WATER QUALITY AND LEAD CONTENT ANALYSIS OF BOAC RIVER, MARINDUQUE

SHEILA FEYE VALERIO LEE
MARGARET MAE CRUZ MAÑO

Submitted to the
Department of Biology
College of Arts and Sciences
University of the Philippines
Manila

In partial fulfillment of the requirements
for the degree of
Bachelor of Science in Biology
April 2003
Department of Biology
College of Arts and Sciences

University of the Philippines
Padre Faura, Manila

Announcement of the
Undergraduate Thesis Presentation

Sheila Feye Lee and Margaret Mae Maaño

Entitled

WATER QUALITY AND LEAD CONTENT ANALYSIS OF BOAC RIVER, MARINDUQUE

For the degree of Bachelor of Science in Biology

8:00 A.M., 1 April 2003
Rizal Hall Room 11A

THESIS ADVISER
Natividad F. Lacdan, M.S.
Professor
Department of Biology, CAS
UP Manila, P. Faura, Manila

THESIS READER
Elena M. Ragragio, M.A.T
Professor
Department of Biology, CAS
UP Manila, P. Faura, Manila

THESIS READER
Samuel M. Go, M.S. Ph.
Professor
Department of Biology, CAS
UP Manila, P. Faura, Manila

Endorsed by:

Ofelia M. Cuevas, M.S.
Chair, Thesis Committee
Department of Biology, CAS
UP Manila, P. Faura, Manila

Authorized by:

Elisa L. Co, Ph.D.
Chair, Department of Biology
College of Arts and Sciences
UP Manila, P. Faura, Manila

Department of Biology
College of Arts and Sciences
University of the Philippines
Padre Faura, Manila

APPROVAL SHEET

The thesis attached hereto, entitled "**Water Quality and Lead Content Analysis of Boac River, Marinduque**" prepared and submitted by Sheila Feye Lee and Margaret Mae Maaño in partial fulfillment of the requirements for the degree of Bachelor of Science in Biology, is hereby accepted.

NATIVIDAD F. LACDAN, M.S.
Thesis Adviser

ELENA M. RAGRAGIO, M.A.T.
Thesis Reader

SAMUEL M. GO, M.S.P.H.
Thesis Reader

Accepted in partial fulfillment of the requirements for the degree of Bachelor of Science in Biology.

ELISA L. CO, Ph.D.
Chair, Department of Biology

MARILOU G. NICOLAS, Ph.D.
Dean, College of Arts and Science

CURRICULUM VITAE

I. Personal

Name: Sheila Feye Valerio Lee
Date of Birth: May 2, 1982
Place of Birth: San Pedro, Laguna
Civil Status: Single
Sex: Female
Nationality: Filipino
Parents:
Father: Mateo G. Lee — Occupation: Businessman
Mother: Fe V. Lee — Occupation: Housewife

II. Educational Background

Date	School	Honors Received
1999 to present	University of the Philippines Manila	
1995 – 1999	Manila Science High School	
1987 – 1995	Saint Francis School	valedictorian

III. Affiliations

UP BIOMAS: Member (2000 to present)

UP Quod Erat Demonstrandum: Member (2000 to present)

ER Volunteer, UP Manila Pahinungod (2001to present)

CURRICULUM VITAE

I. Personal

Name: Margaret Mae Cruz Maaño
Date of Birth: May 26, 1982
Place of Birth: Manila
Civil Status: Single
Sex: Female
Nationality: Filipino
Parents:
Father: Luisito Rosales Maaño — Occupation: Physician
Mother: Clarita Pasamonte Cruz — Occupation: Physician

II. Educational Background

Date	School	Honors Received
1999 to present	University of the Philippines Manila	College Scholar
1995 – 1999	St. Theresa's College, Quezon City	Outstanding Student
1987 – 1995	St. Theresa's College, Quezon City	Outstanding Student

III. Affiliations

UP Quod Erat Demonstrandum: Member (2000 to present)
Vice President, External Affairs (2002 to present)

UP BIOMAS: Member (2000 to present)

UP Biological Sciences Society: Member (2002 to present)

ER Volunteer, UP Manila Pahinungod (2001 to present)

ACKNOWLEDGEMENT

We would like to express our heartfelt thanks to the individuals who have helped make this research a success.

First, to our adviser, Ma'am Lacdan, for her time and patience. This paper would not have been possible without her guidance and supervision.

Our reader, Ma'am Rags, thank you for the pieces of advice and suggestions. They really helped us in making our decisions.

To Prof. Elisa Co, for all the red marks on our proposal, thank you.

To Prof. Rubite for arranging our contact to the Marinduque State College (MSC).

Our appreciation to the staff of MSC for allowing us to use their laboratory equipments and facilities especially to Prof. Emma Cabildo and Engr. Morales for their kindness and generosity.

To the staff of Institute of Chemistry, University of the Philippines Los Baños, thank you.

To Kuya Ed, Kuya Jon, and Ate Tess, thank you for the chemicals.

Our gratitude to the people of Marinduque...

To Dr. Maaño for arranging our stay there and for being with us all the time;
To Agnes for her undying support and assistance;
To Mang Toti for accompanying us in the site and helping us in collecting the samples;
To Clarita for her hospitality;
To Mang Tikboy for our transportation.

Our beloved friends, Alsun, Johanna, Raissa, and Mean, thank you for your help and company. They are very much appreciated.

To BLOCK ONE, batch 2003, for all the memories.

To our dear parents for their moral and financial support.

And to God Almighty for making all these things possible, thank you very much.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

ABSTRACT

This descriptive study deals with the current status of the physico-chemical properties, productivity and sediment analysis of Boac river. The study was conducted in two selected stations, station 1 (upstream, near Barangay Binunga) and station 2 (downstream, near Barangay Lupac). Results of physico-chemical analysis revealed temperature to be 23.67°C – 25°C; pH, 7.66 – 8.81; alkalinity, 0 – 0.00004 mg/L; conductivity, 0 – 0.33μS; turbidity 0 – 3.81 FTU; current speed, 1.41 – 8.31 m/s; current magnitude, 2.7 – 11.9 g; dissolved oxygen, 3.2 – 6.2 mg/L; free carbon dioxide, 2.33 – 6 ppm and biochemical oxygen demand, 0.32 – 2.7 mg/L. Data from light and dark bottle method resulted in respiration values of -9.08 – 10.34 G-cal/m^2 surface; gross primary productivity, -11.65 – 11.17 G-cal/m^2 surface; net primary productivity, -6.19 - 8.69 G-cal/m^2 surface. Lead concentration in water samples were below detectable levels while the amount of lead in sediment samples measured from 0.32 – 2.92 μg/g. Values from physico-chemical analyses and measurement of productivity fell within the normal range (Chapman, 1996) for freshwater ecosystems while the amount of lead in water and sediments were below toxic levels.

