Butuanon River: Understanding the Problem and Developing Sustainable Solutions

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Abstract — The Butuanon River in the Philippines has been facing severe pollution due to the improper discharge of untreated sewage and irresponsible disposal of solid, septic, and industrial wastewater. This paper assessed the problems observed from the upstream section of the river and its connection to the data retrieved from the different assignments performed. With the problem identified, an improved septic tank that not only filters solid waste but also chemical waste was proposed by the researchers. The improved septic tank or SmartSeptic focuses on pre-treating the water by filtering out solid waste, then removing the phosphorus in the wastewater through the good bacteria, Candidatus Accumulibacter, before the now clean water gets discharged into the Butuanon River. The SmartSeptic system solves the problems addressed in the Butuanon River Upstream.

Keywords — *Butuanon River, SmartSeptic, Candidatus Accumulibacter, high phosphate levels, septic and sewage waste pollution*

Part A. Research Report

I. INTRODUCTION

A. Background of the Study

The Butuanon River is a river located in Cebu, Philippines that originates from the mountainous regions of Cebu City and eventually empties into the Mactan Channel, which lies between Lapu-Lapu City and Mandaue City. It is approximately 23 kilometers long, and passes through the cities of Cebu, Mandaue, and the municipality of Consolacion. The river is an important source of water for the surrounding communities and is also used for recreational purposes such as fishing and swimming.

Unfortunately, the river has had to deal with a number of environmental problems over the years, including pollution. The water quality of the river has been severely impacted by this pollution, posing environmental and health hazards to all the users of the Butuanon River.

B. Statement of the Problem

The Butuanon River was declared biologically dead in 1992 by the Department of Environment and Natural Resources (DENR) on account of its polluted state. It is facing severe pollution issues due to various activities such as domestic sewage, solid waste disposal, and industrial waste disposal. The pollution in the Butuanon River is causing harmful effects on its marine life and on the human health of the river users. The lack of management of the pollution sources, the government's failure to strictly enforce the environmental laws, and the river users' disregard for the laws are worsening the problem, making it difficult to maintain the water quality standards of the river.

One of the specific problems that was observed in the Butuanon River Upstream is the disposal of septic and sewage wastes into the river through the pipes embedded in the riprap by the locals residing along the river, and the plastic waste pollution due to the irresponsible waste disposal. A relatively minor issue in the Butuanon River is the flooding experienced by the residents during heavy rains.

C. Objectives of the Study

The main objective of this study is to propose a feasible solution that can resolve the Butuanon River's pollution problem. Specifically, it aims to achieve the following objectives:

- To identify the sources of pollution in the area.
- To analyze the effects of pollution to the users of the river.
- To present a plan for the implementation and maintenance of the proposed solution.

D. Main Research Question

This study aims to answer the main research question and the following sub-questions listed below:

1. What can we do to prevent pollution in the Butuanon River and how can we coordinate with the government for the implementation and maintenance of the solution?
   - 1.1. What are the primary sources of pollution in the Butuanon River Upstream?
   - 1.2. What are the current pollution control measures in place, and how effective have they been in mitigating pollution in the Butuanon River?
   - 1.3. What is the total estimated cost of construction of the solution to be implemented?

II. DATA GATHERING AND METHODS

The data gathering and methods section discusses the different procedures done by the researchers in order to collect and analyze the data that answers the research questions regarding the Butuanon River Upstream's current situation. The terms used for this study is ***Upstream 1*** for the *Pulangbato* portion and ***Upstream 2*** for the *Pit-os* portion of the Butuanon Upstream River.

Maximum Flood Heights

The researchers interviewed and asked the local residents about the river's water level in an extreme flood event. With a measuring tape, the tip was placed on the river embankment to the area identified by the locals as the maximum flood height. The height measured by the researchers was indicated and recorded.

Measuring River Width

The width of the river was determined by measuring from one end to the other using a measuring tape. After, a specified interval was measured from the first point to the next. This procedure was done for three trials since the river is not that wide. The flow width of the river was measured from embankment to embankment with a 4.5 m interval for Upstream 1 and 7.5 m interval for Upstream 2. The total width of the river was measured from riprap to riprap with a 100 m interval for Upstream 1 and Upstream 2.

Urban Water Quality

The researchers took water samples along the Butuanon River Upstream. One bottle of water was collected for Upstream 1 and another for Upstream 2. It was brought back to the school laboratory to perform the assignment. A strip was dipped into the collected water sample to identify the nitrate levels by taking a picture of the strip in the application, Deltares Nitrate. The application presented the results of each strip representing the two samples taken from the two parts of the Butuanon River Upstream. The phosphate levels were determined by dipping another strip into the specified bottle. The resulting strip was then compared to the different color intensities on the packaging. The same procedure was followed for the other parameters such as the pH level, total alkalinity, total hardness, free chlorine, and total chlorine.

For the transparency of the water, a Secchi disk was lowered into the water until the black and white color cannot be identified. The length was then measured and multiplied by 2.

