University of San Carlos
Cebu City, Cebu, Philippines

"METRO CEBU RIVER SCAN CHALLENGE 2023"
RESEARCH REPORT | INNOVATIVE SOLUTION PROPOSAL

Presented to the The Faculty of the Department of Civil Engineering
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PART A. RESEARCH REPORT

INTRODUCTION

BACKGROUND OF THE STUDY

Water pollution can be defined as the contamination of a stream, lake, ocean, or river, in this case. It depletes water quality and makes it toxic for the environment. Unsurprisingly, human activity is the main cause of water pollution. According to a report of the City Environment and Natural Resources Office (CENRO), along with the Environment and Management Bureau in Central Visayas (EMB-7) during the first day of the River Summit in 2022, the main river systems in Cebu City are unclean and dangerous for the general public, particularly those downstream.

Numerous ideas to revive these bodies of water have been planned in response to the emerging pollution problems of the Metro Cebu Rivers, Mahiga, and Butuanon. These two rivers that drain Cebu's metropolitan region are contaminated by solid waste and untreated sewage, causing issues with flooding, water quality, and human health.

Together, students from the University of San Carlos, Rotterdam, and Hanze Universities of Applied Sciences have created innovative solutions to this protracted issue in order to resolve this environmental crisis. This initiative, known as River Scan Challenge 2023, provides help with river and creek rehabilitation in Metro Cebu. From here, the team was assigned to the downstream portion of the Butuanon River, close to Pacific Mall (Figure 1) and the Barangay Alang Alang bridge (Figure 2).

Fig. 1. *Downstream 1 (Butuanon River - Pacific Mall Viewing Deck)*

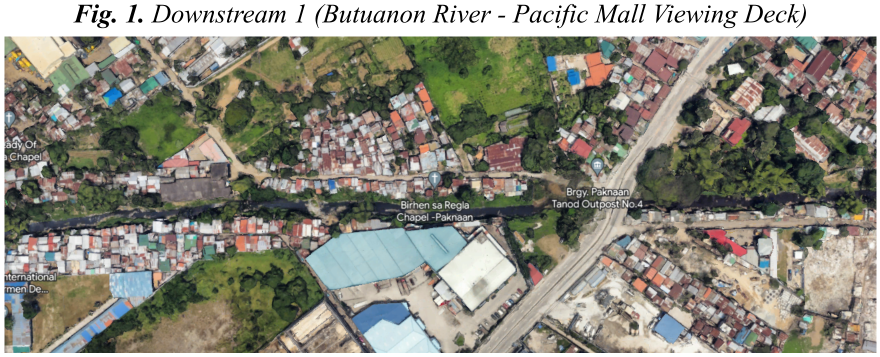


Fig. 2. *Downstream 2 (Butuanon River - Paknaan Bridge)*

STATEMENT OF THE PROBLEM

The Butuanon River, which flows from the mountain barangays of Cebu City down to the urbanized barangays of Mandaue City, was deemed dead in 1992, making it incapable of supporting flora and fauna. However, it was classified as a Class D body in 2002, allowing it to be used for crop irrigation as well as industrial, agricultural, and animal applications. Still, there are several contaminants in the aforementioned river.

The issues that this study focuses on include where the pollution comes from and how the damage might be repaired. Lack of understanding on the part of the government and the populace, together with inadequate wastewater treatment, a lack of political will, and insufficient financing, all contribute to the problem. As there aren't many trash bins, people tend to leave things lying around. There is no system in place for collecting trash as well. This leaves the team questioning how the people can undo the damage that has been done and how life can be brought back into the river.

MAIN RESEARCH QUESTIONS

The study intends to answer the main questions along with its sub-questions as listed below.

1. What are the impacts of industrial and residential practices on river pollution, and how can one develop effective management solutions?
    a. What are the potential sources of pollutants?
    b. What is the current state of environmental conditions and persisting hazards?
    c. What are the most promising and innovative technologies and methods for removing or mitigating pollutants in the river, and how can these approaches be scaled up to achieve meaningful results?

OBJECTIVES OF THE STUDY

This present study's main objective is to develop feasible solutions to overcome the ongoing problem in the aforementioned river. Overall, the study aims to achieve the following objectives:

- To identify the potential source of pollutants
- To assess environmental conditions and persisting hazards, such as water quality, smell, color, and sedimentation
- To provide, plan, and manage practical and economical solutions

METHODOLOGY

This section discusses how the study will be gathered, procured, and interpreted through the different methods and calculations discussed in every assignment. This section provides a clear description of the methods used and discusses how each research question is answered.

I. Maximum Flood Heights

Acquiring the maximum flood heights requires information from the local residents in the vicinity of the assigned area. With that, the researchers talked with local residents and were asked about the water levels of the river in an extreme flood event. The height of that location was measured with a measuring tape or rod.

II. River Width Using Smart Measure Application

In measuring such data, the width of the river was obtained using the application "Smart Measure App" along with a device called a Rangefinder. The accessibility of the location was inconvenient, thus, limiting the measurement to three per River Site. Pictures were taken of the location where the river width was measured.

III. Urban Water Quality

In this assignment, the teams took samples of the water quality at several places along the Butuanon River. This task was supported with measurement strips that displayed the chemical contents of the results on a color card. For Nitrate, such strips were put in the water for a sufficient amount of time. The color of the strip is then compared with the colors on the packaging. The Deltaris Nitrate app was then used for verification of results. Other parameters were taken such as the pH content, Chlorine, Total Hardness, Alkalinity, Nitrate Nitrogen, Nitrite Nitrogen, and also Phosphates.

IV. Riverine Plastic Waste Pollution

Randomized OSPAR Riverbank Monitoring. The method involved randomized sampling in order to make quick assessments in different conditions possible. In this method, the amount and composition of riverine plastic litter were determined on a riverbank using a random subsample. For a riverbank length of 100 m, 6 subsamples of $1m^2$ were collected. The measurement consists of marking down the observed river litter on the adapted OSPAR form per square. All items were counted and registered according to the different categories and types.