Water Quality and Lead Content Analysis of Boac River, Marinduque

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I. INTRODUCTION

Background on the Study

The island of Marinduque is located 170 kilometers southeast of Manila (FIGURE 1). It has an area of 196 square kilometers (PLATE 1 and FIGURE 2). Marinduque is formed by volcanic activity and coral deposition (www.whitetip.com) The island is abundant with natural resources including large deposits of copper, iron and manganese (www.geocities.com) making mining one of the principal industries of the province. One of these mining companies is the Marcopper Mining Corporation (home.online.no). Since 1969, Marcopper has been dumping mine waste in the form of tailings into the Makulapnit-Boac river system (Coumans, 1997). And in 1996, a drainage tunnel of one of the corporation's old mining pit has ruptured. The incident resulted into the release of 1.6 million cubic meters of mine tailings containing trace elements into the aquatic ecosystem (Coumans, 1997). Although heavy metals are a natural part of the environment (Skjelkvale *et al.*, 2001), its toxicity and bioaccumulation pose harmful hazards to man and his surroundings (Rognerud and Fjeld, 2001). Since then, residents living in the vicinity of Boac River suffered from heavy metal contamination (Coumans, 1999).

Statement of the Problem

What is the current status of the water quality and the characteristics of the sediments of Boac River in Marinduque?

Objectives

This study has the following objectives:

General Objective

to describe the current status and lead content of water and sediments of Boac river in Marinduque;

Specific Objectives

1) to determine the physico-chemical properties of the Boac river ecosystem;
2) to determine the primary productivity of the Boac river ecosystem;
3) to determine and compare the lead concentrations of water and sediment samples in the two selected sites (upstream and downstream) of the river.

Significance of the Study

Boac River (PLATE 2) has been used extensively by nearby villages for domestic purposes. With the mine-tailing incident in 1996, the residents have been prevented from using the rivers as a water source. Since then, several companies conducted environmental monitorings of the rivers. While there have been previous studies conducted after the incident, constant monitoring of the rivers is yet to be accomplished. This undertaking will update existing data on the status of the Boac river system.

Analysis of the water quality and sediments could provide baseline information for future remediation plans and environmental management programs of the rivers. And also, results of the study could be significant in preventing further environment damage.

Scope and Limitations

1) This is a descriptive study of the Boac river system.
2) The study was conducted for three days on October 2002 due to time and budgetary constraints.
3) Considering that this was a one-time sampling, whatever inferences made would not be very conclusive.
4) Two areas were used as study sites, station 1in Barangay Binunga (upstream) and station 2 in Barangay Lupac (downstream) all found in Boac river vicinity.
5) The study focused on the following:
    - Physico-chemical analysis of water quality
    - Measurement of productivity (Winkler Titration Method)
    - Sediment analysis of lead content
    - Comparison of lead concentrations in two selected sites of the river (upstream and downstream)
6) Microbiological analysis was not included in the study.
7) Climatic conditions at the time of the study were used only as reference during the study.

II. REVIEW OF RELATED LITERATURE

A. The Island of Marinduque

1) Location

The island of Marinduque is located approximately 170 kilometers southeast of Manila. It has a land area of 196 square kilometers (www.whitetip.com). This heart-shaped island is bounded by the Tayabas Bay and province of Quezon up on the north, Mongpong Pass and the Bondoc Peninsula on the east, Tablas Strait and Mindoro Oriental on the west and Romblon on the south (www.marinduque.gov.ph). Aside from the main island, the province has 17 northern outlying islets and the Tres Reyes and the Elephant Island in the southwest (www.home.online.no). This island was formed by volcanic activity, and subsequent coral deposition. It houses mainly mountains, spectacular cave systems, extensive rainforests covering the foothills, mangroves found in the north and the north-east, coastlines and white sand beaches (www.whitetip.com).

2) Boac River

Marinduque has about 32 river systems. These rivers are all located in the main island with the Boac River Basin being one of the largest of them. Boac River has an estimated length of about 27 kilometers (www.marinduque.gov.ph). For many years, the Boac River has been used extensively domestic purposes such as farming and laundry. This river system, along with Calancan Bay, was

affected by the copper mining activities of the Marcopper Mining Corporation (Coumans, 1997).

B. Marcopper Mining Corporation

1) History

Marcopper mining operations lasted for 27 years. Mining operations started on 1969 in Mount Tapian using both the countryside and Boac River as dumpsites (Damsell, 1999). In 1991, it moved its mining site to San Antonio Pit. Mount Tapian pit was then plugged and converted into a tailings deposit (DENR, 1996).

Seepage was discovered in the disused drainage tunnel beneath the pit in August 1995. It ruptured on the 24th of March of the following year (Bennagen, 2000). Some 1.6 million cubic meters of mine tailings were released into the river system. UN investigations found the waste rock siltation system poorly maintained and that the seeping toxins exceeded international water quality standards (Coumans, 1997).

Upon the request of the island residents, a group of American scientist from the United States Geological Survey (USGS) gave a report on the large mounds of tailings still present in the river and river base catchment area on March 2000. The Department of Environment and Natural Resources used these findings as basis for rejecting remediation proposals (www.miningwatch.ca).

According to the study, extensive tailing deposits were still observed in many places along the river's streambed (Plumice *et al.*, 2000). These acids and heavy metals present in the river leak out from processed ores (Datinguinoo, 2002). The oxidation of exposed sulfur initiates the formation of toxic sulfuric acid and causes the release of heavy metals like cadmium, lead, mercury, zinc and arsenic present in the tailings. The tailing deposits will continue to serve as a source of acids and metals, released during the occurrences of rainstorms, in the years to come (Plumice *et al.*, 2000).

2) Impacts

In mining copper ore, the red rock is crushed. By means of a complex floatation system, metals are separated to produce copper concentrate. There are two by-products from the process: a heavy silt of rocks and sand, and a grey mix of metals including lead, zinc, and sulphur (Damsell, 1999). Marcopper mineral deposit contains sulfide like pyrite, and chalcopyrite. Such mineral deposits are concerned in the formation of acid-rock drainage or ARD. Mining exposes these sulfide-bearing mineral deposits to the atmosphere causing them to react with oxygen and water. These reactions form ground and surface waters characterized by high levels of sulfuric acid and a low pH. Metals found in sulfide minerals are iron, copper, lead, zinc, arsenic, cadmium and others. These metals are released into the acid-rock drainage through sulfide weathering. Rocks with carbonate minerals have the ability to generate waters with the power to neutralize the acid. These deposits produce near neutral rock drainage or NRD (Plumice *et al.*, 2000).

