

Thus, third option is the most suitable and feasible design for achieving the goal of this project as described in chapter 4. Based on materials, process flow, feasibility, monitoring and manpower, and cost, this vertical constructed wetland can improve the efficiency the Rimba Mas landfill to keep up the estimated lifespan of 10 until 15 years. The operation of this landfill also has been monitored adhere with the regulations and guidelines to prevent any complication happen and minimal the environmental issues.

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APPENDIX A

Analysis data August 2019 page 1

BIO SYNERGY
Laboratories Sdn Bhd

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Tel : 04-916 1288 / 2688 Fax : 04-917 3610 / 1698
Website : www.biosynergy.com.my

ilac-MRA | STANDARDS MALAYSIA MS ISO/IEC 17025 TESTING SAMM NO.336 | FOSFA INTERNATIONAL | Gafta

NO OF PAGE. : 1 OF 2
LAB REF. NO. : CL/19080019
REPORT DATE : 11 AUGUST 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
TAPAK PERLUPUSAN SANITARI,
02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 01 AUGUST 2019
TEST PERFORMANCE DATE : 01 AUGUST 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

CHEMICAL / PHYSICAL TEST

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Ammonical Nitrogen	mg/L	APHA 4500-NH_3B & C	1.4
Arsenic as As	mg/L	APHA 3120 B	ND(<0.01)
Barium as Ba	mg/L	APHA 3120 B	ND(<0.01)
BOD5 at 20°C	mg/L	APHA 5210 B & 4500 OC	19
Boron as B	mg/L	APHA 3120 B	0.47
Cadmium as Cd	mg/L	APHA 3120 B	ND(<0.01)
Chromium Hexavalent	mg/L	APHA 3500-Cr B	ND(<0.05)
Chromium Trivalent	mg/L	In-house Method Based On APHA 3500-Cr B & 3120 B	ND(<0.05)
COD	mg/L	APHA 5220 B	196
Colour ADMI	-	APHA 2120 F	87
Copper as Cu	mg/L	APHA 3120 B	0.14
Cyanide	mg/L	APHA 4500-CN C & D	ND(<0.1)
Fluoride	mg/L	APHA 4110 B	0.7
Formaldehyde	mg/L	In House Method based on HACH Spectrophotometer , Method 8110	0.2
Iron as Fe	mg/L	APHA 3120 B	0.20
Lead as Pb	mg/L	APHA 3120 B	ND(<0.01)
Manganese as Mn	mg/L	APHA 3120 B	0.14
Mercury as Hg	mg/L	In-house Method, CL/WT/007, based on APHA 3112B, using FIMS	ND(<0.001)
Nickel as Ni	mg/L	APHA 3120 B	ND(<0.01)
Oil & Grease	mg/L	APHA 5520 B	4.0
pH	-	APHA 4500+H	6.29
Phenol	mg/L	APHA 5530 C	ND(<0.1)
Selenium as Se	mg/L	APHA 3120 B	ND(<0.07)
Silver as Ag	mg/L	APHA 3120 B	ND(<0.01)
Sulphide	mg/L	In-house Method Based On HACH Spectrophotometer, Method 8131	ND(<0.1)

ORIGINAL

Northern Region Lab (SAMM NO.822)
No. 24, Jalan Kelisa Emas, Taman Kelisa Emas, 13700 Seberang Jaya, Penang.
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Central Region Lab (SAMM NO.724)
No. 43, Jalan SS 22/23, Damansara Jaya, 47400 Petaling Jaya, Selangor Darul Ehsan.
Tel : 03-7732 5454 Fax : 03-7732 5757
Southern Region Lab (SAMM NO.877)
No. 7, Jalan Mutiara Emas 6/1A, Taman Mount Austin, 81100 Johor Bahru, Johor.