Riverine Plastic Waste Pollution

The stretch of riverbank of 100 m length was selected, then the beginning and end of the stretch were marked. 10 random numbers were generated from 1 to 100, and each quadrant was placed for the 10 random distances within the 100 m length. 5 quadrants were placed on Upstream 1 and the other 5 quadrants were placed on Upstream 2. The quadrants were made using a plastic twine straw or rope and 4 sticks that were used for each corner with a 1 meter distance for each side. Once the preparation was completed, a picture was taken of the area of the quadrant. After this, the amount of man-made waste was then measured and then collected. These wastes were categorized according to the OSPAR (Oslo and Paris Conventions) monitoring form. This portion is repeated for all ten quadrants. After completing all the quadrants, the data was transferred to the excel sheets and a pie chart was created to show a clearer picture of the data collected.

Ecology of the River

The health of the river was monitored using the miniSASS (Stream Assessment Scoring System) method, which was done in five minutes. The researchers used a mobile device as a timer. During the five minutes, the researchers roamed around the area of the river bank and counted the amount of bugs and insects found, then a picture was taken for documentation. Once the timer ended, the insects and bugs were classified into their specific groups. After that, the total number of insects were summed up, and was divided by the number of groups in order to attain the average score or the miniSASS score. The score was then interpreted using the ecological category condition.

River Stream Velocity

The river stream velocity was measured by the researchers using an orange as the floating object. A part of a river with minimum turbulence was then selected and marked with a distance of 9 m for Upstream 1 and 15 m for Upstream 2. After this, the area was divided into three points. Within these points, the depth in the left side, right side, and center was measured by dipping a stick into the river and measuring the length of the stick that was dipped. Once the measurements were completed, the orange was placed at an area before point one and then the timer was started once it passed point one. The timer was stopped and recorded once it reached the ending point. Once these steps were completed, the velocity and the discharge were calculated.

Turbidity with Secchi Disk

Turbidity can be measured using several methods. For this experiment, the researchers used a Secchi disk which is an 8 inch diameter disk. First, they located a part of the river deep enough to perform the assignment in. After which, the Secchi disk was lowered into the water until the black and white color of the disc was no longer visible and then the depth was recorded. Then, the disk was raised until it was visible again then the depth was recorded. The average depth was then calculated. These steps were repeated twice in order to improve accuracy and precision of results.

Current Pollution Control Measures

The current pollution control measures in place were identified by interviewing the locals and the residents along the river. The effectiveness of these control measures was also identified through the same method.

III. RESULTS AND DISCUSSION

This section examines the results of the data collected from the different methods used, and the interpretation of these results to the situation of the Butuanon River Upstream.

Maximum Flood Heights

The researchers measured a maximum flood height of 4.72 meters (m) for Upstream 1 and 3.22 meters (m) for Upstream 2. As seen in Figure 1 and Figure 2 for Upstream 1 and 2 respectively, the maximum flood height exceeds the riprap of the river to a limited extent.

Figure 1. *Upstream 1 Maximum Flood Height.*

Figure 2. *Upstream 2 Maximum Flood Height.*

Measuring River Width

Both the flow width and total width of the river were measured. The flow width for the 3 points measured in Upstream 1 is 3.00m, 3.10m, and 3.24m, respectively, having an average width of 3.11m. For Upstream 2, the flow width for the 3 points measured is 5.67m, 7.60m, and 7.70m, respectively, having an average width of 6.99 m. For the total width of the river, 3 points were also measured in Upstreams 1 and 2. For Upstream 1, the measured widths are 18.28 m, 12.3 m, and 21.4 m, respectively, having an average width of 17.33 m. For Upstream 2, the measured widths are 17.00 m, 17.60 m, and 36.00 m, respectively, having an average width of 23.53 m. A summary of the data gathered is presented in the tables below.

Table 1. Flow Width of the River.

Upstream 1 (4.5 m interval)	
Point	Width (m)
1	3.00
2	3.10
3	3.24
Average Width	***3.11***
Upstream 2 (7.5 m interval)	
1	5.67
2	7.60
3	7.70
Average Width	***6.99***

Table 2. Total Width of the River.

Upstream 1 (100 m interval)	
Point	Width (m)
1	18.28
2	12.30
3	21.40
Average Width	***17.33***
Upstream 2 (100 m interval)	
1	17.00
2	17.60
3	36.00
Average Width	***23.53***

Urban Water Quality

The results of the assignment on Urban Water Quality can be divided into two parts: (a) Transparency of the Water; and (b) Water Quality.

a. Transparency of the Water

Upon submerging the Secchi disc in the water, an absence of visual detection occurred after a depth of 100 cm or 1.0 m for both Upstream 1 and 2. The Secchi disk was submerged in a deep isolated area of the river, which may not be representative of the whole area assigned to the researchers, but it still represents a portion of the river. The data indicates that the study area of the river exhibits a high level of water clarity. The Secchi depth is often used as an indicator of water clarity and can be influenced by factors such as the amount of sediment, dissolved organic matter, and phytoplankton in the water. A higher Secchi depth indicates clearer water with less suspended material, while a lower Secchi depth indicates murkier water with more suspended material. It is important to note that the Secchi depth is just one indicator of water quality and should be used in conjunction with other measurements and observations to fully assess the health of a river ecosystem.