In most countries, water in many rivers is exposed to substances from simple elements to highly hazardous chemicals from sewage, industrial effluents, and domestic and agricultural wastes (Sah *et al.*, 2000). The toxicity and bioaccumulation of these elements pose harmful hazards to the environment and to human health (Rognerud and Fjeld, 2001).

The tailings flooded low lying areas, destroyed crops and vegetable gardens, clogged irrigation channels and affected two-thirds of the population (Bennagen, 1998). Residents living near the vicinity of Boac River suffered from heavy metal contamination (Coumans, 1999) and up to the present more children appear to have tailing – related illnesses (Datinguinoo, 2002).

In 1997, tests conducted by the Department of Health (DOH) and medical doctors of the University of the Philippines identified toxic levels of heavy metals in the blood of villagers from Boac (Coumans, 1999).

C. Related Studies on Heavy Metal Contamination of Rivers

In 1995, Brit Lisa Skjelvale and her colleagues investigated the concentrations of cadmium, lead, zinc, copper, nickel, cobalt, iron, manganese, chromium, and vanadium in about 3000 lakes in Finland, Denmark, Norway, Sweden, and Russian Kola. The heavy metal concentrations decreased from north to south and increased from west to east. The amount of these heavy metals was affected by deposition, long-range air pollution, local sources, water chemistry, and bedrock geology and soil. And although heavy metal pollution is a minor

ecological problem, it can pose a major problem in running waters like the rivers in Marinduque (Skjelvale *et al.*, 2001)..

Similar to the Boac River system, Willow Creek in Kansas, USA received mine drainage from a nearby Tri-State Mining District. Results showed higher zinc and lead concentrations in that creek as compared to Bush Creek. Bush Creek did not receive any tailing deposits (Roark and Brown, 1996).

Water toxicity is determined by the degree of water pollution. To assess water pollution in Narayani River, Nepal, water from seven sites was analyzed for various physico-chemical parameters like pH, temperature, conductivity, turbidity, total suspended solids (TSS), dissolved oxygen demand (DO), biological oxygen demand (BOD), chemical oxygen demand and total alkalinity. The amount of zinc, lead, copper, and other metals were also determined. Results showed that the water in the river was polluted after receiving effluents from industries, especially the paper industry. The values of pollution indicating parameters like pH, conductivity, suspended solids, alkalinity, and some nutrients and heavy metals were higher just after the input of paper industry effluents (Sah *et al.*, 2000).

Investigations on heavy metals in Lake Chapala in Mexico revealed high copper concentrations in Tilapia liver and high zinc concentrations in Carp liver found there. Observed fishes had fin erosions and a high number of parasitic worms. These symptoms suggest that these organisms were living in a stressed

environment where organic and inorganic contaminants were present (Shine, Ryan, and Ford, 1998).

In a survey conducted by the Environmental Management Bureau in 1994, it was found out that 39 out of the 76 rivers in Luzon were polluted. On the other hand, a 1991 to 1992 monitoring of rivers all – over the country showed that only 45 of the 119 rivers surveyed met water quality standards. All the rivers in Metro Manila have long been declared "biologically dead" except for the upper reaches of the Marikina River (www.oneocean.org). Heavy metals in the Manila Bay tributaries were examined. Ecosystems Research and Development Bureau (ERDB) has a completed study on this as of December 2000. Results showed that the concentration of cadmium found in Pasig, Marikina, San Juan, Tullahan, Tenejeros and Parañaque Rivers were below the set 0.01 ppm water quality standards, while lead content in Parañaque and Marikina was high. Mercury levels found in the five major rivers were below the 2 ppb standard and the presence of zinc was determined but the standards for this metal are yet to be determined (www.laguna.net).

In a related study, it was noted that the levels of concentration of cadmium was found to be from 0.02 to 3 ppm; mercury from 7.5 to 1500 ppb and lead from 0.10 to 30 ppm (Sandoval, 1999)

D. Background on River Evaluation

1) Water Quality Analysis

River pollution arising from industrial development has led to the increasing need for rigorous assessment of river water quality. The components of such assessment programs are defined by the water uses, their water quality requirements, and the need to protect the aquatic environment from further degradation. Studying a given body of water requires an examination of its physico-chemical and biological parameters. Such parameters include turbidity, temperature, pH, salinity and conductivity, color determination, residues of solids, dissolved oxygen, free carbon dioxide and total hardness (Hallare, 2001).

Changes in the structure or quality of the river resulting from anthropogenic activities often produce specific changes in the biological communities. These changes can be used to monitor changes in the river environment. The water sample, which is selected for monitoring, depends on the environmental properties of the chemicals of interest and the objectives of the study. Phosphorus, trace elements, and some organic pollutants may be best evaluated by collection of suspended sediment samples by filtration or centrifugation methods (Chapman, 1996).

2) Sediment Analysis

Concentration of metals in sediments is affected by the element's bioavailability and its concentration in interstitial or pore water. Amorphous sulfide commonly called acid – volatile sulfide (AVS) present in the sediments

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form insoluble sulfide with number of metals, namely cadmium, copper, mercury, nickel, lead, silver and zinc, making these metals biologically unavailable in the pore water (Ankley *et al.*, 1996). In freshwater systems, AVS concentrations are affected by spatial variation, where AVS accumulates more during warm seasons than cold seasons, and temporal variations, where increased production of organic matter and increased sulfate-reducing bacteria activity in the summer raises the sulfate reduction rates in the sediments. Oxidation of sulfudic sediments increases metal mobility and bioavailablity (Besser *et al.*, 1996). Metal adsorption is influenced by pH and occurs mainly in clay – mineral fraction of the sediment (Hassan *et al.*, 1996).

III. MATERIALS AND METHODS

A. Selection of Sampling Stations

A preliminary ocular survey was conducted upon visit to Boac River (PLATE 3 and FIGURE 3). Two stations were selected along the stretch of the river system based on their proximity to nearby villages and distance from one another. Portions of the river located near Barangay Binunga (upstream) and Barangay Lupac (downstream) were chosen as sampling stations. The areas were labeled as station 1 and station 2, respectively. Three 100-meter transect lines [Transect 1 (A), Transect 2 (B) and Transect 3 (C)] were set up parallel to the river in each of these sampling stations. Sampling points were marked at 0-meter, 50-meter and 100-meter points along the transect line.

B. Collection of Samples

Water and sediment samples were collected from these sampling points. Fresh water from the surface of the river and sediment samples were collected from each of the sampling points in the transect lines in three replicates. Six liters of water samples were collected in mineral water bottles previously rinsed with distilled water. Water samples were collected by lowering the bottle into the river until its mouth was an inch below the water surface. Sediment samples were collected using a trowel from the bottom of the river. Fifty grams of sediment samples were taken from each sampling point then stored into zip-lock bags.