Randomized OSPAR Floating Plastic Waste. Since several water systems consist of very slow velocity waters with stable water levels, it is not always possible to measure riverbanks to get an insight into plastic waste in the water system. Therefore, an additional method has been developed to measure floating plastic waste. Probable trash hotspots were taken. The following steps were taken for data collection and a litter hotspot was selected. An estimation of 1 m^2 was made. All items were counted and registered according to the different categories and types indicated in the OSPAR monitoring form. A separate form for each measured m^2 sample was recorded in Excel. The composition of the litter found was determined and visualized in a pie graph.

V. Ecology of the River

The health of the river in this assignment will be the focal point of monitoring with the use of the miniSASS (Stream Assessment Scoring System) method. An instructional video was provided on how to monitor, which, in this case, was using a net to catch possible living organisms around the area of the assigned river. Different macroinvertebrates that the researchers could possibly find were identified according to a certain classification. After the checklist was compiled, the ecological score using the scorecard was determined.

VI. River Stream Velocity

In its simplest term, this method entails detecting the water's surface velocity with a floating object, in this case - an orange and multiplying that velocity by the channel's width and average depth. For the procedure proper, a suitable channel section with minimum turbulence was chosen as the pilot area. The floating object was then thrown into the stream upstream of the upstream marker. Record the time the object floats from point to point, as this was repeated 3 times. Such formulas were then used.

CFS	*= A x V (area multiplied by velocity)*
A (Area)	*= Width of Channel (feet) x Depth of Water (feet)*
V (Velocity)	*= Distance Traveled / Time to travel (feet traveled divided by seconds)*

VII. Turbidity with Secchi Disk

The simplest and most reliable method for determining a river's production is Secchi Disk Depth. This experiment then started off by putting the Secchi Disk into the water. The disk was lowered slowly until it disappeared. The depth of the cord was recorded. The disk was then pulled until it was visible again. Next, the average of two depths was calculated to the cord's nearest half-foot mark. Along with the date and time of the reading, this average depth was noted on the Secchi Data Sheet. For increased measurement precision, this operation was repeated.

Some considerations had to be taken into account since the secchi depth data quality is user dependent, thus, readings may differ from person to person depending on vision. The secchi disk visibility depends on environmental elements including wave activity and sunlight intensity. Therefore, measurements should be made simultaneously in calm waters and in the shade between the hours of 10 am and 4 pm. Thus, the importance of taking several measurements and readings, along with having observers at the side, was essential to ensure the quality of results.

RESULTS AND DISCUSSION

This section of the research report presents and provides interpretation of the quantitative data collected from the measurements, experiments, sampling, and interview. Relevant qualitative data gathered from the methods employed in this River Scan Study structured and analyzed.

I. Maximum Flood Heights

According to a local resident and the eco-enforcer from MCENRO, the maximum flood height for Downstream 1 falls to approximately 2 meters when the rainfall rate is light. If the rainfall rate is heavy, the maximum flood height measurements run to approximately 4.5 meters. On the other hand, during light rains the maximum flood height for Downstream 2 falls to approximately 2.3 meters and 7.5 meters during heavy rains.

Rainfall Rate	Maximum Height
Light Rains	2 m
Heavy Rains	4.5 m

Table 1.1. *Maximum Flood Height (Downstream 1)*

Rainfall Rate	Maximum Height
Light Rains	2.3 m
Heavy Rains	7.5 m

Table 1.2. *Maximum Flood Height (Downstream 2)*

Recently, Typhoon Rai, also known locally as Odette, devastated five provinces in the Visayas, including Cebu City. It also caused the Butuanon river to overflow its embankment and approach the road. The residents also mentioned that in September 2022, the river's water level rose above the embankment, and more recently, in or around February 2023, the river's floodwaters did likewise.

II. River Width Using Smart Measure Application

In obtaining the total width of the river, the most sophisticated method was done by taking three measurements of the width with the aid of a smart measure app in which the average was calculated right after. Based on the measurements taken, the third sections are the widest sections of the river, measuring 9.4 meters and 9.7 meters from both river sites respectively. Also, the average width for the two downstreams were computed and is equal to 8.43 meters and 8.9 meters respectively.

Section Measured	Width (m)	Measurement Tool
1st	6.2	Smart Measure App
2nd	9.4	Smart Measure App
3rd	9.7	Smart Measure App
Total Average	8.43	

Table 2.1. *Width Data for Downstream 1*

Section Measured	Width (m)	Measurement Tool
1st	8.8	Smart Measure App
2nd	8.5	Smart Measure App
3rd	9.4	Smart Measure App
Total Average	8.9	

Table 2.2. *Width Data for Downstream 2*

Figure 2.1 & 2.2. *Locations where width is measured starting from the rightmost red line (Downstream 1 & 2)*

III. Urban Water Quality

This table of test results for urban water quality includes data on a number of variables that were looked at for three different water samples, namely Sample 1, Sample 2A, and Sample 2B.