Table 3. Transparency of the Water Measurements.

Upstream 1		
Subject	*Depth (m)*	*What does this tell you?*
Transparency of the Water	1.00	High Water Clarity
Upstream 2		
Subject	*Depth (m)*	*What does this tell you?*
Transparency of the Water	1.00	High Water Clarity

b. Water Quality

A summary of the results of the different parameters for the water quality in Upstream 1 and Upstream 2 is presented in the tables below.

Table 4. Summary of Water Quality Monitoring Results of Upstream 1.

Parameters	Value	Criteria for Good Water Quality	Remarks
Nitrate/Nitrite (ppm)	0	0-40 ppm	PASSED
pH	8	6.5 - 8.5	PASSED
Alkalinity (ppm)	200	20 - 200 ppm	PASSED
Total Hardness (ppm)	425	75 - 150 ppm	FAILED
Total Chlorine (ppm)	0	0.2 - 0.5 ppm	FAILED
Free Chlorine (ppm)	0	0.2 - 0.5 ppm	FAILED
Phosphate (ppm)	10	0.02-0.035 ppm	FAILED

Table 5. Summary of Water Quality Monitoring Results of Upstream 2.

Parameters	Value	Criteria for Good Water Quality	Remarks
Nitrate/Nitrite (ppm)	1	0-40 ppm	PASSED
pH	8	6.5 - 8.5	PASSED
Alkalinity (ppm)	200	20 - 200 ppm	PASSED
Total Hardness (ppm)	425	75 - 150 ppm	FAILED
Total Chlorine (ppm)	0	0.2 - 0.5 ppm	FAILED
Free Chlorine (ppm)	0	0.2 - 0.5 ppm	FAILED
Phosphate (ppm)	10	0.02-0.035 ppm	FAILED

For Water Quality, there are 7 parameters the study focuses on:

Nitrate/Nitrite (ppm)

The Nitrate value of the river is 0 for both Upstream 1 and 2. There may be inaccuracies with this result due to the limitations of the kit used for the test strips. With the result obtained by the researchers, this means that it is safe for fish to survive. A range from 0 ppm to 40 ppm is a safe range of nitrate for fish to survive.

pH Level

The pH level of both Upstream 1 and 2 is 8. A pH level greater than 7 indicates a base, a pH level less than 7 indicates acidity and a pH level of 7 indicates a state of being neutral. Upstream 1 and 2 displays a strong base and a weak acid. This pH value is already in the range for good quality freshwater.

Alkalinity (ppm)

Upstream 1 and 2 both had a value of 200 ppm for Alkalinity. An alkalinity range of 100-250 ppm for a river is considered normal and will stabilize the pH of the river. Levels between 20-200 ppm are typically found in freshwater. A higher alkalinity in water means the higher amount of calcium carbonate that decreases the water's acidity.

Total Hardness (ppm)

In this experiment, Upstream 1 and 2 resulted in 425 ppm total hardness of water. This amount of hardness in water is considered to be high and can harm water ionizers and reduce water flow.

Total Chlorine (ppm) and Free Chlorine (ppm)

The free and total chlorine of Upstream 1 and Upstream 2 is both 0 ppm. According to WHO, CDC, EU, and other organizations, an amount of 0.2 to 0.5 ppm of chlorine is recommended in order to destroy all organisms in the water. The Butuanon river failed in the total and free chlorine values since there is no chlorine present in its water.

Phosphate (ppm)