C. Water Quality Analysis

1) Physico-chemical Analysis

Methods for water quality analysis were adopted from General Ecology Concepts and Selected Laboratory Exercises by Arnold V. Hallare (2001). After the collection of water samples, the water quality parameters like temperature, pH, alkalinity, conductivity, turbidity, current, dissolved oxygen (DO), free carbon dioxide and biochemical oxygen demand (BOD) were measured. The measurement of the parameters was done in three replicates.

Water Temperature

To measure the temperature of the sampling point, 25 milliliters of water sample was transferred to a 50-milliliter beaker. A Hanna HI8014 multi-tester meter (PLATE 4) was used to determine the temperature of the water sample. A probe was immersed into the beaker. It was made sure that the tip of the probe did not touch the bottom nor the sides of the beaker. The knob of the water analyzer was turned until the temperature of the water sample appeared in the digital monitor. All values will be recorded in degrees Celsius.

Water pH

After recording the temperature reading on the monitor, the same multi-tester meter was used to determine the pH of the water sample. Before the water analyzer was used to measure pH, it was standardized to neutrality (pH 7).

Following the same precautionary measured used to measure the temperature, the knob of the multi-tester meter was again turned until the pH value of the water sample could be read on the digital monitor. The obtained pH reading of the water sample was then recorded.

Alkalinity

One hundred milliliters of the sample was placed in a flask and 2 drops of phenolphthalein was added. The solution was titrated using 0.01N hydrochloric acid until the color disappeared once it turned red. If the sample remains colorless, alkalinity is zero. Alkalinity was determined by multiplying the concentration of the acid with the volume of titrant used to reach the first end point. The product was divided by the volume of the sample. Five drops of methyl orange were added then titration using hydrochloric acid was continued until the methyl orange color was lost or an old rose or salmon color appeared.

$$PA = \frac{\text{concentration of acid} \times \text{volume of titrant used in first endpoint}}{\text{volume of sample}}$$

Total Alkalinity = $\frac{\text{acid concentration} \times \text{titrant volume used in 2nd endpoint}}{\text{volume of sample}}$

Bicarbonate Alkalinity = TA – PA

Conductivity

Conductivity was measured using a Hanna HI8733 conductivity meter (PLATE 5). Twenty-five milliliters of well-mixed water sample was poured into the lower half of a previously cut mineral water bottle. The probe was lowered to about an inch below the water surface. Appropriate buttons were manipulated and conductivity was recorded in microSiemens (μS).

Turbidity

Five milliliters of water sample was transferred to 5-milliliter vial. Sides of the vial were wiped with a dry cloth to avoid detection of water outside the vial. The vial was inserted into the Hanna HI93703 microprocessor turbidity meter (PLATE 6). The start button was pressed and the measured value for turbidity appears on the digital monitor.

Current

Current of the river was measured in terms of magnitude and speed. The magnitude of water current was measured using clod cards made from plaster of Paris. This method was adopted from the Doty (1971). The weight of the clod cards was taken and then pinned at the bottom of the river for

every sampling point. They were left there for the duration of the activity. After all the other procedures were finished, the clod cards were taken out of the water and their new weight was recorded. The magnitude of the current was the difference between the weight of the clod card after immersion and the weight of the clod card before immersion. To measure the speed of the current, a piece of styrofoam was tied to the end of a one-meter string. This set up was placed on the surface of the river. The styrofoam was released as the hand of the observer still held the free end of the string. The time it took the string to stretch to its full extent was noted. The reciprocal of this value was recorded as current speed.

Dissolved Oxygen

Composite sampling was used to collect the water samples to be tested for the amount of dissolved oxygen. In this method, 1 liter of water sample was collected per sampling point. For each transect line, the samples collected from 0 M, 50 M and 100 M sampling points were combined into a single sample in a large 4 liter mineral water bottle then mixed well. Water samples to be used for dissolved oxygen were transferred to a 350-milliliter mineral water bottle.

The Winkler Titration Method was used to measure the amount of dissolved oxygen present in the water. In this method, 2 milliliters of manganese sulfate reagent followed by 2 milliliters of alkali-iodide azide

reagent was introduced beneath the surface of the water sample. The bottle was shaken well and inverted at least 15 times. The sample was allowed to precipitate after which concentrated sulfuric acid was immediately added by allowing the acid to run down the neck of the bottle. This was mixed until the floc dissolved leaving a clear yellow-orange solution.

After 4 to 8 hours, 203 milliliters of the sample was titrated to a very pale yellow color using fresh 0.025 N sodium thiosulfate. The level of sodium thiosulfate was be read before and after titration. The solution turned blue after the addition of 1 to 2 milliliters of starch solution. The titration was continued until the solution changed from blue to clear. Clarity persisted even after agitation. The amount of thiosulfate used was calculated. The result was used to compute for the dissolved oxygen.

DO = ml of NaSO3 used x N/0.025

Determination of Free Carbon Dioxide

Water sample was collected in mineral water bottles and stored in a cool temperature of 4 to 10°C. One hundred milliliters of the water sample was poured in a beaker making sure that there are no bubbles. Ten drops of phenolphthalein was added after which the solution was titrated using N/44NaOH solution until a pink color appeared. The amount of free carbon

dioxide in parts per million was the volume of sodium hydroxide titrated multiplied by 10.

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand test was carried out using the measurements of dissolved oxygen. This test required a period of five days. Dissolved oxygen was determined once the sample is collected. Then the sample was incubated at 20°C. After five days, the dissolved oxygen of the sample was determined once more. The difference in dissolved oxygen between the first day measurement and the measurement after the fifth day became the biochemical oxygen demand.

Lead Analysis

Water samples were tested for the presence of lead. Composite sampling was used in collecting water samples for lead analysis. Composite sampling for each transect line was repeated three times. Prior to analyses, the samples were fixated by the addition of 1.5 milliliter concentrated nitric acid per liter of sample then refrigerated. Then the samples were brought to the Analytical Services Laboratory of the Institute of Chemistry at the University of the Philippines, Los Baños for lead analysis. The presence of lead was tested using Flame Atomic Absorption Spectrophotometry (Appendix A)

2) Biological Analysis (Measurement of Productivity)

Productivity was measured using the Light and Dark Bottle Method adopted from General Ecology Concepts and Selected Laboratory Exercises by A. Hallare. Three 350-milliliter mineral water bottles with cover were used to measure the productivity of the river system. The first bottle was labeled as the initial bottle. The second was covered up using aluminum foil then marked as the dark bottle. And the last one became the light bottle.

Each of these bottles was filled with composite water samples. The initial bottle was tested using the Winkler Titration Method following the same procedures specified for dissolved oxygen determination. The initial oxygen content was recorded as milligrams per liter.