Parameter Tested	Sample 1	Sample 2A	Sample 2B
Nitrate (ppm)	0	0	0
Nitrite (ppm)	0	0	0
Total Chlorine (ppm)	0	0	0
Free Chlorine (ppm)	0	0	0
Hardness	25	25	25
Alkalinity (ppm)	>240	>240	>240
Ph	8.1	8.4	8.4
Phosphates (ppm)	23	23	23

Table 3.1. *Parameter Test Results*

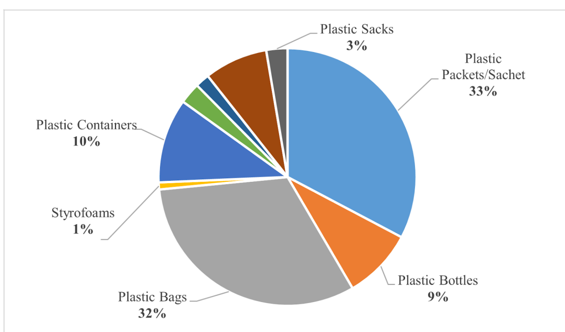
Nitrate and **Nitrite** from septic systems, animal waste, and fertilizers can degrade bodies of water and stimulate rapid growth of algae. The absence of such chemicals is a good sign for the overall river health. The absence of both **chlorine** in the data suggests that the water may not have been treated with chlorine or the chlorine may have dissipated over time. This may allow the risk of bacterial and viral contamination in the water, thus, endangering communities. The three samples all had a **water hardness** rating of 25, indicating that the river has a relatively low mineral content. The high **alkalinity** value of >240 for all samples suggests that the water is basic in nature and has a high buffering capacity against sudden changes in pH, hence, protecting aquatic organisms. The **pH** test results suggest that the water is basic in nature and may require treatment to reduce pH if it exceeds the acceptable range. Although **phosphorus** $([PO_4]^{3-})$ is a nutrient for plant life, excessive amounts harm water quality and encourage eutrophication, which is the decrease of dissolved oxygen in water caused by an increase in river minerals. The normal value for phosphates in water is only 0.02 ppm, thus, the river is found to be anoxic with a phosphate result of 23 ppm.

IV. Riverine Plastic Waste Pollution

The procured tallies were then categorized using a monitoring form in accordance with their different types. This is shown in a graphical representation as presented below.

River Scan Challenge 2023 - Site Inspection and Assignments							
Riverine Plastic Waste Pollution Assignment							
River Banks Waste Pollution							
Riverine Test	Downstream 1: Pacific Mall			Downstream 1: Paknaan Bridge			**Total No. of Tallied Plastics**
	I	II	III	I	II	III	
Product Packets and Sachets	3	3	4	12	9	6	37
Plastic Bottles	3	2	3	0	0	3	11
Plastic Bags (Shopping Bags)	3	6	2	4	13	8	36
Polystyrene Parts (Styrofoams)	0	0	0	0	1	0	1
Plastic Containers	1	2	1	4	3	1	12
Rubberized Items	0	0	0	2	0	1	3
Product Cans	0	0	0	0	0	2	2
Fibre Sheets (Clothing Wastes)	0	0	4	0	5	0	9
Rice Sacks	0	0	0	0	3	0	3
Floating Plastic Waste Pollution							
Riverine Test	Downstream 1: Pacific Mall			Downstream 1: Paknaan Bridge			
	I	II	III	I	II	III	
Product Packets and Sachets	3	2	2	8	4	4	23
Plastic Bottles	0	1	0	4	0	0	5
Plastic Bags (Shopping Bags)	3	0	2	13	4	2	24
Polystyrene Parts (Styrofoams)	0	1	0	0	0	0	1
Plastic Containers	0	3	2	5	0	0	10
Product Cans	0	0	1	5	0	0	6
Fibre Sheets (Clothing Wastes)	0	0	2	0	1	0	3
Wood Drifts	0	0	0	0	1	0	1

Table 4.1. *Monitoring Form with Total Tallies of Plastic Pollution Waste*



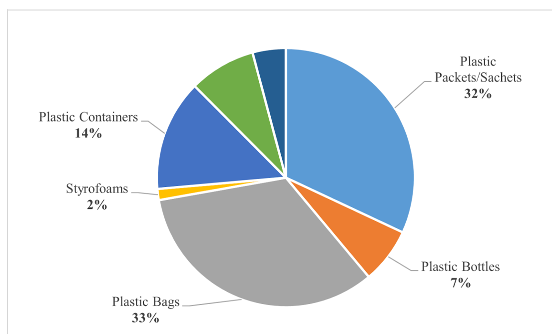


Figure 4.1*. & 4.2 Composition of plastic waste along the riverbanks (4.1) and in floating waters (4.2) of the Butuanon River*

The most gathered trash in the riverbanks were plastic packets/sachets that consist of 33% of the accumulated trash. It was followed by plastic bags, plastic containers, plastic bottles, plastic sacks and styrofoam respectively. Additionally, the most gathered objects in the square quadrant in stable water levels were plastic bags which covered 33% of the accumulated trash, followed by plastic packets or sachets, plastic containers, plastic bottles and styrofoams, respectively.

On the basis of the data analysis of riverbank characteristics and floating plastics, the researchers can conclude based on the Plastic Waste Categories, that for the Pieces per $1m^2$ floating, the total tally of plastics in sample one reached a number of 30 pieces making floating river waters ***"Severely Polluted"*** from Category E. For the Pieces per 100m riverbank, the total tally of plastics goes around 100 thus making the riverbanks of our assigned areas ***"Extremely Polluted"*** from Category F.

V. Ecology of the River

The Stream Assessment Scoring System (miniSASS) was used to monitor the health of a river. It is based on the sensitivity of the various animals to water quality. One notable catch and discovery was the rat-tailed maggots (*Eristalis tenax)*.