*ND denotes Not Detected | NG denotes No Growth | (< Numeric number) denotes detection limits | Symbol * denotes parameter which is not accredited*

Analysis data August 2019 page 2

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CERTIFICATE OF ANALYSIS

RECEIVED DATE : 01 AUGUST 2019
TEST PERFORMANCE DATE : 01 AUGUST 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Temperature	mg/L	APHA 2550 B	26.0
Tin as Sn	mg/L	APHA 3120 B	ND(<0.01)
Total Suspended Solid	mg/L	APHA 2540 D	44
Zinc as Zn	mg/L	APHA 3120 B	0.15

Remarks :

BOD commencing Date: 01/08/2019
American Public Health Association, Standard Method for Examination of Water and Wastewater, 21th Edition, 2005.

NAWAL SYIFA', *Chemist*
BSc. MMIC (M/4802/7910/17)

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384 1539 / 1540 Fax : 04-384 1537

ND denotes Not Detected | NG denotes No Growth | (< Numeric number) denotes detection ...
Symbol * denotes parameter which is not accredited ...

Analysis data September 2019 page 1

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Website : www.biosynergy.com.my

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MS ISO/IEC 17025 TESTING SAMM NO.336

NO OF PAGE.	:	1 OF 2
LAB REF. NO.	:	CL/19090281
REPORT DATE	:	25 SEPTEMBER 2019
TO	:	GREEN RESOURCE RECOVERY SDN BHD TAPAK PERLUPUSAN SANITARI, 02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE	:	19 SEPTEMBER 2019
TEST PERFORMANCE DATE	:	19 SEPTEMBER 2019
SAMPLE DESCRIPTION	:	TREATED WATER

CHEMICAL / PHYSICAL TEST

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Ammonical Nitrogen	mg/L	APHA 4500-NH_3B & C	4.4
Arsenic as As	mg/L	APHA 3120 B	ND(<0.01)
Barium as Ba	mg/L	APHA 3120 B	ND(<0.01)
BOD5 at 20°C	mg/L	APHA 5210 B & 4500 OC	18
Boron as B	mg/L	APHA 3120 B	0.21
Cadmium as Cd	mg/L	APHA 3120 B	ND(<0.01)
Chromium Hexavalent	mg/L	APHA 3500-Cr B	ND(<0.05)
Chromium Trivalent	mg/L	In-house Method Based On APHA 3500-Cr B & 3120 B	ND(<0.05)
COD	mg/L	APHA 5220 B	116
Colour ADMI	-	APHA 2120 F	33
Copper as Cu	mg/L	APHA 3120 B	0.07
Cyanide	mg/L	APHA 4500-CN C & D	ND(<0.1)
Fluoride	mg/L	APHA 4110 B	0.6
Formaldehyde	mg/L	In House Method based on HACH Spectrophotometer , Method 8110	0.2
Iron as Fe	mg/L	APHA 3120 B	0.16
Lead as Pb	mg/L	APHA 3120 B	ND(<0.01)
Manganese as Mn	mg/L	APHA 3120 B	0.13
Mercury as Hg	mg/L	In-house Method, CL/WT/007, based on APHA 3112B, using FIMS	ND(<0.001)
Nickel as Ni	mg/L	APHA 3120 B	ND(<0.01)
Oil & Grease	mg/L	APHA 5520 B	2.0
pH	-	APHA 4500+H	7.38
Phenol	mg/L	APHA 5530 C	ND(<0.1)
Selenium as Se	mg/L	APHA 3120 B	ND(<0.07)
Silver as Ag	mg/L	APHA 3120 B	ND(<0.01)
Sulphide	mg/L	In-house Method Based On HACH Spectrophotometer, Method 8131	ND(<0.1)

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Tel : 07-351 8666 Fax : 07-359 5353

*ND denotes Not Detected | NG denotes No Growth | (< Numeric number) denotes detection limits | Symbol * denotes parameter which is not accredited*