On the other hand, both dark and light bottles were left suspended in the location from which the water samples were taken. The bottles were left there for the remainder the testing period. At the end of the testing period, each of the bottles was tested using the Winkler Titration Method and the results were recorded as dark bottle oxygen content and light bottle oxygen content, respectively.

Values for parameters such as respiration, gross primary productivity and net primary productivity were computed using the formulas below. Measurement of productivity was also done in three replicates.

Respiration = Initial bottle – Dark bottle

Gross Primary Productivity (GPP) = Light bottle – Dark bottle

Net Primary Productivity (NPP) = GPP – Respiration

D. Lead Content Analysis of Sediment Samples

Sediment samples were also combined into composite samples per transect line. Composite sampling per transect line was repeated three times. Sediment samples were analyzed at the Analytical Services Laboratory. Flame Atomic Absorption Spectrophotometry (Appendix A) was used in the analysis of lead content. Concentration of lead in the sediment was recorded in micrograms per gram (μg/g).

IV. RESULTS

A. Description of Sampling Stations

An ocular survey of the Boac River System was conducted (PLATE 3). Upstream (station 1) and downstream (station 2) portions of the river were chosen as sampling stations.

Station 1 was located upstream of the Boac River near the vicinity of Barangay Binunga (PLATE 7). It was approximately 10 kilometers away from the mining site. The water appeared bluish as large rocks were observed at the river floor. Water levels increased gradually from the side to the middle portion of the river. Three transects were laid parallel to the riverbank [Transect 1 (1A), Transect 2 (1B) and Transect 3 (1C)] (FIGURE 4). Water samples were collected from each of these sampling points. Collection for 1A and 1B took place around 10:00 A.M. while collection for 1C was around 2:00 in the afternoon.

Station 2, on the other hand, was located downstream near Barangay Lupac (PLATE 4). This area was approximately 22 kilometers away from the mining site. Water here appeared greenish in color and the river floor was covered with layers of sediments. Station 2 was wider than station 1 and the depth of river varied abruptly from one portion to another. Again, three transect lines were laid parallel to the shore [Transect 1 (2A), Transect 2 (2B) and Transect 3 (2C)] (FIGURE 5). Water samples were collected around 9:30 AM for 2A and around 11:30 AM for 2B and 2C. Different

water quality parameters were determined from the water samples collected from each sampling point.

B. Water Quality Analysis

1) Physico-Chemical Analysis

The water samples from each site were tested for their physico-chemical properties. Values of temperature, pH, alkalinity, conductivity, turbidity, current, dissolved oxygen (DO), free CO_2 and biochemical oxygen demand (BOD) were obtained in the water samples collected. Measurements of these parameters are seen in Tables 1 and 2.

Temperature

Temperature of water samples in station 1 ranged from 24 to 25°C (TABLE 10). At 1A, it increased drastically from 0 to 50m then decreased from 50 to 100m. 1B and 1C had a slightly descending trend. Relatively, 1B had the higher values while 1C had the lower ones (TABLE 1).

The observed temperatures in station 2 were all 24°C except at 100m of 2A where it was found to be at 23.67°C (TABLE 2). Temperature values for station 1 were higher than those recorded from station 2 (TABLE 3 and FIGURE 6).

pH

The pH values detected from station 1 ranged from 7.84 up to 8.81 (TABLE 10). Both 1A and 1C followed a descending-ascending pattern. 1B pH values decreased from 0 to 100m. Values were relatively higher at 1A and lowest at 1C (TABLE 1).

As seen in Table 2, pH ranged from 7.66 – 8.05 in station 2. A general trend of decreasing values was observed in all transect lines with 2A having the highest values. Of the three transects, 2B had the greatest differences in pH between sampling points while values at 2A were almost the same at all points (TABLE 2). Recorded values were higher in station 1 than station 2 (TABLE 3 and FIGURE 7).

Alkalinity

Alkalinity in all 3 transects of station 1 measured 0.0001 (TABLE 1). No shifts in values were observed from 0 to 100m of 1A, 1B, and 1C (TABLE 1).

The alkalinity of the samples from station 2 ranged from 0 - .00004 (TABLE 10) with a decreasing trend from 0 to 100 m at 2B and 2C. Moreover, the lowest and highest values were recorded at 2B and 2C respectively. 2A, on the other hand, had increasing alkalinity (TABLE 2). Alkalinity was lower downstream than upstream (TABLE 3 and FIGURE 8).

Conductivity

Conductivity upstream had a range of 0 to 0.33 (TABLE 10). In 1A, conductivity decreased from 0 to 50m then increased from 50 to 100m. 1B and 1C

followed the same straight-line pattern. The highest values were at 1A and lowest at 1B and 1C. 1A values had the widest range (TABLE 1).

The values of conductivity downstream were 0 in all transects as shown in Table 2. Conductivity was higher upstream than downstream (TABLE 3 and FIGURE 9).

Turbidity

Turbidity values in station 1 ranged from 0 up to 2.26 (TABLE 10). Measurements for 1A followed an increasing trend from 0 to 100m, 1B, a downward-upward rhythm, and 1C, a descending pattern. The lowest values for the study site were taken from 1C, the highest values from 1A. 1A had the widest range turbidity values, while 1B had the smallest (TABLE 1).

The turbidity of the water in station 2 ranged from 1.44 – 3.81 (TABLE 10). 2A had increasing values from 0 to 100m. On the other hand, values slightly increased from 0 to 50 m point of 2B and decreased at 100m point. The inverse of which occurred at 2C where turbidity decreased from 0 to 50 m with a slight increase at 100 m point. 2A had the highest recorded turbidity while 2C had the lowest (TABLE 2). Higher turbidity was recorded station 2 than in station 1 (TABLE 3 and FIGURE 10).

Current

Current speed in station 1ranged from 0.16 to 0.71m/s (TABLE 10). 1A and 1B followed the same down and up pattern. Speed decreased drastically from 0 to 50m then increased from 50 to 100m. The decrease in 1B was sharper than

1A. Of the two transects, 1A relatively had the higher set of values. Measurement of current speed at 1C was not accomplished due to precautionary measures (TABLE 1).

Current speed in station 2 ranged from 0.16 – 0.29 as seen in Table 10. Both 2A and 2B had increasing values at 0 to 50m before decreasing at 100m while 2C had a decreasing pattern. 2A had the lowest speed while 2B had the highest (TABLE 2). Current was faster in station 1 than in station 2 (TABLE 3 and FIGURE 11).

Current magnitude in Binunga ranged from 3.35 to 11.9 g (TABLE 10). Some of the clod cards were carried away due to the strength of the current, as others lost their labels. Due to these circumstances, the general trend for each transect was not detected. But from the remaining data, it could be noted that the highest value was found in the 1B while 1C had the lowest values (TABLE 1).

