International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 4s, 2025
https://www.theaspd.com/ijes.php

Design of Septage Treatment Facility in one of the State Universities in the Philippines

Dr. Laarni M. Castor [1]
[1] *Central Philippines State University, Kabankalan City, Philippines.*
E-mail: lcastor@cpsu.edu.ph, *Orcid: 0009-0005-9428-2794*
[*] Corresponding author: Dr. Laarni M. Castor

Abstract: This study responds to the mandate set forth by RA 9274 or the Clean Water Act of 2004, proposing to design a septage treatment facility in CPSU Main Campus, Kabankalan City. Data was gathered by calculating the number of students enrolled, the non-students who stayed in the boarding houses, and the consumers of the CPSU Water System. Numerical factors from the Environmental Engineering book were combined with the data gathered to produce the septage and BOD loading rates. The septage and BOD loading rates, together with the equations of open–channel and cantilever retaining walls, determined the sizes and hydraulic capacity of the ponds and tank. The septage will go through a series of ponds while undergoing the natural treatment process and will be released as a clean effluent to the ground. In contrast, the dried sludge will be released as a soil conditioner of fertiliser.

Keywords: Water treatment system, Septage management, Protecting the environment.

1. Introduction

RA 9275, or the Philippine Clean Water Act of 2004, is a national law that aims to protect the country's water bodies from pollution. This law mandates the implementation of sewerage and septage management programs in the country. Unfortunately, in the Philippines, only about 7% of households have access to sewerage or wastewater treatment programs, and while more than 80% of households have septic tanks, most of them are unmaintained. Most septic tank sludgers also dispose of septage in the wrong way. (Implementer's Guide to Lime Stabilization, 2012).

Under normal circumstances, septage accumulates in septic tanks and needs to be regularly collected, treated, and disposed of to protect our health and the environment. The lack of substantial wastewater treatment services led to poor environmental sanitation and health conditions. Untreated wastewater spreads disease-causing bacteria and viruses, making the water unfit for drinking, threatening biodiversity, and deteriorating the overall quality of life. (Septage Management for Local Governments, 2007).

Thanks to technological advances in wastewater treatment and disposal, many communities are even recognising that water, once used, can still be put to productive use – making wastewater a largely untapped renewable freshwater source for increasing food production and facilitating in areas where water is needed. (Treating Wastewater as a Resource, 2015)

2. Synthesis

Septage treatment facilities or plants have been set up around the globe to reduce or minimise water pollution. The Philippines was not an exemption. Several Local Government Units (LGUs) have adopted this technology. Septage treatment comes in many forms: mechanised, chemical, natural, or a combination. Each technology differs in application but has the same objective: to produce a cleaner effluent released to the ground and eventually minimise water pollution.

Prior Art 1, "The process of treating septage", utilised mechanical processes and apparatus for the treatment of septage, particularly grease trap waste. The process converts the septage into biosolids (sludge) and wastewater dischargeable to the environment. The treated septage achieves pathogen reduction and reduced vector attraction. Treatment of septage by pasteurisation destroys harmful pathogens. An alkaline compound forms a filter cake from the solids fraction of the pasteurised septage, preventing vector attraction while producing beneficial biosolid. The liquid fraction of the septage by biological process allows for its discharge in the environment.

Prior to Art 2, the "Septage treatment system" was a treatment process designed to eliminate liquid discharge to groundwater. The method uses primary treatment, secondary treatment, and tertiary treatment. The tertiary treatment uses a greenhouse system to reclaim septage water after it has gone through primary and secondary treatments. The greenhouse system fosters ecologically sound usage of septage waste to minimise the environmental impact of septage waste.

Prior Art 3, the "Septage treatment system" present invention generally includes a septage treatment system comprising a primary treatment of a receiving station to pump the septage from the vehicle, an equalising tank to receive septage from the receiving station, and two or more mixing and odour control tanks to generate waste activated sludge. Then, a second treatment comprising an aeration tank to receive waste-activated sludge from the primary treatment system and to generate waste effluent, and a tertiary treatment process system comprising wetland ditches to receive water effluent from the aeration tank and to generate filtered water effluent from the wetland ditches and to generate filtered water effluent and an aquaculture hydroponics and sand bed greenhouse to generate filtered water effluent. These treatment process systems are made up of a septage treatment facility.