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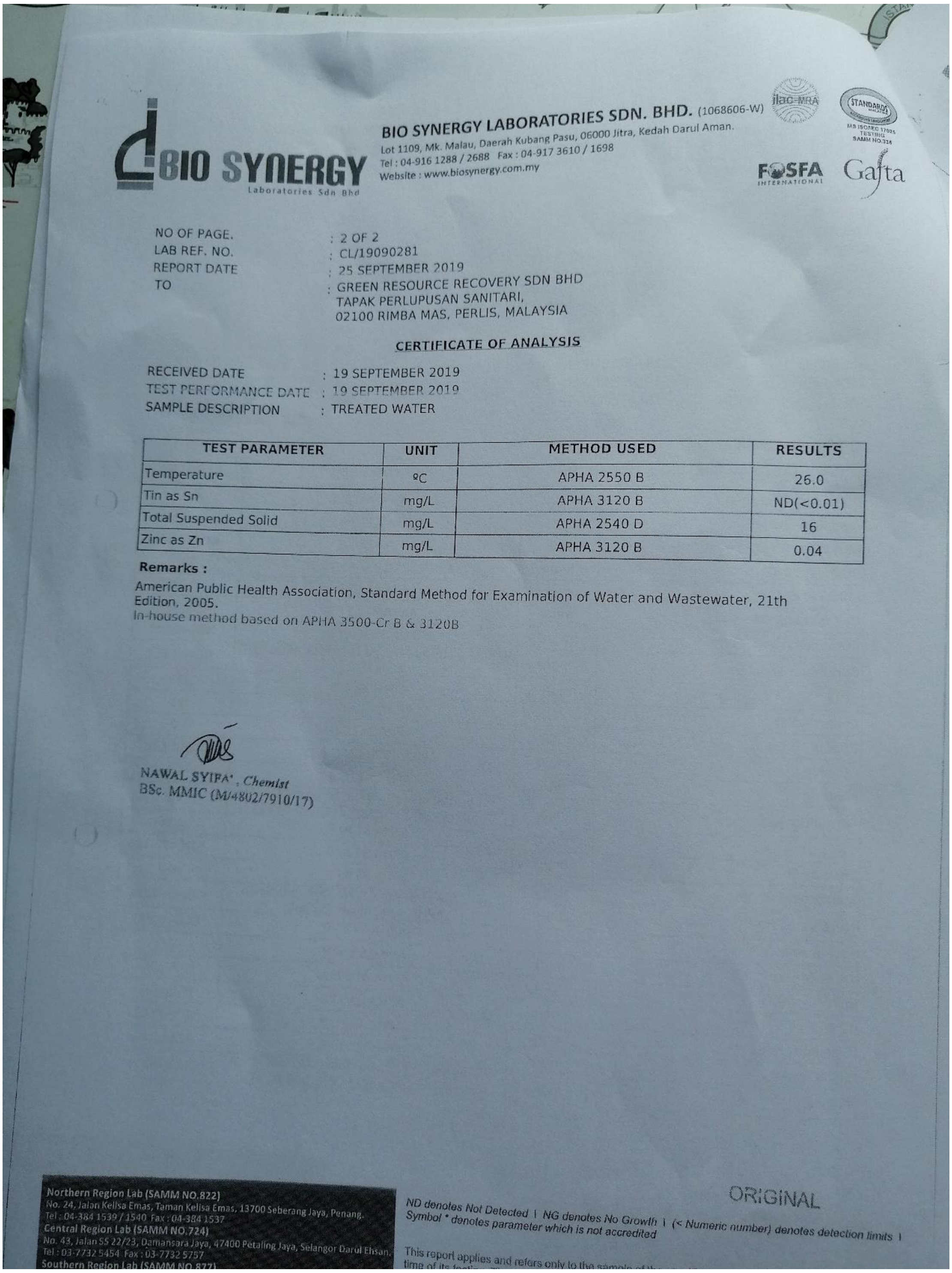

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Website : www.biosynergy.com.my

NO OF PAGE. : 2 OF 2
LAB REF. NO. : CL/19090281
REPORT DATE : 25 SEPTEMBER 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
TAPAK PERLUPUSAN SANITARI,
02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 19 SEPTEMBER 2019
TEST PERFORMANCE DATE : 19 SEPTEMBER 2019
SAMPLE DESCRIPTION : TREATED WATER

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Temperature	ºC	APHA 2550 B	26.0
Tin as Sn	mg/L	APHA 3120 B	ND(<0.01)
Total Suspended Solid	mg/L	APHA 2540 D	16
Zinc as Zn	mg/L	APHA 3120 B	0.04