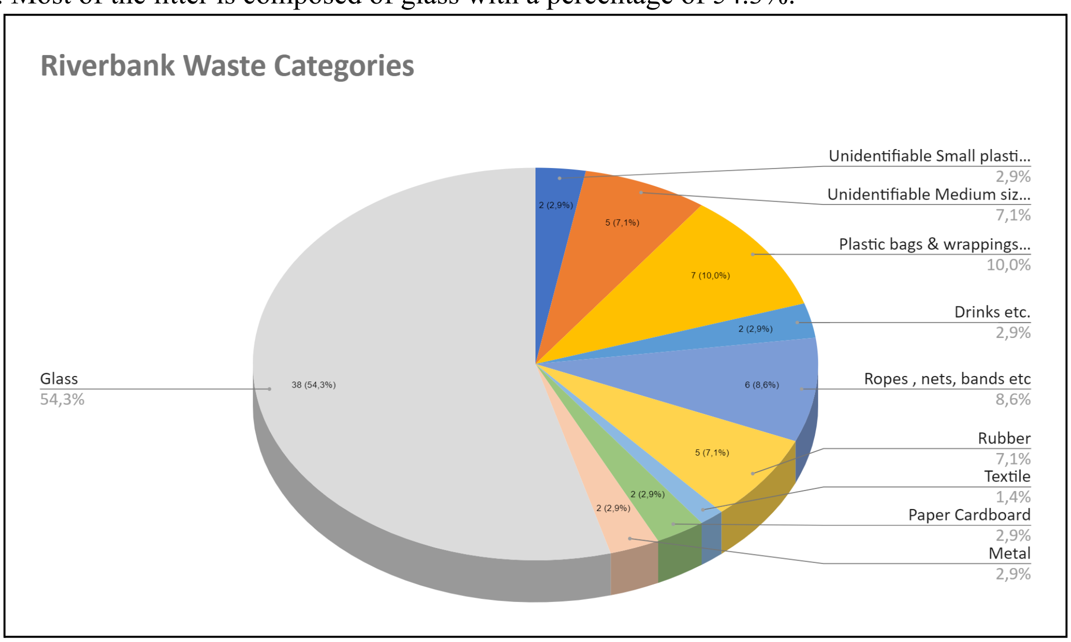
From the data gathered, Upstream 1 and Upstream 2 have phosphate of 10 ppm which is a high value because the normal phosphorus of natural water is 0.02 ppm. The ideal amount of phosphate is 0.035 ppm. An excessive amount of phosphate in a body of water leads to too much algae that consumes oxygen and blocks sunlight that is essential for the survival of aquatic life.

Riverine Plastic Waste Pollution

The researchers only performed the Randomized OSPAR Riverbank Monitoring method since there is very little trash found in the river, and each quadrant within the 100m distance is clean with no trash. There are 70 total items found in the 10 quadrants of the riverbank, and 22 of them are plastics.

Figure 3. *Quadrant 1 located 2 m from the starting point.*

The graph below shows the summarized result of the composition of the litter found in the upstream portion. Most of the litter is composed of glass with a percentage of 54.3%.



Graph 1. *Riverbank Waste Categories Graph.*

Based on the data collected, the total number of plastic waste on the riverbank is 22 pieces per 100 m. With this, it can be interpreted that the Butuanon River Upstream is **slightly polluted in terms of plastic waste** according to the plastic waste categories index attached below.

Table 6. Plastic Waste Categories Index.

Riverine Plastic Waste						
Category	A	B	C	D	E	F
Pieces per 1m^2 floating	0 - 1	2-5	6 - 25	26-50	51-100	100>
Pieces per 100 m riverbank	<10	10 - 50	51 - 250	251-500	501-1000	1000>
	(Almost) clean	Slightly polluted	Polluted	Severely Polluted	Heavily polluted	Extremely polluted

The mean density of litter found in the riverbank was identified to be **7 items per square meter** as computed below.

$$\frac{70\ items}{10\ square\ meters} = 7\ items\ per\ square\ meter$$

Ecology of the River

The miniSASS score for both Upstream 1 and 2 is 4.69 and 2.92, respectively. The river category is rocky-type so based on the ecological category table, the miniSASS score for both Upstream 1 and 2, which are less than 5.3, shows that the ecology of the river has a very poor condition. The ecology of a river is closely linked to its health. A healthy river ecology is characterized by a diverse range of species and a balanced ecosystem. With the result obtained from this assignment, there is only a small number of groups or species in the Butuanon River Upstream; thus, leading to the conclusion of a ***very poor ecological condition***.

Table 7. Determining the miniSASS score for Upstream 1.

Groups	Sensitivity Score
Flat Worms	0
Worms	0
Leeches	0
Crabs or shrimps	0
Stoneflies	0
Minnow mayflies	0
Other mayflies	0
Damselflies	12
Dragonflies	5
Bugs or beetles	19
Caddisflies (cased&uncased)	0
True flies	20
Snails	5
Total Score:	***61***
Number of Groups:	***13***
Average Score (miniSASS score):	***4.69***

Table 8. Determining the miniSASS score for Upstream 2.

Groups	Sensitivity Score
Flat Worms	0
Worms	0
Leeches	0
Crabs or shrimps	0
Stoneflies	0
Minnow mayflies	0
Other mayflies	0
Damselflies	0
Dragonflies	3
Bugs or beetles	10
Caddisflies (cased&uncased)	0
True flies	25
Snails	0
Total Score:	***38***
Number of Groups:	***13***
Average Score (miniSASS score):	***2.92***

Table 9. Ecological Category of the River.