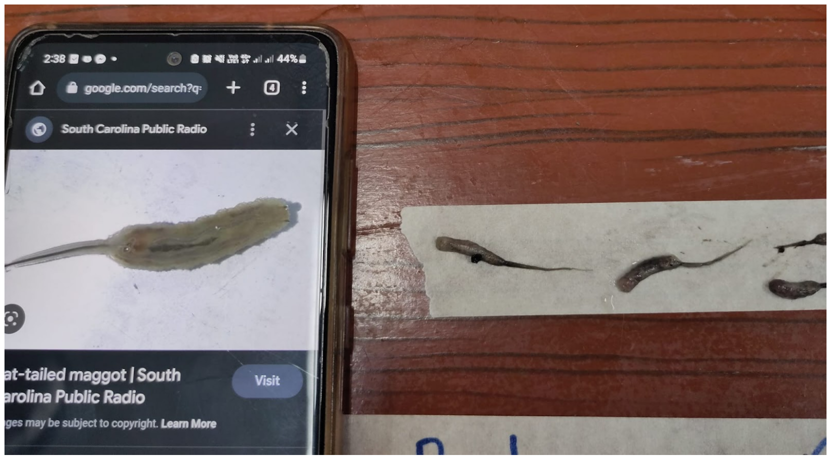
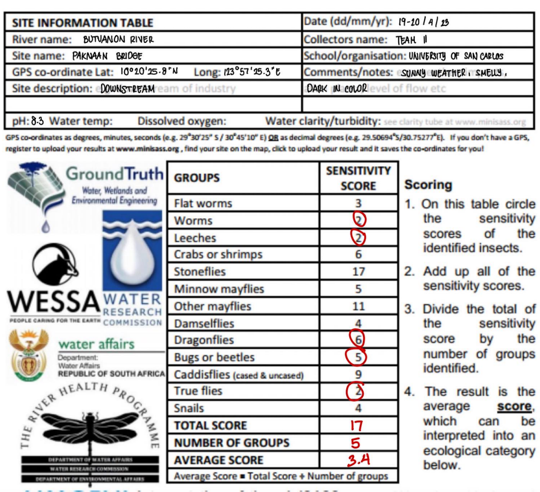


Figure 5.1. *Rat-tailed maggots collected from Butuanon River*

Red-tailed maggots are aquatic larvae that have a cylindrical shape with patches of horizontal folds dividing the body into segments. The prevalence of these single invertebrates in the Butuanon River indicates a detrimental effect on human health. Occasionally, Eristalis tenax larvae can lead to urogenital myiasis, enteric pseudomyiasis, or gastrointestinal myiasis in people.

Based on the scorecard of the miniSASS, the health of the river is found to be very poor (seriously/critically modified) with less 5.1 score under the Rocky type category.



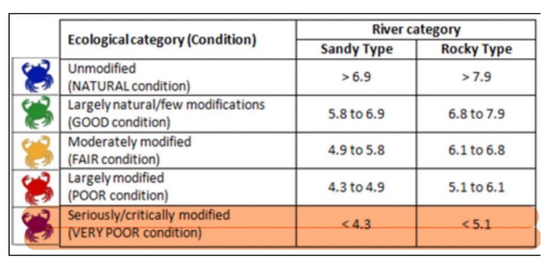
SITE INFORMATION TABLE	Date (dd/mm/yr): 19-20 / 4 / 23
River name: BUTUANON RIVER	Collectors name: TEAM 11
Site name: PAKNAAN BRIDGE	School/organisation: UNIVERSITY OF SAN CARLOS
GPS co-ordinate Lat: 10°20'25.8"N Long: 123°57'25.3"E	Comments/notes: SUNNY WEATHER, SMELLY,
Site description: DOWNSTREAM eam of industry	DARK IN COLOR level of flow etc
pH: 8.3 Water temp: Dissolved oxygen:	Water clarity/turbidity: see clarity tube at www.minisass.org

GPS co-ordinates as degrees, minutes, seconds (e.g. 29°30'25" S / 30°45'10" E) OR as decimal degrees (e.g. 29.50694°S/30.75277°E). If you don't have a GPS, register to upload your results at www.minisass.org , find your site on the map, click to upload your result and it saves the co-ordinates for you!

GROUPS	SENSITIVITY SCORE
Flat worms	3
Worms	2
Leeches	2
Crabs or shrimps	6
Stoneflies	17
Minnow mayflies	5
Other mayflies	11
Damselflies	4
Dragonflies	6
Bugs or beetles	5
Caddisflies (cased & uncased)	9
True flies	2
Snails	4
TOTAL SCORE	17
NUMBER OF GROUPS	5
AVERAGE SCORE	3.4
Average Score = Total Score ÷ Number of groups	

Scoring

1. On this table circle the sensitivity scores of the identified insects.
2. Add up all of the sensitivity scores.
3. Divide the total of the sensitivity score by the number of groups identified.
4. The result is the average **score**, which can be interpreted into an ecological category below.



Ecological category (Condition)	River category	
	Sandy Type	Rocky Type
Unmodified (NATURAL condition)	> 6.9	> 7.9
Largely natural/few modifications (GOOD condition)	5.8 to 6.9	6.8 to 7.9
Moderately modified (FAIR condition)	4.9 to 5.8	6.1 to 6.8
Largely modified (POOR condition)	4.3 to 4.9	5.1 to 6.1
Seriously/critically modified (VERY POOR condition)	< 4.3	< 5.1

Figure 5.2. & 5.3 *miniSASS Scorecard & miniSASS Ecological Categories*

VI. River Stream Velocity

The product of the cross-sectional area and the velocity is equal to the volume flow rate, which is measured in CFS which stands for "cubic feet per second," which is a unit of measurement referring to the volume and speed of water flow. Higher CFS values are associated with higher river heights or cross-sectional area, as a greater volume of water is flowing through the river. As per finding, downstream 2 has a higher CFS value due to a higher value of area compared to downstream 1.