Remarks :

American Public Health Association, Standard Method for Examination of Water and Wastewater, 21th Edition, 2005.
In-house method based on APHA 3500-Cr B & 3120B

NAWAL SYIFA', *Chemist*
BSc. MMIC (M/4802/7910/17)

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Southern Region Lab (SAMM NO.877)

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NO OF PAGE. : 1 OF 2
LAB REF. NO. : CL/19100578
REPORT DATE : 30 OCTOBER 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
TAPAK PERLUPUSAN SANITARI,
02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 23 OCTOBER 2019
TEST PERFORMANCE DATE : 23 OCTOBER 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

CHEMICAL / PHYSICAL TEST

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Ammonical Nitrogen	mg/L	APHA 4500-NH_3B & C	0.9
Arsenic as As	mg/L	APHA 3120 B	ND(<0.01)
Barium as Ba	mg/L	APHA 3120 B	0.01
BOD5 at 20°C	mg/L	APHA 5210 B & 4500 OC	13
Boron as B	mg/L	APHA 3120 B	0.19
Cadmium as Cd	mg/L	APHA 3120 B	ND(<0.01)
Chromium Hexavalent	mg/L	APHA 3500-Cr B	ND (<0.05)
Chromium Trivalent	mg/L	In-house Method Based On APHA 3500-Cr B & 3120 B	ND (<0.05)
COD	mg/L	APHA 5220 B	192
Colour ADMI	-	APHA 2120 F	80
Copper as Cu	mg/L	APHA 3120 B	0.17
Cyanide	mg/L	APHA 4500-CN C & D	ND (<0.1)
Fluoride	mg/L	APHA 4110 B	0.63
Formaldehyde	mg/L	In House Method based on HACH Spectrophotometer , Method 8110	0.1
Iron as Fe	mg/L	APHA 3120 B	0.08
Lead as Pb	mg/L	APHA 3120 B	ND(<0.01)
Manganese as Mn	mg/L	APHA 3120 B	0.14
Mercury as Hg	mg/L	In-house Method, CL/WT/007, based on APHA 3112B, using FIMS	ND(<0.001)
Nickel as Ni	mg/L	APHA 3120 B	0.01
Oil & Grease	mg/L	APHA 5520 B	2.4
pH	-	APHA 4500+H	6.30
Phenol	mg/L	APHA 5530 C	ND (<0.1)
Selenium as Se	mg/L	APHA 3120 B	ND(<0.07)
Silver as Ag	mg/L	APHA 3120 B	ND(<0.01)
Sulphide	mg/L	In-house Method Based On HACH Spectrophotometer, Method 8131	ND (<0.1)

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NO OF PAGE. : 2 OF 2
LAB REF. NO. : CL/19100578
REPORT DATE : 30 OCTOBER 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
TAPAK PERLUPUSAN SANITARI,
02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 23 OCTOBER 2019
TEST PERFORMANCE DATE : 23 OCTOBER 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Temperature	ºC	APHA 2550 B	26.0
Tin as Sn	mg/L	APHA 3120 B	ND(<0.01)
Total Suspended Solid	mg/L	APHA 2540 D	48
Zinc as Zn	mg/L	APHA 3120 B	0.14

Remarks :
BOD Commencing Date :23/10/2019
American Public Health Association, Standard Method for Examination of Water and Wastewater, 21th Edition, 2005.

NAWAL SYIFA', *Chemist*
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Tel : 07-351 8666 Fax : 07-359 5353

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Website : www.biosynergy.com.my

NO OF PAGE. : 1 OF 2
LAB REF. NO. : CL/19110443
REPORT DATE : 05 DECEMBER 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
TAPAK PERLUPUSAN SANITARI,
02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 28 NOVEMBER 2019
TEST PERFORMANCE DATE : 28 NOVEMBER 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