3. Research Significance

This study is a response to the mandate set forth by the Clean Water Act of 2004. The local government units (LGUs) are tasked to implement the Act by providing septage treatment facilities for its constituents. The technology that comes with treating the septage varies from one to the other. A state university with a vast land area also responded to this mandate by proposing building a treatment facility. This proposal will benefit not just the state university but also the community as it will generate employment for the people and awareness to protect public health. Another thing is that this will also open further studies in septage treatment for the researchers.

This study is focused on the design of the septage treatment facility, with the septage undergoing the natural process. Hydraulic structures made of reinforced concrete are utilised to withstand the different elements of nature and protect the groundwater from seepage.

4. Objectives of the Study

The main objective of the study is to design a septage treatment facility in CPSU Main Campus, Kabankalan City, Negros Occidental. The specific objectives are the following:

1. To lay out the site development plan for the septage treatment facility.

2. To determine the dimensions and hydraulic design capacity of the following:
   a) The receiving tank;
   b) The sludge – drying bed;
   c) The anaerobic pond;
   d) The facultative pond;
   e) The maturation pond;
   f) The planted gravel filter and
   g) The constructed wetland

5. Description of the Study

5.1 Design Criteria

The data gathering includes several students enrolled, the persons staying in the boarding houses (non-students) and the consumers of the CPSU Water System to get the septage generation rate for the desired sizes of the ponds. These data were multiplied by the factors provided by the Standard Handbook of Environmental Engineering, 2nd Edition, by Robert A. Corbitt, to produce the septage generation rate, together with these data where different depth values were also taken from the same reference.

Different factors of BOD per person, including the projection of the student population to increase by 20%, were used from the same environmental engineering book to determine the size of the sludge-drying bed. These factors were multiplied by the data gathered from the number of students enrolled, the persons staying in the boarding houses (non-students), and the consumers of the CPSU Water System. The data produced the BOD loading rates. The solids surface loading rate value was also taken from the same book and multiplied by the BOD loading rate to make the sludge–drying bed size.

Table 1 was used to determine the size of the sludge drying bed. As suggested by Corbitt, the researcher adopted the 1 3 length-to-width ratio for convenience throughout the ponds and tank sizes.

The equations of open channels to get the most efficient sections of the ponds were used. Determining the most efficient cross-section was important because this would also be economical based on the theory of open channel. For the section to be economical, it must have the least wetted perimeter because this would require less grading and lining in the channel. The ponds used the trapezoidal section formula for the most efficient cross sections.

The treatment ponds utilised a trapezoidal cross section because this type of section is ideal for structures excavated from the earth. The trapezoidal ponds will be made of reinforced concrete. These were designed as cantilever retaining walls because retaining walls are built to hold back one-sided lateral confinement of soil or other loose material and, in this case, the septage on the other side of the wall.

Provisions from the National Structural Code of the Philippines (NSCP 2015) were used in the design and analysis of the ponds. The engineering equations and procedures used to stabilise the structure were taken from the book Design of Reinforced Concrete. A suitable freeboard was also provided to allow waves and water–surface disturbances to occur in the ponds.

Figure 1 shows the flow chart diagram of the study. This diagram started with data gathering on the number of students enrolled, persons staying in the boarding houses (non-students), and the consumers of the CPSU Water System. The numbers gathered were multiplied by the factors in the Standard Handbook of Environmental Engineering to get the septage and BOD loading rates. The loading rates determined the ponds and tank's dimensions and hydraulic capacity. Two shapes were utilised in this study: the trapezoidal and rectangular sections. The ponds utilised in the trapezoidal section were the anaerobic pond, the facultative pond, the maturation pond, the planted gravel filter, and the constructed wetland. On the other hand, the receiving tank and the sludge–drying bed utilised the rectangular section. The diagram ended when the ponds, tank dimensions, and hydraulic capacity were determined.