Ecological category (Condition)	River Category	
	Sandy Type	Rocky Type
NATURAL CONDITION (Unchanged/untouched – Blue)	> 6.9	> 7.2
GOOD CONDITION (Few modifications – Green)	5.9 to 6.8	6.2 to 7.2
FAIR CONDITION (Some modifications – Orange)	5.4 to 5.8	5.7 to 6.1
POOR CONDITION (Lots of modifications – Red)	4.8 to 5.3	5.3 to 5.6
VERY POOR CONDITION (Critically modified – Purple)	< 4.8	< 5.3

River Stream Velocity

For Upstream 1, the measured *width of water in channel*, *distance traveled*, and *area of the river* is ***10.21 ft***, ***29.53 ft***, and ***4.17 ft***, respectively. These measurements are used to calculate the velocity and discharge of the river. The adjusted velocity is calculated by multiplying 0.85 to the average velocity.

Table 10. Upstream 1 River Stream Velocity Data.

Point	Depth, left (ft)	Depth, center (ft)	Depth, right (ft)	Time (s)	Velocity (ft/s)	Discharge (CFS)
1	0.82	0.85	0.23	49.73	0.18	0.75
2	0.67	0.69	0.34	51.1	0.18	0.73
3	0.50	0.56	0.21	50.81	0.18	0.74
Average Depth (per point)	***0.26***	***0.70***	***0.26***	Average Velocity	***0.18***	***0.74***
Average Depth	***0.41***			Adjusted Velocity	***0.15***	

For Upstream 2, the measured *width of water in channel*, *distance traveled*, and *area of the river* is ***22.93 ft***, ***49.22 ft***, and ***15.87 ft***, respectively. These measurements are used to calculate the velocity and discharge of the river. The adjusted velocity is calculated by multiplying 0.85 to the average velocity.

Table 11. Upstream 2 River Stream Velocity Data.

Point	Depth, left (ft)	Depth, center (ft)	Depth, right (ft)	Time (s)	Velocity (ft/s)	Discharge (CFS)
1	0.39	0.62	0.47	82.00	0.18	2.90
2	0.45	0.85	0.70	83.00	0.18	2.87
3	0.51	0.92	0.75	85.00	0.18	2.80
Average Depth (per point)	***0.64***	***0.80***	***0.64***	Average Velocity	***0.18***	***2.86***
Average Depth	***0.69***			Adjusted Velocity	***0.15***	

Based on the data obtained by the researchers, it is understandable that there is a low discharge (CFS) for the rivers examined as both are considerably shallow and have low water level. In addition, gathering of data was done during the dry season; thus, explains the low water level. The scale of the width of the river to the water level also compliments the low discharge (CFS) as the river is too wide for the amount of water running through it.

Turbidity with Secchi Disk

If a Secchi disk disappears at a shallow depth, it indicates that the water is turbid and has a high level of suspended particles, which can reduce light penetration and affect photosynthesis in aquatic plants. If the disk disappears at a deeper depth, it indicates that the water is clearer and has a lower level of suspended particles. Based on the measurements as shown in the tables below, the water in the Butuanon River Upstream is clearer since the disk disappeared at a depth of 1.38 m for Upstream 1 and 0.93 m for Upstream 2. There is also a lower level of suspended particles.

Table 13. Turbidity with Secchi Disk result for Upstream 1.

	Trial 1	Trial 2	Trial 3
Depth 1 (m)	1.43	1.44	1.44
Depth 2 (m)	1.34	1.33	1.33
Average Depth (each trial)	1.38	1.38	1.38
Average Depth	***1.38***		

Table 14. Turbidity with Secchi Disk result for Upstream 2.

	Trial 1	Trial 2	Trial 3
Depth 1 (m)	1.00	1.00	1.00
Depth 2 (m)	0.85	0.84	0.86
Average Depth (each trial)	0.93	0.92	0.93
Average Depth	***0.93***		

As seen in the table above, depth 1 is the measurement when the Secchi disk is no longer visible and depth 2 is the measurement when the Secchi disk is visible again.

Current Pollution Control Measures

One of the current pollution control measures in place is the Biofence. This control measure is made of bottles wrapped in a net used to trap garbage implemented in Barangay Pit-os. The effectiveness of the Biofence is yet to be determined since this measure was only implemented during the week of the fieldwork. The researchers were able to observe pieces of trash collected by the Biofence which is an initial conclusion for its effectiveness.

Figure 4. *Biofence located in the Butuanon River Upstream in Barangay Pit-os.*

Another current pollution control measure is the River Clean-Up program. This was implemented in Barangay Pit-os; thus, this measure only focuses on cleaning up a certain area of the river and not the whole 23-kilometer long river. This program has been implemented seven times with the most recent one taking place last February 2023.

There are no current initiatives or programs implemented in Barangay Pulangbato based on the interview conducted by the Political Science students last April 19, 2023.

IV. CONCLUSION AND RECOMMENDATIONS

The Butuanon River is a significant environmental concern that needs to be addressed. The river serves as a vital source of water for various purposes, but the presence of pollutants has made it unsafe for these purposes. The river pollution due to the septic, sewage, and plastic wastes also pose a significant threat to the health of humans and to marine life in the surrounding areas.