CHEMICAL / PHYSICAL TEST

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Ammonical Nitrogen	mg/L	APHA 4500-NH_3B & C	4.5
Arsenic as As	mg/L	APHA 3120 B	ND(<0.01)
Barium as Ba	mg/L	APHA 3120 B	ND(<0.01)
BOD5 at 20°C	mg/L	APHA 5210 B & 4500 OC	18
Boron as B	mg/L	APHA 3120 B	0.20
Cadmium as Cd	mg/L	APHA 3120 B	ND(<0.01)
Chromium Hexavalent	mg/L	APHA 3500-Cr B	ND(<0.05)
Chromium Trivalent	mg/L	In-house Method Based On APHA 3500-Cr B & 3120 B	ND(<0.05)
COD	mg/L	APHA 5220 B	320
Colour ADMI	-	APHA 2120 F	73
Copper as Cu	mg/L	APHA 3120 B	0.09
Cyanide	mg/L	APHA 4500-CN C & D	ND(<0.1)
Fluoride	mg/L	APHA 4110 B	0.8
Formaldehyde	mg/L	In House Method based on HACH Spectrophotometer , Method 8110	ND(<0.1)
Iron as Fe	mg/L	APHA 3120 B	0.18
Lead as Pb	mg/L	APHA 3120 B	ND(<0.01)
Manganese as Mn	mg/L	APHA 3120 B	0.13
Mercury as Hg	mg/L	In-house Method, CL/WT/007, based on APHA 3112B, using FIMS	ND(<0.001)
Nickel as Ni	mg/L	APHA 3120 B	ND(<0.01)
Oil & Grease	mg/L	APHA 5520 B	2.6
pH	-	APHA 4500+H	7.33
Phenol	mg/L	APHA 5530 C	ND(<0.1)
Selenium as Se	mg/L	APHA 3120 B	ND(<0.07)
Silver as Ag	mg/L	APHA 3120 B	ND(<0.01)
Sulphide	mg/L	In-house Method Based On HACH Spectrophotometer, Method 8131	ND(<0.1)

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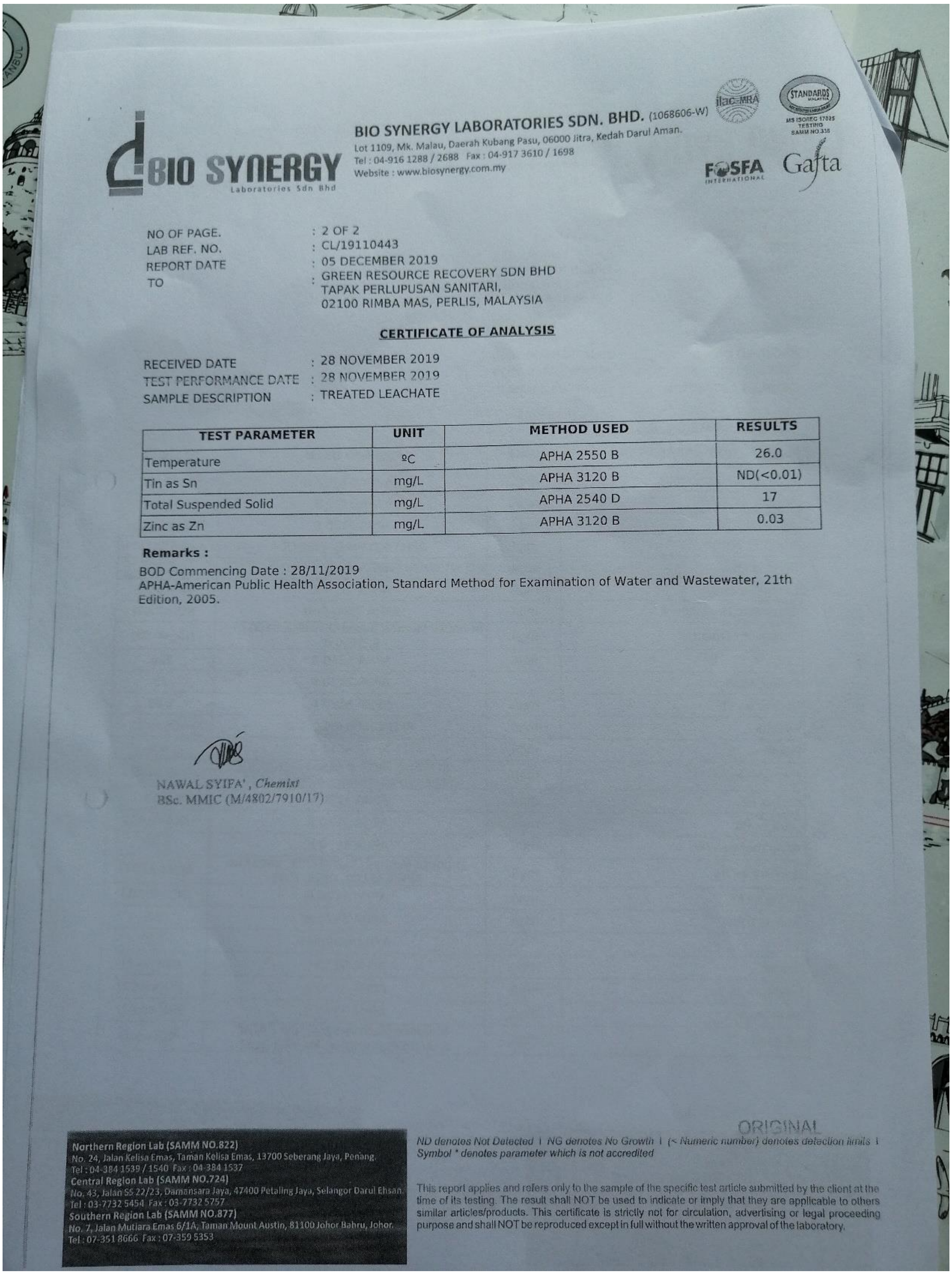
Analysis data November 2019 page 2