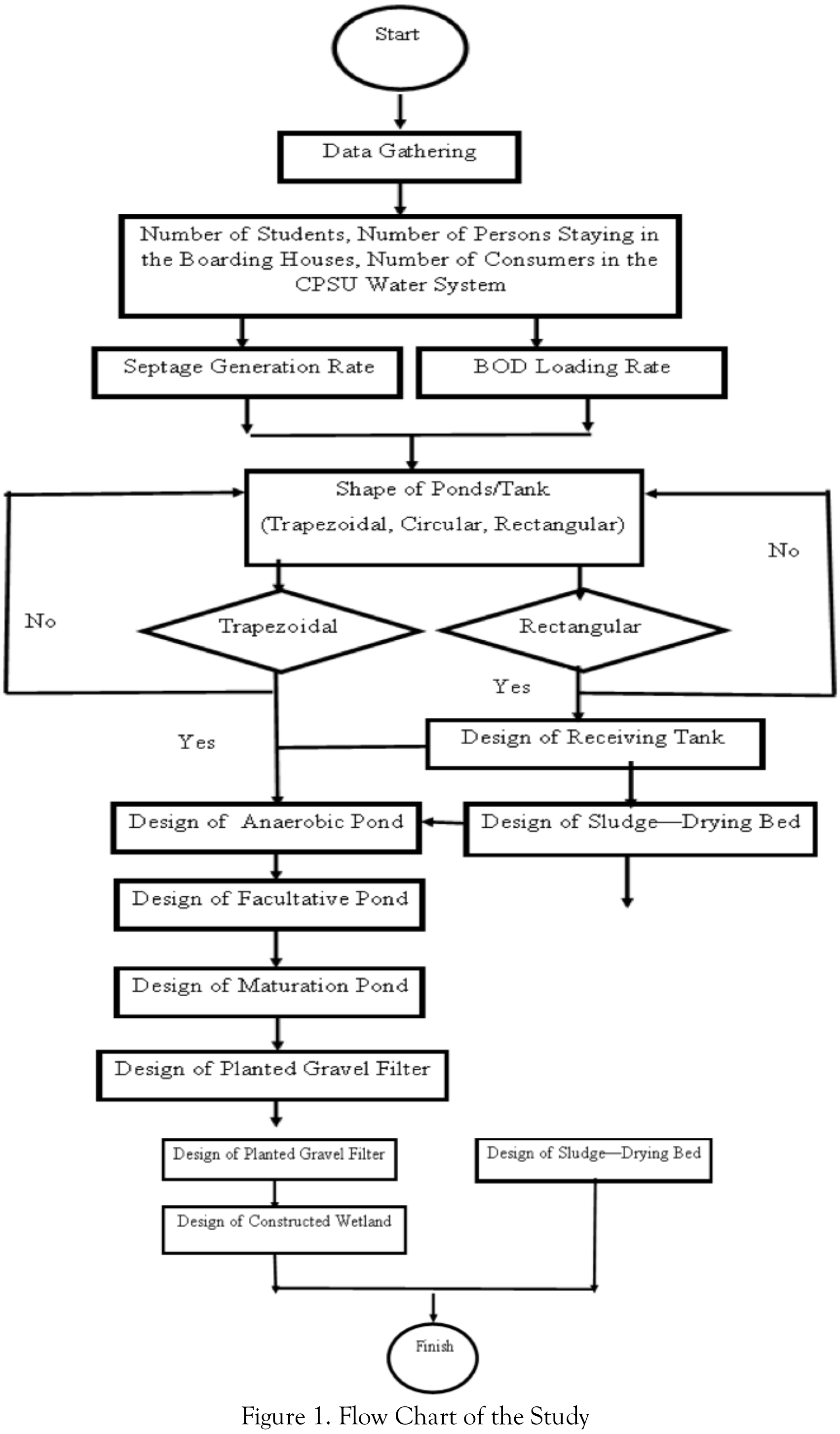

Figure 1. Flow Chart of the Study

5.2 The receiving Tank

The receiving tank has a rectangular cross-section with the following dimensions: its length is 27 meters, width is 9 meters, and depth is 3.0 meters. The collected septage goes to the anaerobic pond for treatment, while the suspended solids collected from the trash rack go to the sludge drying bed.

5.3 The Sludge – Drying Bed

The sludge–drying bed has a rectangular cross-section with the following dimensions: a length of 3 meters, a width of 1 meter, and an assumed depth of 1.5 meters. The sludge–drying bed contains suspended solids that were filtered by the trash rack. The bed includes enough screens to separate the water content from the suspended solids. The water goes through the underdrain pipe to the anaerobic pond for treatment. The bed also contains fine sand and gravel beneath to filter the sludge. The sludge will be released as a soil conditioner or fertiliser.