Table 1.a *Downstream 1 River Stream Velocity Data - Length (49ft), Width (20.34ft)*

	Trial 1	Trial 2	Trial 3	Total Average
Time (sec)	26.92	34.93	23.84	28.56
Velocity (ft/s)	1.82	1.40	2.06	1.76

Table 2.a *Downstream 2 River Stream Velocity Data - Length (65ft), Width (27.88)*

	Trial 1	Trial 2	Trial 3	Total Average
Time (sec)	155	175	163	164.33
Velocity (ft/s)	0.42	0.37	0.40	0.40

Table 1.b *Downstream 1 River Stream Depth Data*

Depth 1	Depth 2	Depth 3	Depth 4	Depth 5	Average Depth
0.65	0.62	0.56	0.49	0.59	**0.58**

Table 2.b *Downstream 2 River Stream Depth Data*

Depth 1	Depth 2	Depth 3	Depth 4	Depth 5	Average Depth
5.97	5.54	5.81	5.75	6.29	**5.87**

Table 3 *CFS data of Downstream 1 & 2*

	Velocity	Area	CFS	Adjusted Velocity	Adjusted CFS
Downstream1	1.76	11.80	20.77	1.50	17.7
Downstream 2	0.40	163.66	65.464	0.34	55.64

VII. Turbidity with Secchi Disk Method

Condition	Trial 1
Not Visible	15 cm
Visible	10 cm

Table 7.1. *Results of the Test Performed in Downstream 1*

Condition	Trial 1	Trial 2	Trial 3
Not Visible	15 cm	20 cm	20 cm
Visible	10 cm	10 cm	10 cm

Table 7.2. *Results of a Single Trial in Downstream 2*

Table 7.1. summarizes the results of a single experimental trial conducted in Downstream 1. It shows that the water in Downstream 1 is visible up to a depth of 10 cm but becomes turbid or not visible at a depth of 15 cm. Table 7.2. displays the results of the test performed in Downstream 2. As per findings, the water downstream remains visible up to a depth of 10 cm, implying that the water is relatively clear and has a lower degree of turbidity. This observation was consistent across all three trials conducted downstream. During the initial trial, the water was not visible or characterized by a high degree of turbidity at a depth of 15 cm. Similarly, in both the second and third trials, the water is also turbid or not visible at a depth of 20 cm. In general, turbidity measurements can be used to assess the quality of water.

CONCLUSION AND RECOMMENDATION

This section of the paper critically discusses the strong and weak points of the answers to the defined sub-questions. The innovative aspect of the solution is thoroughly highlighted in this section. Concrete directions and recommendations are provided for further research of the topic.

The study highlights the problems associated with the pollution in Butuanon River and focuses on identifying the sources of pollution, assessing environmental hazards and conditions, and developing feasible solutions to mitigate the pollution.

River contamination is a major issue in numerous countries. In addition to contributing to fish species' extinction, it can make people sick. Sewage or industrial waste poured into rivers causes the majority of the pollution in rivers. Regarding stream quality and river safety, there are often no laws or restrictions in place. Many rivers have seen severe damage from a variety of contaminants that endanger plant and animal life as well as the ecosystem.

Feasible solutions to mitigate pollution in Butuanon River may include regulations on industrial waste disposal, more effective agricultural practices, and public education campaigns to raise awareness about the importance of protecting the river. Additionally, the development of new technologies for water treatment and pollution mitigation can also be explored.

The researchers have chosen to concentrate on the common problem with the river, which is the accumulation of trash. The Great Bubble Barrier and Trash Booms are the two recommended solutions when it comes to issues concerning the water, while the clever system of Underground Garbage Bins would be suitable for land. In the Netherlands, these strategies were most effective. Rivers and canals are where the majority of plastic pollution that ends up in the oceans originates; there, it kills wildlife, destroys boats, and hastens climate change.

Overall, addressing the problems associated with pollution in Butuanon River requires a coordinated effort from government, industry, and the general public. By working together, it is possible to protect this vital natural resource and ensure that it remains a healthy and vibrant ecosystem for generations to come.

PART B. PRACTICAL SOLUTION

DESIGN OF THE SOLUTION

While there are many things that need to be done in order to protect the environment, one highly important method of maintaining its health is to reduce water pollution, for which there are many effective solutions that can assist with this goal. The researchers are aware that simply planning community clean-ups will not suffice for the rehabilitation of the Butuanon River, therefore, different approaches are being considered for this environmental crisis.

The researchers have chosen to concentrate on the regular issue with the river, which is the accumulation of trash, hence, the Great Bubble Barrier and Trash Booms are the two suggested solutions when it comes to issues concerning the water, while the smart system of Underground Garbage Bins is appropriate for land. These methods were most successfully used in the Netherlands. Most of the plastic that ends up in the oceans comes from rivers and canals, where it kills wildlife, ruins boats, and accelerates climate change. However, it is extremely impossible to collect and remove plastic debris after it has gotten into the oceans.

In regards with the Bubble Barrier, it intercepts plastic waste before it reaches the sea. The technology behind the Bubble Barrier is simple: air is blasted through a perforated tube positioned diagonally on the riverbed to generate a curtain of bubbles that drives plastic up to the surface and into a litter trap that gathers the garbage, either on land or in the water. Regular emptying of the litter trap is required as well. The Bubble Barrier has, so far, been shown to capture an average of 86 percent of plastic trash. In the Netherlands, several of these barriers have been installed, including one in Westerdok, a well-known canal in Amsterdam. Through this, the North Sea is prevented from receiving an average of 8,000 pieces of plastic trash every month. With this being a successful project, the researchers have considered this method to be executed in the polluted rivers in Cebu City, particularly in the downstream section of the Butuanon River.

Another proposed solution is the Trash Booms. These garbage booms are used to confine and reduce pollution in waterways such as ponds, rivers, canals, and channels. Gross pollutants can be diverted to a catchment region where they can be collected from the waterway by strategically placing a floating debris boom. Booms for trash and debris have become one of the most useful instruments for containing and collecting debris in recent years due to rising water pollution. This floating barrier keeps riverside plastic waste from polluting the ocean and is inexpensive since it can be easily made from locally procured materials. The effectiveness of garbage and debris booms in preventing contaminated objects from entering waterways has been investigated in certain research. For instance, an article mentioned the use of fence booms in Sydney Harbour. By catching the garbage that is carried by the Parramatta River toward the harbor, this boom manages the floating waste in the bay. The material captured in the boom is then taken out and disposed of. These certain studies can assist local governments in putting in place measures that safeguard their rivers using booms that catch garbage and other debris.