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NO OF PAGE. : 2 OF 2
LAB REF. NO. : CL/19110443
REPORT DATE : 05 DECEMBER 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
TAPAK PERLUPUSAN SANITARI,
02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 28 NOVEMBER 2019
TEST PERFORMANCE DATE : 28 NOVEMBER 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Temperature	ºC	APHA 2550 B	26.0
Tin as Sn	mg/L	APHA 3120 B	ND(<0.01)
Total Suspended Solid	mg/L	APHA 2540 D	17
Zinc as Zn	mg/L	APHA 3120 B	0.03

Remarks :
BOD Commencing Date : 28/11/2019
APHA-American Public Health Association, Standard Method for Examination of Water and Wastewater, 21th Edition, 2005.

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NO OF PAGE. : 1 OF 2
LAB REF. NO. : CL/19120187
REPORT DATE : 19 DECEMBER 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
TAPAK PERLUPUSAN SANITARI,
02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 12 DECEMBER 2019
TEST PERFORMANCE DATE : 12 DECEMBER 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

CHEMICAL / PHYSICAL TEST

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Ammonical Nitrogen	mg/L	APHA 4500-NH_3B & C	3.8
Arsenic as As	mg/L	APHA 3120 B	ND(<0.01)
Barium as Ba	mg/L	APHA 3120 B	ND(<0.01)
BOD5 at 20°C	mg/L	APHA 5210 B & 4500 OC	18
Boron as B	mg/L	APHA 3120 B	0.23
Cadmium as Cd	mg/L	APHA 3120 B	ND(<0.01)
Chromium Hexavalent	mg/L	APHA 3500-Cr B	ND(<0.05)
Chromium Trivalent	mg/L	In-house Method Based On APHA 3500-Cr B & 3120 B	ND(<0.05)
COD	mg/L	APHA 5220 B	240
Colour ADMI	-	APHA 2120 F	58
Copper as Cu	mg/L	APHA 3120 B	0.14
Cyanide	mg/L	APHA 4500-CN C & D	ND(<0.1)
Fluoride	mg/L	APHA 4110 B	0.6
Formaldehyde	mg/L	In House Method based on HACH Spectrophotometer , Method 8110	ND(<0.1)
Iron as Fe	mg/L	APHA 3120 B	0.18
Lead as Pb	mg/L	APHA 3120 B	ND(<0.01)
Manganese as Mn	mg/L	APHA 3120 B	0.14
Mercury as Hg	mg/L	In-house Method, CL/WT/007, based on APHA 3112B, using FIMS	ND(<0.001)
Nickel as Ni	mg/L	APHA 3120 B	0.01
Oil & Grease	mg/L	APHA 5520 B	2.8
pH	-	APHA 4500+H	6.74
Phenol	mg/L	APHA 5530 C	ND(<0.1)
Selenium as Se	mg/L	APHA 3120 B	ND(<0.07)
Silver as Ag	mg/L	APHA 3120 B	ND(<0.01)
Sulphide	mg/L	In-house Method Based On HACH Spectrophotometer, Method 8131	ND(<0.1)