5.4 The Anaerobic Pond

The anaerobic pond has a trapezoidal cross-section with the following dimensions: 27 meters, a top width of 9 meters, a bottom width of 5.6 meters, an adequate depth of 3 meters and a wall height of 3.9 meters. A freeboard of 0.9 meters is provided to allow movement on the water's surface. The average daily flow can be determined using the maximum hourly, daily, weekly, monthly, and yearly or instantaneous peak flow computations based on the most significant volume of flow anticipated to occur for that particular time.

The researcher utilised the monthly average flow computation because of the anticipation that once this treatment facility is in operation, the user's fee will be incorporated into the monthly bill payment of the CPSU Water System as part of its operations and maintenance. The septage stays in the anaerobic pond for 25 days, after which the detention time has elapsed, and the septage is then moved to the facultative pond.

5.5 The Facultative Pond

The facultative pond has a trapezoidal cross-section with the following dimensions: a length of 27 meters, a top width of 9 meters, a bottom width of 6.2 meters, an adequate depth of 2.4 meters, and a wall height of 3.3 meters. After the detention time has elapsed, the septage stays in the facultative pond for 25 days and then moves to the maturation pond.

5.6 The Maturation Pond

The maturation pond has a trapezoidal cross-section with the following dimensions: a length of 57 meters, a top width of 19 meters, a bottom width of 18.5 meters, an adequate depth of 0.45 meters, and a wall height of 1.35 meters. The septage stays in the maturation pond for 30 days, and after the detention time has elapsed, it is moved to the planted gravel filter.

5.7 The Planted Gravel Filter

The planted gravel filter utilised in this study is the slow and rapid sand filter because it differs only in filter slow rates and cleaning practices from other filtration systems. The slow and rapid filtration data were used to determine the dimensions of the planted gravel filter.

The planted gravel filter has a trapezoidal cross-section with the following dimensions: a length of 30 meters, a top width of 10 meters, a bottom width of 8.3 meters, an adequate depth of 1.5 meters and a wall height of 2.4 meters. The septage stays in the planted gravel filter for 26 days in which after the detention time has elapsed, the septage is then moved to the constructed wetland.

5.8 The Constructed Wetland

The wetland has a trapezoidal cross-section with the following dimensions: a length of 39 meters, a top width of 13 meters, a bottom width of 12 meters, an adequate depth of 0.8 meters, and a wall height of 1.7 meters. The septage stays in the constructed wetland for 28 days. After the detention time has elapsed, it is released to the ground as a clean effluent.

6. Description of Technology

The septage goes through a series of treatment ponds while undergoing the natural process. In nature, organic material is used as food/energy for bacteria, protozoa, algae, and other life forms for their growth and metabolism. Natural treatment systems purify wastewater much like nature. Organic material in the wastewater is absorbed and broken down by microorganisms, green plants, and other life forms. (Wisconsin Department of Natural Resources, Wastewater Operator Certification, Introduction to Ponds, Lagoons, and Natural Systems Study Guide, 2013)

The treatment ponds and tanks are to be reinforced concrete to withstand the forces of nature and prevent seepage to the ground underneath. These treatment ponds have pipes, connectors, and valves underneath the ground to transport the septage from one pond to the other.

7. Gathering of Data

These are the officially enrolled 6266 students from 2007-2019. The value obtained was multiplied by the Environmental Handbook factor to obtain the septage generation rate.

There were 44 boarding houses inside the campus, and 944 people (students) lived/stayed in them. The value obtained was multiplied by the factor from the Environmental Handbook to get the septage generation rate.

The value obtained for the consumers of the CPSU Water System is 132 because not all boarding houses utilise the school's water system. The barangay also provides water to the community on campus. The value obtained was multiplied by the Environmental Handbook factor to get the septage generation rate.

7.1. The Ponds and Tank

The septage generation rate and the equations of an open channel of the most efficient cross-section of a trapezoid were used to get the area, which was multiplied by its corresponding depths. The volume for the receiving tank, sludge–drying bed, anaerobic pond, maturation pond, facultative pond, planted gravel filter, and constructed wetland was achieved.