The data showed that the magnitude of the current in Lupac ranged from 2.7 – 9.9 (TABLE 10). Values were generally increasing at 2A. However, no data were obtained from 50 and 100m points of 2B and 50m point of 2C. The magnitude was lowest at 0m of 2A and highest at 2C (TABLE 2). Current was stronger in station 1 (upstream) than in station 2 (downstream) as seen in (TABLE 3 and FIGURE 12).

Dissolved Oxygen

Dissolved oxygen (DO) readings in station 1 ranged from 3.2 to 5.2 mg/L (TABLE 4). 1B followed a decreasing pattern as 1C increased from sample 1 to 2

then decreased slightly from 2 to 3. Due to unavoidable circumstances, only 1 sample from 1A was completely tested for its dissolved oxygen content. DO was relatively higher at 1C and lower at 1B (TABLE 4).

As shown in Table 5, dissolved oxygen content in station 2 ranged from 4.62 – 6.2 mg/L. 2A followed a descending-ascending pattern from sample 1 to 3, while DO of 2B and 2C initially increased then decreased at sample 3. Samples from 2C had higher DO content compared to the other samples. Lowest values were recorded at 2B. Values in station 2 were higher than station 1 (TABLE 6 and FIGURE 13).

Free Carbon Dioxide

Station 1 free carbon dioxide ranged from 2.33 to 3.67 mg/L (TABLE 1). 1A values followed an up and down pattern from 0 to 100m while 1B followed a decreasing-increasing trend. The highest values were found in 1B and 1C and lowest in 1A (TABLE 1).

Table 10 indicated that the amount of free CO_2 in station 2 ranged from 3.33 – 6.00 mg/L. The values at 1A showed an increasing pattern from 0 to 100m. The amount of free CO_2 at 2B descended from 0 to 50m then ascended significantly upon reaching the 100 m point. The opposite was observed at 2C. The values initially increased then decreased at the third sampling point. The highest readings were obtained at 100 m of 2A and 2B and lowest at 0m of 2C (TABLE 2). Free carbon dioxide was higher in station 2 was higher than station 1 (TABLE 3 and FIGURE 14)

Biochemical Oxygen Demand (BOD)

From the results of the first and second readings of the DO, the biochemical oxygen demand (BOD) was obtained. The obtained BOD from station 1 ranged from 0.65 to 2.7 mg/L. 1B decreased from sample 1 to 2 then increased starting sample 2 to 3. Relatively, values were higher at 1B and lower at 1C (TABLE 4).

The BOD of the samples from station 2 ranged from 0.32 – 2.40. Sample 1 of 2B had the lowest BOD while sample 2 of 2C had the highest (TABLE 5). Higher BOD was recorded from station 1 than from station 2 (TABLE 6 and FIGURE 15).

Lead Analysis

The lead content in the water samples collected were not detected. Lead content in the samples were below the limit of detection. Lead content in station 1 and station 2 were below detectable levels (0.93 μg/L) as seen in TABLES 7 and 8. Lead content in water samples were the same for both stations (TABLE 9).

2) Biological Analysis (Measurement of Productivity)

Water samples for productivity were collected compositely. Based on the oxygen content of these samples in the initial, dark and light bottles, parameters such as respiration, gross primary productivity and net primary productivity were determined. Calculated values for these parameters are seen in Tables 4 and 5.

Respiration

In station 1 respiration values from the first transect ranged from -9.08 – 10.34 G-cal/m^2 surface (TABLE 11). 1A had a roughly decreasing trend from sample 1 to 3 as 1C values followed an abrupt up and down pattern. 1B had the relatively lower values, while 1C had the relatively higher ones (TABLE 4).

Table 5 indicated that the respiration in station 2 ranged from -2.81 – 5.89 G-cal/m^2 surface 2A and 2B followed a descending-ascending pattern. Values greatly decreased from sample 1 to 2 then greatly increased at sample 3. 2C had a different pattern. An increase from sample 1 to 2 was followed by an abrupt decrease at sample 3. Respiration values were higher in station 2 than in station 1 (TABLE 6 and FIGURE 16).

Gross Primary Productivity

Gross Primary Productivity (GPP) values in the upstream station ranged from -0.44 – 11.17 G-cal/m^2 surface (TABLE 11). 1A followed a slightly ascending pattern from sample 1 to 3. 1C had abrupt changes, increasing from sample 1 to 2 then decreasing from sample 2 onwards. 1A had the relatively lower values while 1C had the higher ones (TABLE 4).

GPP in the downstream station ranged from -11.65 – 5.89 G-cal/m^2 surface (TABLE 11). GPP of 2A showed an increasing trend while 2B followed a descending-ascending pattern. And values at 2C were decreasing. 2B had the lowest values recorded, as 2C had the highest (TABLE 5). GPP was higher upstream than downstream (TABLE 6 and FIGURE 17).

Net Primary Productivity

Net Primary Productivity (NPP) values in station 1 ranged from 0.44 – 8.69 G-cal/m^2 surface (TABLE 11). Based on the obtained data, trend increased from sample 1 to 2 then decreased from 2 to 3. Shifts from one sample to another were rough. 1A had the lowest value as 1C had the highest. Values from one sample differed greatly from the next (TABLE 4).

NPP in station 2 ranged from -6.19 – 2.09 G-cal/m^2 surface (TABLE 11). NPP of 2A initially increased then decreased at sample 3 while 2B had a generally decreasing trend. For 2C, the NPP at first decreased then increased at sample 3. Among the three transects, 2C had the highest recorded, while 2B had the lowest (TABLE 5). Values were lower in station 2 than station 1 (TABLE 6 and FIGURE 18).

C. Lead Content Analysis of Sediment Samples

Sediment samples were analyzed for their lead content. Amount of lead in these samples were recorded in Tables 7 and 8.

In station 1, lead content in the sediment samples ranged from 0.32 to 2.92μg/g (TABLE 7). Both 1A and 1C followed a down-up pattern with values of only slight differences from sample 1 to 3. 1B followed the trend but shifts from one sample to another were great (TABLE 7).

In station 2, sediment samples were also obtained and tested for the presence of lead. Analysis of the sediments showed that the amount of lead present ranged from 1.53 – 2.29 μg/g (TABLE 8). Relatively the same amount of lead was present in sample 2 of 2A and 2C. Among the samples, sample 3 from 2B had the lowest lead content. Both 2A and 2C followed the same descending-ascending trend while 2B followed an ascending-descending one. Also, the amounts of lead at 2B were more closely related compared to the values at 2A and 2C. Station 1 had higher lead content in its sediments than station 2 (TABLE 9 and FIGURE 19).