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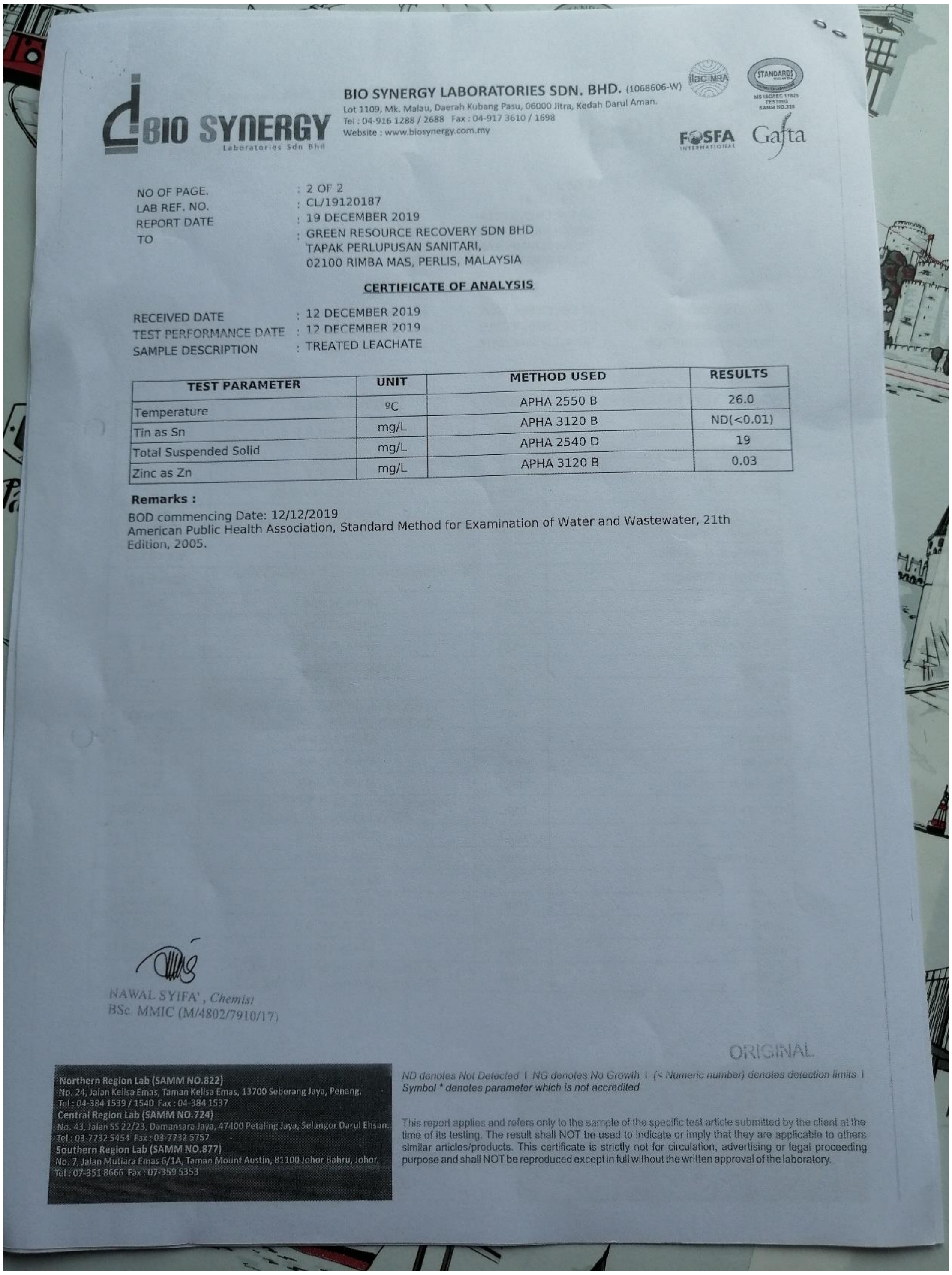
Tel : 07-351 8666 Fax : 07-359 5353