One of the strongest points of the Butuanon River Upstream is its high water clarity and lower level of suspended particles. Another aspect that stands out is the result of the Riverine Plastic Waste Pollution assignment, which showed that the river was only slightly polluted in terms of plastic waste. With these, it can be concluded that the state of plastic pollution in the Butuanon River Upstream is minimal and its water is considered clear.

The weak points in the Butuanon River Upstream are the high phosphate levels and total hardness in its water. One of the vulnerabilities of the river is its very poor ecological condition based on the miniSASS score obtained by the researchers. Another weak point for the river is the lack of programs by the local government unit that could help alleviate the problems identified in the Butuanon River Upstream.

With this, the researchers propose an improved septic tank system for a greener future for the rivers. The innovative septic tank will be called SmartSeptic, a three-chamber septic tank focusing on three steps: (1) Pre-Treatment; (2) Pre-Settling; and (3) Post-Sedimentation. The SmartSeptic aims to solve the problems addressed in the upstream portion of the Butuanon River.

Part B. Practical Solution

DESIGN OF THE SOLUTION

The SmartSeptic is an innovative septic tank that answers the problems addressed in the upstream section of the Butuanon River. Instead of the traditional septic tank that holds wastewater long enough to allow solids to settle down, the SmartSeptic does not only filter out solid waste but also chemical waste. The end product of the SmartSeptic is clean water that can be discharged to the Butuanon River Upstream.

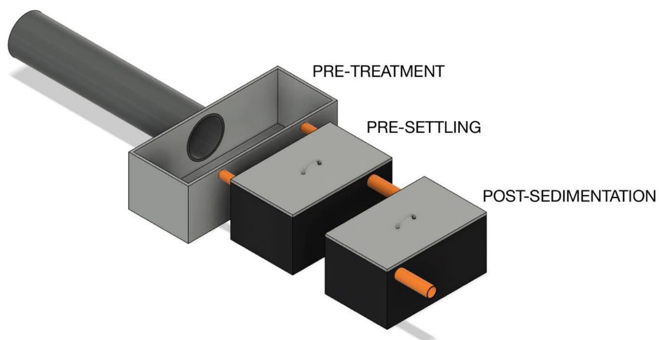


Figure 5. *Isometric view of the SmartSeptic system.*

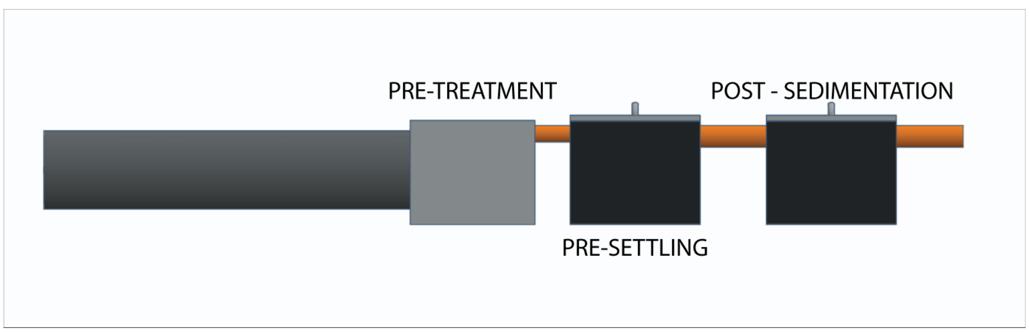


Figure 6. *Left Elevation view of the Smartseptic system.*

The SmartSeptic is a wastewater system underground for the locals residing along the river so that the researchers may be able to solve the improper disposal of the residents of their sewage and septic waste to the river. It will be located 1.5m below the residential area, and the existing pipes that the residents have will be diverted and connected to the main pipe of the SmartSeptic. The SmartSeptic is composed of three chambers that have three different functions, which will be discussed in the subsections below.

I. Pre-Treatment

The first chamber is the pre-treatment chamber. Once the septic and sewage wastes of the residents reach the first chamber, solid waste such as sanitary and fecal waste will be filtered out using nets made out of nylon. Nylon is a good material for filtering out solid waste because it is strong, it does not decompose, and it is budget-friendly. It is also durable when exposed to water and sunlight. The solid waste filtered in this chamber will be collected every 3 years. After the initial filtering out of solid waste, the wastewater will proceed to the second chamber.

II. Pre-Settling

The pre-settling chamber is the second chamber which is where the good bacteria, Candidatus Accumulibacter phosphatis, will be added for the purpose of removing phosphorus from wastewater. Phosphorus is one of the weak points identified in the Butuanon River Upstream, which is why this is specifically being addressed in this chamber.

The Candidatus Accumulibacter phosphatis is a common bacterial community member of sewage treatment and wastewater treatment plants performing enhanced biological phosphorus removal (EBPR). The effectiveness of EBPR can be increased by using coagulation to assist in reducing the amount of organic matter and suspended particles in the wastewater. Coagulation can assist in the phosphate removal from wastewater by adsorbing part of the phosphate onto the flocs. However, often, this is not the primary mechanism via which coagulation increases EBPR effectiveness. Instead, the main advantage of coagulation is eliminating organic debris and suspended particles that could obstruct Candidatus Accumulibacter bacteria from performing their function.