V. DISCUSSION

A. Evaluation of Sampling Stations

Most rivers exhibit a downstream decrease in gradient along their length. Slopes are steep in the headwaters and become less in the downstream. And the particle size of bed material shifts from an abundance of coarse materials upstream to mostly finer materials downstream (Allan, 1995). This explains why station 1 exhibited deeper waters with boulders and rocky substrates while station 2 was relatively shallow with mainly sand at the bottom. The differences in the physical characteristics of the upstream and downstream portions of the river made them fit to serve as basis for the preliminary analysis of the physico-chemical properties of the river.

B. Water Quality Analysis

1) Physico-chemical Analysis

Temperature

Running water temperature varies on seasonal and daily times scales as well as in different locations due to influences brought about by climate, elevation, streamside vegetation and groundwater inputs (Allan, 1995). Temperature values for both stations fell either a little below or within the optimum range set by the Bureau of Fisheries and Aquatic Resources (TABLE 10). Temperature is lowest in the higher upstream areas but gradually becomes warmer in the lower regions (Horne and Goldman, 1994). However, relatively

higher temperatures were recorded in station 1 compared to station 2 (FIGURE 6). This maybe attributed to the difference in the time of day when the temperatures of the samples were taken. Temperatures at station 1 were measured around 10:00 AM to 2:00 PM while at station 2, 9:30 to 11:30 AM.

pH

pH measures the concentration of hydrogen ions in a compound. It is determined by the calcium bicarbonate content of the freshwater system. The presence of carbon dioxide, carbonic acid, bicarbonate and carbonate ions acts as a buffering system preventing extreme pH values that are harmful to the body of water (Allan, 1995). pH values fell within the optimum range given by the BFAR (TABLE 10) and were maintained by this system. Higher recorded values in the upstream (FIGURE 7) can be attributed to the presence of more ions in that area. With more ions present, this portion of the river had a relatively more effective buffering capacity.

Alkalinity

Alkalinity, on the other hand, refers to the amount of bicarbonates, carbonates and hydroxides responsible for shifting pH values to the alkaline range. pH values affect the proportion of these compounds in water (Allan , 1995). At intermediate pH levels of 6.5 to 10.5, bicarbonate ions predominate the waters. Levels of these ions decline at a reading of 8.3 (Wetzel, 1983). Alkalinity values were within the normal range based on compilation made by advanced Biology students from Ida High School, U.S.A. from 1996 to 1997

(TABLE 10). Higher alkalinity observed in station 1 (FIGURE 8) is brought about by the higher pH observed in this area.

Conductivity

Conductivity is the ability of water to conduct an electric current (Chapman, 1996). It is affected by the presence of ions in the body of water. These molecules are capable of reducing the resistance of water to electron flow (Allan, 1995). With few ions to reduce resistance, conductivity would be relatively low or zero. Conductivity in station 1 was higher than station 2 (FIGURE 9). This may be accounted by the presence of more ions in the area.

Turbidity

Turbidity caused by clay, silt and other suspended particles limits the penetration of light into a body of water (Odum, 1971). Turbidity results from the scattering and absorption of incident light by the particles consisting of organic and inorganic matter and soluble organic compounds (Chapman, 1996). Values for turbidity fell within the normal range set by Chapman (TABLE 10). Higher turbidity in station 2 (FIGURE 10) maybe brought about by the presence of more suspended particles coming from run-offs and effluents.

Current

Current velocity is the rate of water movement (Chapman, 1996). It depends upon the size, shape, steepness of the stream channel, roughness of bottom, depth and rainfall (Smith, 1974). Velocity varies widely in different portions of the same stream from one time to another (Odum, 1971). Current

speed fell within normal range based on values set by Chapman (TABLE 10). Downstream (station 2) due to its greater width and lower depth, had a slower current in comparison to speed in the upstream portion (station 1). Also in station 2, where the gradient is less, velocity decreases. Current speed is directly proportional to its magnitude as seen in Figure 11 and 12. An increase in speed corresponds to an increase in current magnitude.

Dissolved Oxygen (DO)

Solubility of oxygen in water is also influenced by temperature and photosynthetic activity of algae and plants (Chapman, 1996). Metabolic activity of organisms including oxygen consumption increases along with temperature causing a decrease in the amount of dissolved oxygen present in the river (Allan, 1995). DO values fell within the normal range set by the DENR (TABLE 10). Thus, DO was lower at station 1 where temperature and productivity were higher compared to station 2 (FIGURE 6, 14, and 17).

Oxygen content is also influenced by current. Current allows greater contact of water with the atmosphere (Smith, 1974). Current in station 2 was slower. However, its colder temperature increased its capacity to hold oxygen explaining its higher DO (Ida High School, 1997).

Free Carbon Dioxide

Free carbon dioxide comprises the concentration of carbon dioxide and carbonic acid making it dependent on respiration and pH. Values for free CO_2 fell within the normal range set by Chapman(TABLE 10). Respiration of aquatic

biota produces CO_2 (Chapman, 1996). Thus with higher respiration rates in station 2, the amount of free CO2 is higher (FIGURES 13 and 16).

Carbon dioxide when mixed with water becomes carbonic acid. Presence of carbonic acid lowers the pH of the solution. Thus, station 2 with higher free CO_2 had lower pH values compared to station 1 (FIGURE 7 and 13).

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is the difference between the oxygen production of plants and amount of oxygen needed for respiration of aquatic organisms (Stiling, 1992). BOD fell within the normal range set by the DENR (TABLE 10). BOD is inversely proportional to respiration. This accounts for higher BOD in station 1 accompanied by lower respiration values in that same area (FIGURE 15 and 16)

Lead Analysis

As time passes by, lead particles begin to settle at the bottom of the river. This explains the undetected levels of the heavy metal observed in both sampling stations (TABLE 12). Normal value set by the DENR was 0.05 mg/L.

2) Biological Analysis (Measurement of Productivity)

Respiration

Respiration, the reverse of photosynthesis, provides the energy needed for reproduction and maintenance of plants (Smith, 1974). The decline of oxygen in the dark bottles indicates the amount of respiration by producers and consumers in

the waters (Odum, 1971). Station 2 had higher respiration values compared to station 1 (TABLE 6 and FIGURE 16).

Gross Primary Productivity

Gross Primary Production (GPP) refers to the total rate of photosynthesis (Odum, 1971). DO is inversely proportional to metabolic activity or productivity (Chapman, 1996). This shows that more oxygen is consumed in more productive waters due to the activities of organisms present there. Thus explaining the lower DO in station 1 with higher productivity values (FIGURE 14 and 17).

Higher temperature increases metabolic activity and consequently the primary productivity of producers. Hence, the higher productivities in station 1 can also be attributed to its warmer temperatures (FIGURE 6 and 17).