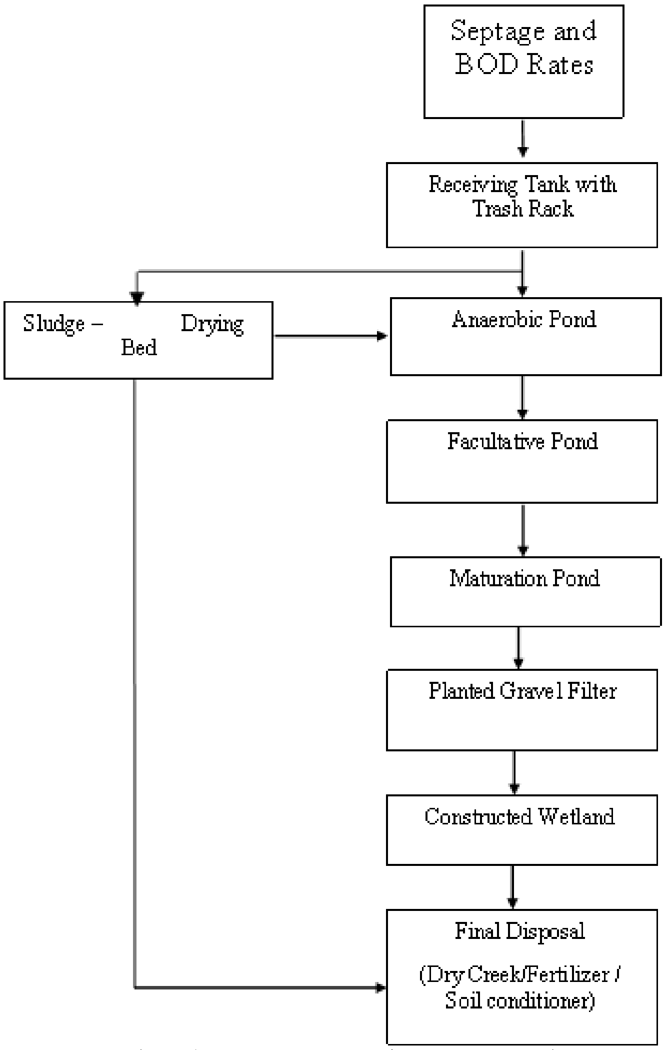

Figure 2. Flow chart of septage undergoing natural process

7.2. Detention Days

The biological activity in a stabilisation pond is affected by three climatic conditions. First, sunlight is the driving force of photosynthesis and oxygen production in the pond. The depth penetrating the pond will determine the depths at which algae grow and produce oxygen. The second is temperature. This activity affects the rate of bacterial and algal growth/activity. As temperature rises, activity increases. Lastly is the wind, which provides natural mixing to the pond. Some oxygen transfer occurs at the pond surface. When adequate mixing of the food (BOD), oxygen, algae, and bacteria occurs, the entire pond is a natural, active biological treatment facility. Stabilisation ponds have historically provided long detention times (greater than 150 days) for wastewater to be stabilised through natural processes. (Wisconsin Department of Natural Resources, Wastewater Operator Certification, Introduction to Ponds, Lagoons, and Natural Systems Study Guide, 2013)
Different values for the detention days were achieved for the various treatment ponds by dividing the volume of each pond by the 30-day average flow.

8. Interpretation of Data

Table 1. Summary of the dimensions and hydraulic capacity of the ponds and tanks

Ponds / Tank	Length, m	Top width, m	Bottom width, m	Water Depth, m	Volume, m^3	Average Daily Flow, m^3/day	Detention Time, days	Freeboard, m	Height of Wall, m	Volume, m^3
Receiving Tank	27	9		3.0	729	24				

Sludge – Drying Bed	3	1		1.5	4.5					
Anaerobic Pond	27	9	5.6	3.0	591.30	20	25	0.90	3.9	768.69
Facultative Pond	27	9	6.2	2.4	492.48	16	25	0.90	3.3	677.16
Maturation Pond	57	19	18.5	0.45	480.94	16	30	0.90	1.35	1442.81
Planted Gravel Filter	30	10	8.3	1.5	411.94	14	26	0.90	2.40	658.80
Constructed Wetland	39	13	12	0.80	390		28	0.90	1.7	828.75

The receiving tank has a rectangular cross-section with the following dimensions: a length of 27 meters, a width of 9 meters, and a depth of 3 meters. The collected septage goes through the anaerobic pond for treatment, while the suspended solids collected from the trash rack go to the sludge drying bed. A density polyethene pipe (HDPE) of 360 mm in diameter will be used as an underground pipeline to transmit the septage from pond to pond.