Overall, coagulation can be a practical step to boost EBPR's effectiveness which depends on the Candidatus Accumulibacter bacteria's ability to extract phosphorus from wastewater. Coagulation can aid in removing organic matter and suspended particles from the wastewater to increase the activity of the good bacteria and the process' overall effectiveness.

III. Post-Sedimentation

Post-Sedimentation is the last chamber in the SmartSeptic. In this chamber, water that has been filtered and cleaned is stored and then discharged into the Butuanon River Upstream. The clean water that will be discharged into the upstream portion can also help alleviate the polluted water problems in the midstream and downstream section of the river since the water upstream flows towards these sections.

The SmartSeptic is more efficient in cleaning out the wastewater before it is discharged into the Butuanon River. It is an excellent investment for the government to prioritize environmental protection, long-term cost savings, and sustainable living.

Other than the SmartSeptic, the River Clean Up program implemented by Barangay Pit-os must be continued. The researchers propose that the different Barangays where the river traverses shall also work together with Barangay Pit-os in this program so that a wider area may be covered in the clean up initiative. This clean-up program must be implemented twice a year, but the frequency of this activity may also be increased depending on the current state of the Butuanon River Upstream.

The existing pollution control measure in the Butuanon River Upstream, the Biofence, will be implemented in other areas of the river as well. Instead of the curved orientation that was the initial placement of the Biofence, the researchers propose to have it placed diagonally and attached from one end of the riprap to the other. The diagonal orientation of the Biofence can facilitate the movement of the solid waste to a designated area; thus, it will be easier to collect garbage since it is mostly concentrated in one area.

LOCATIONAL ANALYSIS

The SmartSeptic can be located in either of the two proposed locations, Location A and B, as presented in the figures below.

Location A

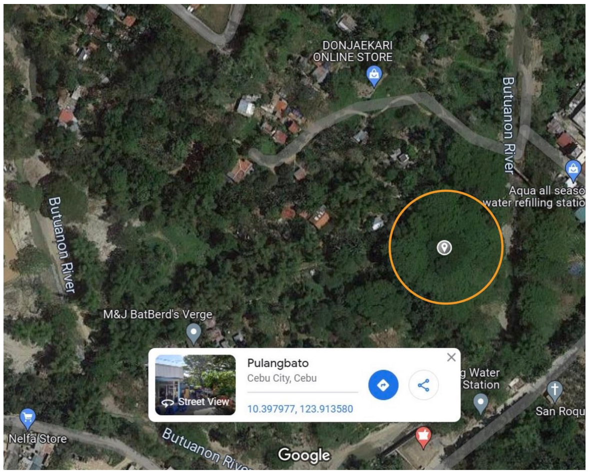


Figure 7. *Location A is the first proposed location for the SmartSeptic.*

Location B

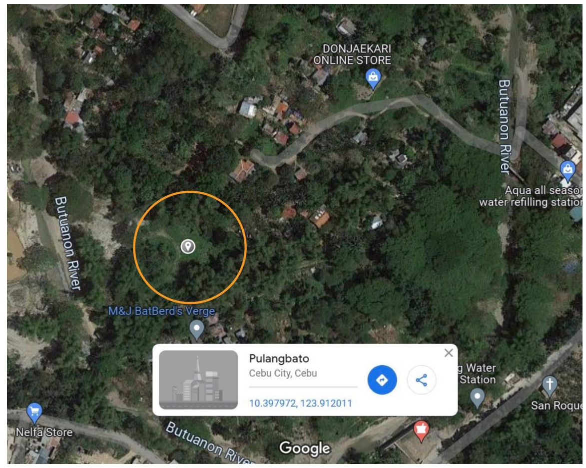


Figure 8. *Location B is the second proposed location for the SmartSeptic.*

Location A and B are located at the specific coordinates found in each of their figures. Their locations are in close vicinity to the residential houses along the river, which is a must for the proposed locations since the existing pipes of the households must be redirected towards the SmartSeptic's main pipe. Furthermore, the sites are situated near the river, approximately 25m away, which enables the clean water to be discharged into it.

These two proposed locations are only based on the data from Google Maps. The researchers were not able to collect data on the location of the different households along the Butuanon River Upstream due to time constraints and limited manpower.

SOCIAL COST-BENEFIT ANALYSIS WITH EXPLANATION

The cost of this project is estimated at **Php 3,474,880.72**. The SmartSeptic's construction and maintenance is quite expensive, but this is a long-term solution that also brings about long-term cost savings as compared to band-aid solutions that have to be implemented every now and then.

Table 15. Estimated Cost of the Proposed Solution.