Lastly, the Underground Garbage Disposal is a smart system that connects surface-level trash cans to underground ones that store garbage from nearby residences until it is time for pickup. This type of strategy for handling domestic waste was originally used in Amsterdam. The majority of the storage bin is concealed beneath the pavement's surface, with only a small portion of it visible above ground. For the disposal of waste, a sizable underground storage facility is lifted out. Furthermore, this method is a genius way to eliminate trash. Storing the garbage underground not only prevents bins from overflowing onto the street, but it also keeps wildlife away that may otherwise be attracted to the garbage.

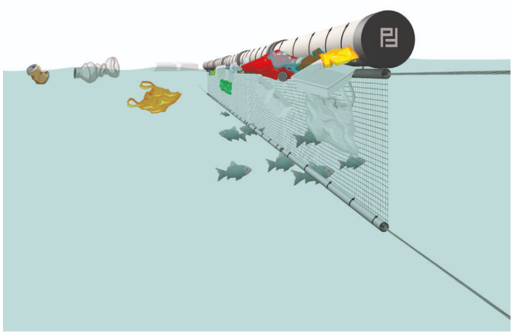


Figure A. *Trash Boom Technology*

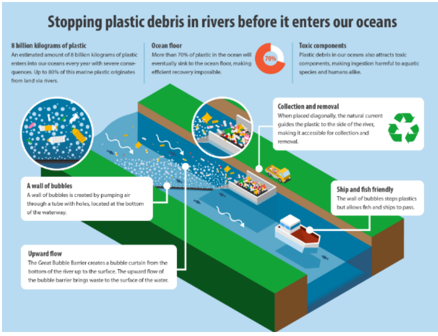


Figure B. *Bubble Barrier Technology*

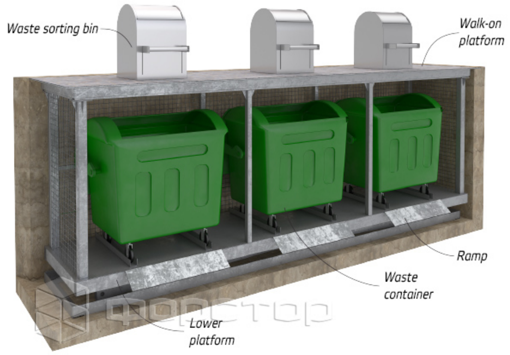


Figure C. *Underground Trash Bin*

LOCATIONAL ANALYSIS

This section of the study discusses how the site was being selected. From the researcher's consensus, the most suitable site for the proposed innovative technological solutions are shown in the topographical representation as shown below. Site locations are significantly chosen related to the area assigned to the group for the River Scan Challenge 2023.

Trash Boom Technology

The selected site for this solution shall be located in two sites: *(1) Pacific Mall Area*, approximately near U.N. Avenue and at *(2) Paknaan Bridge Area*, approximately near A.C Sanchez Street, and Ouano Avenue of Barangay Paknaan. The floating nets serves as the primary collector of macro wastes. Thus, having placed both floating nets in such areas becomes an advantage of procuring wastes along the designated areas.

Bubble Barrier Technology

From the researchers consensus, the most suitable site for the proposed innovative technological solution would be *Under the Paknaan Bridge* for reasons: (1) Depth conditions for the technology is sufficient (2) Flows of Micro wastes are often (3) The bubble barrier becomes the center location for both Trash Boom Technology's Sites.

Underground Trash Bins

The underground trash bins shall be located in convenient areas such as central places where local residents can easily access. Thus, the location for such innovative technological solutions shall be at *(1) a designated free spot near the Paknaan Bridge (2) at the Pacific Mall*. These areas were the pilot locations for the bins as the areas are accommodated to the locals.

Figure D. *Locations for the Innovative Technological Solutions*

SOCIAL COST-BENEFIT ANALYSIS WITH EXPLANATION

Underground Trash Bin Materials Cost Estimate				
Item	**Size / Dimension / Description**	**Price per Unit**	**Quantity**	**Subtotal**
Mild Steel Plate	Thickness: 10 mm Size: 4 x 8ft	Php 10,808.00	5	Php 54,040.00
Metal Trash Bin	2 x 2 ft	Php 4,000.00	1	Php 4,000.00
Total				**Php 58,040.00**

Implementing underground garbage bins can have several social benefits, which contribute to the overall cost-benefit analysis. Here are some potential social benefits:

1. **Aesthetics and Urban Environment.** Underground garbage cans contribute to the aesthetic appeal of cities. The removal of typical above-ground bins makes the streets cleaner and more visually appealing. This can improve the overall quality of the urban environment, making it more appealing to both residents and visitors.

2. **Reduce Litter and Pollution.** Underground garbage cans serve to prevent litter and pollution. Because the bins are hidden bel
3. ow, they are less likely to overflow or be vandalized, preventing garbage from being spread on the streets or ending up in surrounding bodies of water. This helps to create a cleaner and healthier living environment.

4. **Odor Control.** When compared to regular open bins, underground bins are designed to reduce odors. The sealed containers and efficient waste management systems help to contain and regulate odors, resulting in a more pleasant and sanitary environment for adjacent people and businesses.

5. **Public Health and Safety.** Underground garbage cans can help to reduce health and safety hazards. Traditional bins, especially when overflowing, can attract bugs and rodents, resulting in disease transmission. Underground dumpsters make waste less accessible to pests, lowering the risks connected with them. Furthermore, removing above-ground bins minimizes possible tripping hazards and obstructions on sidewalks, hence improving pedestrian safety.

6. **Efficient Space Utilization**. Underground garbage cans make better use of urban space. By removing the requirement for a large number of above-ground bins, more space is freed up for other uses, such as pedestrian paths, outdoor seating, or recreational areas. This improves the urban landscape's overall livability and functionality.