The sludge–drying bed contains the suspended solids filtered by the trash rack. It includes screens that separate the water content from the suspended solids. The water goes through the underdrain pipe to the anaerobic pond for treatment. The bed also contains fine sand and gravel beneath to filter the sludge.

The sludge drying bed has a rectangular cross-section with the following dimensions: a length of 3 meters, a width of 1 meter, and a depth assumed to be 1.5 meters. The dried sludge will be released as a soil conditioner or fertiliser.

The anaerobic pond has a trapezoidal cross-section with the following dimensions: a length of 27 meters, a top width of 9 meters, a bottom width of 5.6 meters, an adequate depth of 3 meters and a wall height of 3.9 meters. A freeboard of 0.9 meters is provided to allow movement on the water surface. The average daily flow can be determined using the maximum hourly, daily, weekly, monthly, yearly or instantaneous peak flow computations based on the most significant volume of flow anticipated to occur for that particular time.

The researcher utilised the monthly average daily flow computation because of the anticipation that once this treatment facility is in operation, the user's fee will be incorporated in the monthly bill payment of the CPSU Water System as part of the facility's operations and maintenance. The septage stays in the anaerobic pond for 25 days, after which the detention time has elapsed, and the septage is then moved to the facultative pond.

The facultative pond has a trapezoidal cross-section with the following dimensions: a length of 27 meters, a top width of 9 meters, a bottom width of 6.2 meters, an adequate depth of 2.4 meters, and a wall height of 3.3 meters. The septage stays in the facultative pond for 25 days, after which the detention time has elapsed, and then it moves to the maturation pond.

The maturation pond has a trapezoidal cross-section with the following dimensions: a length of 57 meters, a top width of 19 meters, a bottom width of 18.5 meters, an adequate depth of 0.45 meters, and a wall height of 1.35 meters. The septage stays in the maturation pond for 30 days, and after the detention time has elapsed, it is moved to the planted gravel filter.

The researcher preferred the slow and rapid sand filtration systems for the planted gravel filter pond because they differ only in filter slow rates and cleaning practices from the other filtration systems. The data from the slow sand filtration were used to determine the dimensions of the planted gravel filter.

The planted gravel filter has a trapezoidal cross-section with the following dimensions: a length of 30 meters, a top width of 10 meters, a bottom width of 8.3 meters, an adequate depth of 1.5 meters and a wall height of 2.4 meters. The septage stays in the planted gravel filter for 26 days in which after the detention time has elapsed, the septage is then moved to the constructed wetland.

The water hyacinths or wetlands have a trapezoidal cross-section with the following dimensions: a length of 39 meters, a top width of 13 meters, a bottom width of 12 meters, an adequate depth of 0.8 meters, and a wall height of 1.7 meters. The septage stays in the constructed wetland for 28 days. After the detention time has elapsed, the septage is released to the ground as a clean effluent.

The maturation pond, the planted gravel filter, and the constructed wetland are also trapezoidal in cross-section.

However, their walls will not be designed as cantilever retaining walls because their height failed to meet the minimum requirement of 3 meters. Nevertheless, the walls of these ponds, namely the maturation pond, the planted gravel filter, and the constructed wetland, will still be reinforced concrete.

The receiving tank and the sludge–drying bed are both in rectangular sections. These structures will also be using reinforced concrete, and the researcher prefers to divide the depth of the receiving tank by two (2), from 3 meters to 1.5 meters, for a more effortless transfer of the septage from the haulier truck. Since the height of the walls of the receiving tank and the sludge–drying bed are the same, the researcher no longer finds it necessary to apply the design and analysis of a cantilever retaining wall.

A septage treatment facility will be developed at CPSU Main Campus with a space that is not constrained. It will adopt a natural treatment process and comprise the following ponds and tanks: the receiving tank, the sludge–drying bed, the anaerobic pond, the facultative pond, the maturation pond, the planted gravel filter, and the constructed wetland.

9. Results and Discussion

This chapter summarises the different sizes of the ponds and tanks, namely the receiving tank, the sludge–drying bed, the anaerobic pond, the facultative pond, the maturation pond, the planted gravel filter, and the constructed wetland that made up the CPSU Septage Treatment Facility. The results were achieved by using the engineering equations of a cantilever retaining wall and the principles of open channel.