*ND denotes Not Detected | NG denotes No Growth | (< Numeric number) denotes detection limits | Symbol * denotes parameter which is not accredited*

Analysis data December 2019 page 2



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NO OF PAGE. : 2 OF 2
LAB REF. NO. : CL/19120187
REPORT DATE : 19 DECEMBER 2019
TO : GREEN RESOURCE RECOVERY SDN BHD
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02100 RIMBA MAS, PERLIS, MALAYSIA

CERTIFICATE OF ANALYSIS

RECEIVED DATE : 12 DECEMBER 2019
TEST PERFORMANCE DATE : 12 DECEMBER 2019
SAMPLE DESCRIPTION : TREATED LEACHATE

TEST PARAMETER	UNIT	METHOD USED	RESULTS
Temperature	ºC	APHA 2550 B	26.0
Tin as Sn	mg/L	APHA 3120 B	ND(<0.01)
Total Suspended Solid	mg/L	APHA 2540 D	19
Zinc as Zn	mg/L	APHA 3120 B	0.03

Remarks :
BOD commencing Date: 12/12/2019
American Public Health Association, Standard Method for Examination of Water and Wastewater, 21th Edition, 2005.

NAWAL SYIFA', *Chemist*
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APPENDIX B

Design Simulation Software - WASDA

DESIGN EQUATIONS

BOD

Required surface area

$$A = Q_{ave} \ln(C_i/C_o) \,/\, [(k)(d_w)(\eta)]$$

Hydraulic loading rate

$$HLR = 100 \times Q_{ave} / A$$

where

C_o	= effluent BOD, mg/L
C_i	= influent BOD, mg/L
A	= surface area, m^2
Q_{ave}	= average daily flow through the wetland, m^3/d
d_w	= depth of flow, m
η	= porosity
k	= BOD removal-rate constant
	= $0.678 \times 1.06^{(T - 20)}$
HLR	= hydraulic loading rate, cm/d

DESIGN EQUATIONS

NH_4 (Nitrification)

Required surface area

$$A = Q_{ave} \ln(C_i/C_o) \,/\, [(k)(d_w)(\eta)]$$

Hydraulic loading rate

$$HLR = 100 \times Q_{ave} / A$$

where

C_o	= effluent NH_4, mg/L
C_i	= influent NH_4, mg/L
A	= surface area, m^2
Q_{ave}	= average daily flow through the wetland, m^3/d
d_w	= depth of flow, m
η	= porosity
k	= NH_4 removal-rate constant
	= $0.2187 \times 1.048^{(T - 20)}$
HLR	= hydraulic loading rate, cm/d

DESIGN EQUATIONS

NO3 (Denitrification)

Required surface area

$A = Q_{ave} \ln(C_i/C_o) / [(k)(d_w)(\eta)]$

Hydraulic loading rate

$HLR = 100 \times Q_{ave} / A$

where

C_o = effluent NO_3, mg/L

C_i = influent NO_3, mg/L

A = surface area, m^2

Q_{ave} = average flow rate, m^3/d

d_w = depth of flow, (m)

η = porosity

k = NO_3 removal-rate constant

$= 1.0 \times 1.15^{(T - 20)}$

HLR = hydraulic loading rate, cm/d

DESIGN EQUATIONS

TSS

Effluent TSS

$C_o = C_i\,(0.1139 \times 0.00213\,HLR)$

where

C_o = effluent TSS, mg/L

C_i = influent TSS, mg/L

HLR = hydraulic loading rate, m/