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	SUBTOTAL
Labor	Manpower	10	laborer per day	425	₱127,500.00
Concrete	Ready-Mix Concrete (Kimwa)	300	cu.m	5805	₱1,741,500.00
Reinforcing Bars	16mm, 6m	24000	kg	40	₱960,000.00
PVC Pipe	4 inch diameter, 6m long	17	pcs	589.16	₱10,015.72
PVC Pipe	10-inch diameter, 6m long	8	pcs	3600	₱28,800.00
Excavation	Earth	300	cu.m	1000	₱300,000.00
Backfill	Earth	300	cu.m	1000	₱300,000.00
Net	Nylon	50	m	46.3	₱2,315.00
Candidatus Accumulibacter	Good Bacteria	0	N/A	N/A	₱0.00
Biofence	Recyclable Materials	0	N/A	N/A	₱0.00
SmartSeptic Cleaning	Cleaning every 3 years	1	truck	4750	₱4,750.00
				TOTAL COST:	**₱3,474,880.72**

The table above presents the list of items to be considered in the implementation of the solution, along with its quantity and cost. It should be noted that the good bacteria used in our SmartSeptic, the Candidatus Accumulibacter, is not available for commercial purchase. This bacteria will be obtained through the American Type Culture Collection (ATCC), which is a private, nonprofit organization dedicated to the acquisition, preservation, and distribution of diverse biological materials. The researchers propose that the government work hand-in-hand with the ATCC in acquiring the good bacteria needed for the SmartSeptic. Another thing to take note of is that the Biofence is completely made of recyclable materials, which is why the cost for this product is not applicable. Last but not the least, cleaning is a necessary part of the maintenance of the solution. The SmartSeptic must be cleaned every three years and the additional costs for this maintenance is included in the estimated cost of the project.

The proposed project will be funded by the government. The government must heavily invest in solutions that aim to revive our rivers since river pollution is a very serious problem in Cebu City, and it must be addressed immediately to prevent the eventual death of marine life.

PLANNING

The Local Government Unit (LGU) is a big part of the solution to be implemented by the researchers since they play a major role in a community's development, and address its community's problems and concerns. Once the SmartSeptic proposed solution is adopted by the LGU, the implementation process of the solution can start. The LGU can also coordinate with other stakeholders involved in the implementation of the SmartSeptic to enhance its feasibility.

STAKEHOLDERS INVOLVED

The stakeholders are vital in the implementation of the SmartSeptic, the continuation of the River Clean Up program and Biofence project. The different stakeholders involved are listed and discussed in the next few paragraphs.

Cebu City LGU (Local Government Unit)

The Cebu City LGU holds the greatest sway since it is the sole city government body accountable for the establishment and implementation of local ordinances pertaining to safeguarding public health and the health of the city's rivers. Moreover, they possess the most extensive resources to cater to the requirements and preferences of the people of Cebu. The Cebu City LGU is responsible for formulating and enforcing measures to safeguard the environment and the general public. Nevertheless, due to the irregular implementation of environmental policies in Cebu City, the impact of this favorable disposition is not being fully realized.

Environment NGOs (Non-governmental Organization)

Environmental NGOs hold a considerable level of power because they provide financial assistance, volunteer support, and expert knowledge to aid in the enforcement of local laws that pertain to the conservation of the environment and the welfare of the public. However, their influence is not as substantial as that of the Cebu City LGU, as these organizations aggregate their resources to address gaps in the system. Additionally, since they are non-governmental organizations, they are not involved in the decision-making process, which lessens their overall impact.

Residents living near Butuanon River Upstream

Due to the fact that human waste is the primary cause of the pollution in the river, the proposed policy and current policies have a significant impact on the public. This high level of influence is because it makes the public realize the importance of safeguarding the Butuanon River in Cebu City, including the safety of the people.

Mass Media

The dissemination of political information and the facilitation of public discussions on topics such as environmental conservation in Cebu City are significantly influenced by the mass media. Although they do not partake in the decision-making process, their impact is substantial. The mass media serves as a platform for discussions about the preservation of the Butuanon River's health, which the public can access. Moreover, the Cebu City LGU can receive feedback in the form of political support or criticism from the mass media, which collectively promotes awareness and acknowledgment regarding the protection of the river's health.

OPERATION AND MAINTENANCE

The operation and maintenance of the SmartSeptic project should be handled by the Local Government Unit (LGU) because they are responsible for accommodating the needs of their communities. The LGUs of Cebu City and Mandaue City should work together in implementing the project. The LGUs can also collaborate with the Department of Public Services (DPS) to effectively address the problem of solid waste management.

The maintenance activities necessary for the proposed solution include proper waste collection, inspection of the SmartSeptic, and cleaning of the SmartSeptic. Waste collection should strictly be carried out weekly by the government so that waste will not accumulate in the area. The SmartSeptic project will be inspected twice a year, but this may lessen in frequency over time as long as the effectiveness of the solution is ensured. Cleaning the SmartSeptic should also be done every three years to prevent the accumulation of solid waste that could cause future problems. Regular cleaning can reduce the need for repairs and prolong the life of the system.

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