The site development plan of the septage treatment facility, shown in Figure 13, was provided. As stated earlier, the site development plan is in Sitio Tamlang, Brgy. Camingawan, Kabankalan City, which is estimated to be 3.3 kilometres from CPSU Main Campus. The septage treatment facility has the coordinates 9° 50' 10.20" N and 122° 52' 11.15" E.

Figure 1. Site Development Plan of the Proposed CPSU Septage Treatment Facility

10. Conclusions

The site development plan for the septage treatment facility (STF) at the CPSU Main Campus, Kabankalan City, was provided (see Figure 11). The STF is located at Sitio Tamlang, Brgy. Camingawan, with coordinates at 9° 50' 10.20" N, 122° 52' 11.15" E, is estimated to be 3.3 kilometres from CPSU Main Campus.

The ponds' designed dimensions and hydraulic capacity are as follows: the receiving tank has a length of 27 meters, a width of 9 meters, and a depth of 3 meters. Its capacity is 729 m3.

The sludge drying bed has dimensions of 3 meters in length, 1 meter in width, and 1.5 meters assumed depth. Its capacity is 4.5 m3.

The anaerobic pond is 27 meters long, 9 meters wide at the top, 5.6 meters wide at the bottom, and 3.9 meters high at the wall. Its capacity is 591.30 m3.

The facultative pond has the following dimensions: a length of 27 meters, a top width of 9 meters, a bottom width of 6.2 meters, and a wall height of 3.3 meters. It has a capacity of 492. 48 m3.

The maturation pond has the following dimensions: a length of 57 meters, a top width of 19 meters, a bottom width of 18.5 meters, and a wall height of 1.35 meters. It has a capacity of 480. 94 m3.

The planted gravel filter has the following dimensions: a length of 30 meters, a top width of 10 meters, a bottom width of 8.3 meters, and a wall height of 2.4 meters. It has a capacity of 411.75 m3.

The constructed wetland has the following dimensions: a length of 39 meters, a top width of 13 meters, a bottom width of 12 meters, and a wall height of 1.7 meters. It has a capacity of 390 m3.

The most efficient and economical sections/dimensions were obtained using the hydraulic principles of open channels. At the same time, the stability of the walls was achieved using the NSCP Code of 2015 and the design of the cantilever retaining wall in reinforced concrete.

A septage treatment facility will be developed at CPSU Main Campus with no space constraint. It will consist of the following ponds and tanks: the receiving tank, the sludge–drying bed, the anaerobic pond, the facultative pond, the maturation pond, the planted gravel filter, and the constructed wetland. This facility will adopt the natural treatment process.

Based on this study, it was observed that the ponds' size depends on the population's size. The bigger the population, the bigger the ponds' size, which will result in a bigger volume capacity of the ponds. The volume capacity, when divided by the average daily flow, will always result in a longer detention time, and the fact that the size of the pipe to be used to transmit the septage from one pond to another is also dependent on a more significant volume capacity of the ponds and tank.

Based on the data gathered, the ponds and tank, including the office and the concrete pavement for the vehicles' entry and exit, will require less than half a hectare of land. Future expansion might be needed if the community outside CPSU also wants to use the treatment facility.

11. Recommendations

It is recommended that the technology of the natural treatment process be adopted since this is easy to implement and is very convenient to use. The ponds and tanks must be reinforced concrete to avoid seepage and leaks in the soil beneath.

It is also important to note that implementing this treatment facility is commendable as it would create a venue for other government agencies to pursue future research and innovation, especially in agriculture and wastewater management. Further studies on this topic also open more possibilities, especially regarding the criteria for the final disposal of the cleaner effluent to the ground.

Thus, this proposal could make the CPSU community a pilot institution responding to the government's call to protect the groundwater beneath and the environment. The researcher would be pleased to implement the design sizes if given the opportunity.

12. Acknowledgement

I want to thank everyone who contributed to my academic accomplishments. First, I thank my better half, who supported me with love and understanding. Without you, I could never have reached this current level of success. Secondly, I thank my committee members, who have provided patient advice and guidance throughout the research process. Lastly, I thank my colleagues, who were always ready to assist me in preparing the manuscripts. Thank you all for your unwavering support!
To the Lord Almighty who made this thesis possible. To God be the glory!

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