Trash Boom Materials Cost Estimate				
Item	**Size / Dimension / Description**	**Price per Unit**	**Quantity**	**Subtotal**
Fish Net	1 roll, 90 meters	Php 3,669.00	1	Php 3,669.00
Plastic Bottles	Recycled Bottles	-	1000	-
Rope	Thickness: 7.5 mm Length: 150 m	Php 1,645.00	1	Php 1,645.00
PVC Pipe	19 mm	Php 93.00	8	Php 744.00
Total				**Php 6,058.00**

Implementing trash booms can have several social benefits, which contribute to the overall cost-benefit analysis. Here are some potential social benefits:

1. **Easy to install.** The installation of litter booms is not particularly difficult, and they are available in a variety of sizes and models to suit various needs. Floatable debris can be caught in huge numbers by litter booms. Individual maintenance is rather easy to perform and doesn't involve entering a limited place.

2. **Useful to any operator's arsenal.** These floating booms are intended to efficiently prevent any floating human-made rubbish that may be present in the seas, in addition to excluding or containing naturally existing floating waste like tree branches or seaweed and reeds.

3. **Reduce Litter and Pollution.** Waterways are kept clear and fit for human consumption, which not only increases their effectiveness and performance because less time and resources are required to maintain them, but also safeguards crucial infrastructure from interruption.

Bubble Barrier Materials Cost Estimate				
Item	**Size / Dimension / Description**	**Price per Unit**	**Quantity**	**Subtotal**
Rubber Perforated Tube	5 mm inner diameter, 7 mm outer diameter, 10 m length	Php 1,603.14	2	Php 3,206.28
Steel Cable	6 mm dia, 10 m length	Php 420.00	2	Php 840.00
Concrete Blocks	500 psi, 0.4 m x 0.2 m x 0.8 inches	Php 32.00	15	Php 480.00
Compressor	Vespa 15 HP Air Compressor Belt Driven 56.5 CFM, 115 PSI (gas) or Ingersoll Rand 7.5 HP Rotary Screw Compressor, 200 V, 27.5 CFM, 115 PSI (electric)	Php 153,000.00 Php 120,000.00	1 2	Php 153,000.00 Php 240,000.00
Container	20 ft Shipping Container (used)	Php 10,000.00	1	Php 10,000.00
Plastic Litter Trap	DIY Trap	Php 1,500.00	1	Php 1,500.00
Total (Compressor: Vespa)				**Php 169,026.28**
Total (Compressor: Ingersoll Rand)				**Php 256,026.28**

Implementing bubble barriers in the rivers of Mandaue City can have several social benefits, which contribute to the overall cost-benefit analysis. Here are some potential social benefits:

1. **Reduce Plastic Pollution.** By collecting plastic debris and preventing it from migrating downstream, bubble barriers help to reduce plastic pollution in waterways. This contributes to improved canal cleanliness and reduces the quantity of plastic garbage that ends up in the ocean, where it can affect marine life and ecosystems.

2. **Improve Public Health.** Plastic pollution can harm public health, especially in locations where rivers are used for fishing, swimming, or other recreational activities. Bubble barriers can assist enhance the general health and safety of local populations by lowering the amount of plastic debris in waterways.

3. **Increase Awareness and Education.** Implementing bubble barriers can aid in raising public awareness and education about the issue of plastic pollution. This can motivate individuals and businesses to take more responsibility for their garbage and promote more sustainable community behaviors.

4. **Economic Benefits.** Reduced plastic pollution can have a positive economic impact on the local community. Cleaner rivers can draw more tourists and businesses, increasing revenue and job opportunities. Reduced plastic pollution can also minimize the costs of cleaning and maintaining waterways, freeing up resources for other projects and investments.

5. **Improve Biodiversity.** Plastic pollution has the potential to harm animals and biodiversity in rivers and neighboring places. Bubble barriers can help to maintain and preserve local ecosystems by decreasing plastic pollution and promoting a healthy habitat for plant and animal life.

6. **Social Cohesion.** By bringing together local communities, businesses, and government agencies to address a common problem, bubble barriers can foster social cohesion. This can instill a sense of community pride and responsibility while also encouraging a more collaborative and long-term approach to environmental protection.

PLANNING

The implementation of the proposed solutions would require the government to follow a structured approach. Here are some potential steps that the stakeholders could take to implement the river rehabilitation efforts namely the underground trash bins, trash booms and bubble barriers as:

1. **Conduct a feasibility study.** The government could conduct a feasibility study to assess the suitability of implementing the proposed solutions in the target areas. This study could evaluate factors such as the size of the river, the strength of the current, and the type of waste that is prevalent in the river. This could also involve consulting with local communities and businesses to determine areas of high waste generation and areas that would benefit most from the implementation of these solutions.

2. **Identify suitable locations.** The government could identify suitable locations for the installation of the rehabilitation structures. This could involve consulting with local communities and businesses to determine areas of high waste generation and areas that would benefit most from the solution implementation.

3. **Design and manufacture.** Once the suitable locations have been identified, the government could design and manufacture the underground trash bins, bubble barriers, and trash booms. This could involve engaging with waste management companies or consulting with design experts to create these proposed solutions using the materials that are appropriate for the target areas.

4. **Installation.** The government could install the underground trash bins, bubble barriers and trash booms in the identified locations. This would involve excavating the area and installing the bins, as well as connecting them to the waste management system. Also, the barrier and booms should be connected to the riverbed ensuring that it is functioning correctly.

5. **Educate the public.** To ensure that the rehabilitation structures are used effectively, the government could educate the public on how to use them. This could involve distributing information leaflets or organizing community events to promote the benefits of the new waste management system.

6. **Monitor and maintain.** Once the rehabilitation structures have been installed, the government could monitor their use and maintenance. This could involve regular inspections to ensure that the structures are functioning correctly and are not becoming overloaded.

Although the solution is made with low costs, it still requires an investment from the LGU. This investment will allow these rivers to be equipped with the researcher's innovative ideas. The first investment can best be the placing of the underground garbage bins. These developments must happen simultaneously, because they only work well in combination. Moreover, local water engineers can help the LGU install the Bubble Barrier System, as well as the Trash Booms at the sewage.

STAKEHOLDERS INVOLVED

The implementation of the proposed solutions requires the active participation of various stakeholders, namely the Mandaue City local government, private entities, relevant academic institutions, landowners, and citizens. Ultimately, the Mandaue City local government shall be the lead agency for the implementation of the rehabilitation and development efforts of the Butuanon River. They will carry out most phases, such as budget allocation, material procurement, construction, and maintenance.

In addition, the continuity and preservation of the structures will also be entrusted to the government. Further in-depth feasibility studies of the proposed solution will be carried out by academic institutions to further improve rehabilitation efforts. Private entities are essential supporting organizations to the social development projects. Aside from extending help to raise awareness about such projects, the private sectors can enter public-private partnership with the government to upscale the proposed solutions. Landowners should cooperate should their property be affected by the installation of rehabilitation structures. Lastly, the cooperation to throw garbage at designated bins and avoid littering from citizens is a great factor in the success of the river rehabilitation.

OPERATION AND MAINTENANCE

The type of solution, location, and ownership of the water body are among the variables that typically determine who is responsible for overseeing and maintaining a river cleaning and improvement project. In general, the operation and maintenance of the solution may fall within the purview of governmental organizations like the Department of Environment or Water Resources. In a joint effort to clean and develop the river, other stakeholders, including the government, business community, non-governmental organizations, and local communities, may also share some of the responsibilities.

One of the key benefits of providing underground trash bins is the instant reduction in the ugly visual impact caused by the thousands of bins left out on the streets. There would be extra room available if all the brick-built bin shops and other locations where bins are gathered were removed. Proper maintenance of underground trash bins is essential to ensuring that they function effectively and efficiently. Here are some maintenance activities that should be carried out:

1. **Regular Cleaning.** Underground trash cans should be cleaned on a regular basis to avoid the accumulation of odors and bacteria. This entails removing any waste from the container and washing it with a high-pressure hose or other cleaning equipment.
2. **Emptying.** Underground garbage cans should be emptied on a regular basis to avoid overflow and make room for new waste. The frequency with which the container is emptied will be determined by the amount of waste created in the area.
3. **Inspections.** Inspections should be performed on a regular basis to look for any damage to the subterranean trash container, such as cracks or leaks. Any damage should be rectified as soon as possible to prevent waste from escaping into the surrounding environment.
4. **Maintenance of Composting and Recycling Systems.** If the subterranean garbage bin incorporates a composting or recycling system, it should be serviced on a regular basis to ensure proper operation. Checking the compost or recycling materials, adding fresh materials as needed, and stirring the compost to promote decomposition are all possible.
5. **Pest Control.** Underground trash cans may attract pests such as rodents or insects, which can lead to health issues and disease transmission. Pest control techniques, such as placing bait or traps near the bin or using insecticides, should be implemented.

Additionally, one of the advantages of the Bubble Barrier is that it can operate 24/7 without the need for operators once installed, so little to no supervision is needed. To facilitate the safe and sanitary management of solid waste from the underground garbage bins, the Department of Public Services will facilitate the regular collection of garbage generated within the area. The maintenance activities that should be carried out for bubble barriers are as follows:

1. **Regular Cleaning.** Bubble barriers should be cleaned on a regular basis to minimize debris buildup and to guarantee that they continue to perform effectively. This may entail manually clearing debris or utilizing equipment such as nets or skimmers.

2. **Maintenance of Air Compressor.** The air compressor that powers the bubble barrier should be maintained on a regular basis to ensure proper operation. Checking the oil levels, replacing filters, and correcting any damage are all possible.
3. **Inspection of Bubble Tubes.** The bubble tubes used to create the barrier should be inspected on a regular basis to ensure they are not broken or clogged. Any damage or obstructions should be rectified as soon as possible.
4. **Replacement of Bubble Tubes.** The bubble tubes may become worn or damaged over time and must be replaced. The frequency of replacement will be determined by the river's usage and circumstances.

5. **Monitoring.** It is critical to assess the effectiveness of the bubble barrier on a regular basis to verify that it is working properly. This could include gathering data on the amount of material kept out of the river or performing visual inspections.

Lastly, trash booms are structures designed to trap and collect floating debris in rivers or other bodies of water. Maintenance activities for trash booms typically include:

1. **Regular Inspections.** Trash booms should be inspected on a regular basis to ensure that they are correctly installed and working as intended. Inspecting the boom for signs of damage or wear, such as tears or holes, and ensuring that it is correctly fastened, are examples of such tasks.
2. **Cleaning.** Debris in the boom should be removed on a regular basis to avoid blockages and maintain the boom's effectiveness. Cleaning may entail physically removing material with nets or other instruments, or it may entail the use of equipment such as skimmers or pumps.
3. **Repair.** Any damage or wear to the boom, such as tears or holes, should be fixed as soon as possible to avoid the boom becoming ineffective.
4. **Replacement.** The boom may get worn or damaged over time, to the point that restoration is no longer viable or practical. The boom should be replaced in such circumstances.
5. **Monitoring.** It is critical to examine the effectiveness of the boom on a regular basis to verify that it is working properly. This could include gathering statistics on the amount of material avoided from entering the river or performing visual inspections.

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LINKS

Google Drive of the individual Google Docs for each assignment
https://drive.google.com/drive/u/0/folders/1PCn3s9Kwnb1R5GuV7MYyFyh3ZTA-MnAE

Presentations Google Drive
https://drive.google.com/drive/folders/1CXZteFi4BCA99ISIYBjXggG5IZGG3MKU