Net Primary Productivity

Net Primary Productivity (NPP) is defined as the rate at which of organic matter is stored in plant tissue after respiratory utilization took place during the period of during the period of measurement (Odum, 1971). NPP is equated to GPP minus energy lost by plant respiration (Stiling, 1992). NPP varies directly with GPP but inversely with respiration. Higher GPP increases the amount of energy that maybe stored, as higher respiration lessens the amount of energy left for storage. Station 1 had a higher NPP compared to station 2. This could be supported by the higher GPP and lower respiration found in that station (FIGURES 16, 17, and 18).

C. Lead Content Analysis of Sediment Samples

Water moving downstream carries with it a load of debris that sooner or later is deposited within or along the stream. When the water reaches level land, its velocity is greatly reduced, and the load it carries is deposited as silt, clay, or mud (Smith, 1974). This may explain why lead analysis of water samples resulted in undetected amounts while considerable amounts of lead were detected in the sediment (TABLES 7, 8 and 12).

Lead content in the sediments of station 1 were higher than those in station (FIGURE 19). The contour of this portion of the river allows its sediments to settle within the area of the station (FIGURE 3). However, since 2-200 μg/g would indicate the normal amount of lead in sediments, the results obtained from both stations were below toxic levels (Torrey, 1978). Thus, the lead contents of stations 1 and 2 were not harmful to the ecosystem.

VI. SUMMARY

The island of Marinduque is rich in natural resources (www.whitetip.com). One of its river systems, Boac, was affected by the copper mining activities of the Marcopper Mining Corporation (Coumans, 1997).

This study aims to describe the physico-chemical properties, productivity, and sediment characteristics of the Boac river. Upstream and downstream portions of the river were chosen as sampling stations. One near Barangay Binunga (Station 1) and the other near Barangay Lupac (Station 2).

Temperature was higher in station 1 due to the difference in the time of day when the sample was collected. Presence of more carbon dioxide, bicarbonate and carbonic acid gave station 1 a higher pH and a more effective buffering capacity. With a higher ph, this station also had a higher alkalinity. Higher conductivity in station 1 was brought about by the presence of more ions there. With more suspended particles brought about by effluents, waters were more turbid in station 2. Higher gradients in the upstream brought about faster and stronger currents in that portion of the river. Cooler temperature in station 2, allowed more DO to be present in the waters. Free carbon dioxide was higher in station 2 due to its lower pH. Higher BOD was observed in station 1.

Through the light and dark bottle method, the productivity of the river was determined. Higher respirations were recorded in station 2 can be accounted to the

presence of minimal producers and consumers in the station. Higher temperature in station 1 brought about higher GPP and NPP.

The amount of lead in the water samples were found to be below detectable amounts, which are 0.94 μg/g. Conversely, lead concentration in the sediment samples were below toxic levels.

VII. CONCLUSIONS

Based on the study, it could be concluded that:

1) Generally, values of physico-chemical parameters were within the normal range.
2) Low productivity in station 2 was observed due to the presence of minimal producers and consumers (GPP and NPP).
3) In both stations, lead concentrations in water samples were undetected while, sediments contained considerable amounts. However, obtained values were within the normal range.
4) Within the time frame of the study, Boac river had low lead content.

VIII. RECOMMENDATIONS

1. It is recommended that a continuous monitoring be conducted to make an assessment of the water quality and sediments of Boac River, Marinduque.
2. Concentration of other metals like cadmium, mercury, copper, and zinc may be analyzed.
3. The midstream portion of the river should be included in the study to provide more data for comparison.
4. Sufficient financial support should be provided to lessen limitations and make a more extensive study.
5. Transect lines may be laid perpendicular to the riverbank if the width of the river allows it.

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FIGURES

Figure 1. Map of the Philippines showing the position the island of Marinduque

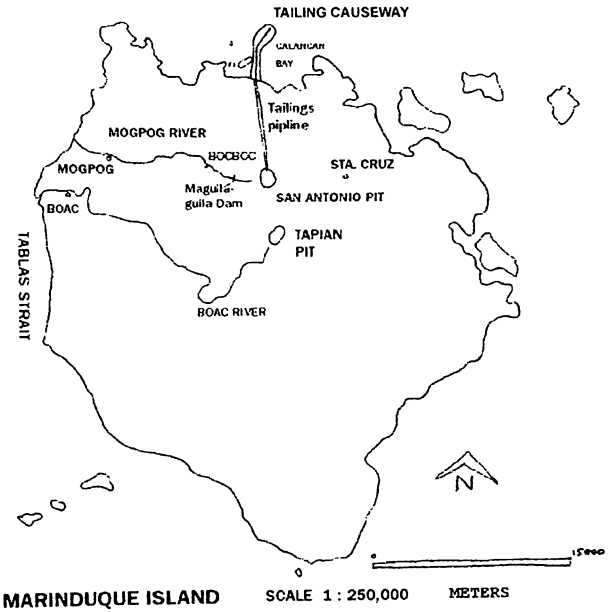
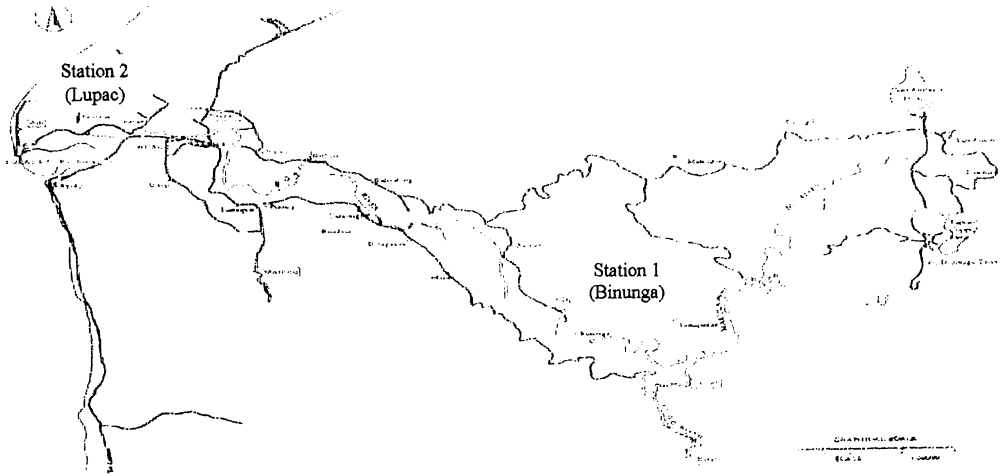


Figure 2. Map of Marinduque showing the location of Boac River



Map 2. Barangays along the Boac and Makulapnit Rivers and coastal areas

Figure 3. Map of Boac River showing the location of Barangay Binunga (Station 1) and Barangay Lupac (Station 2)

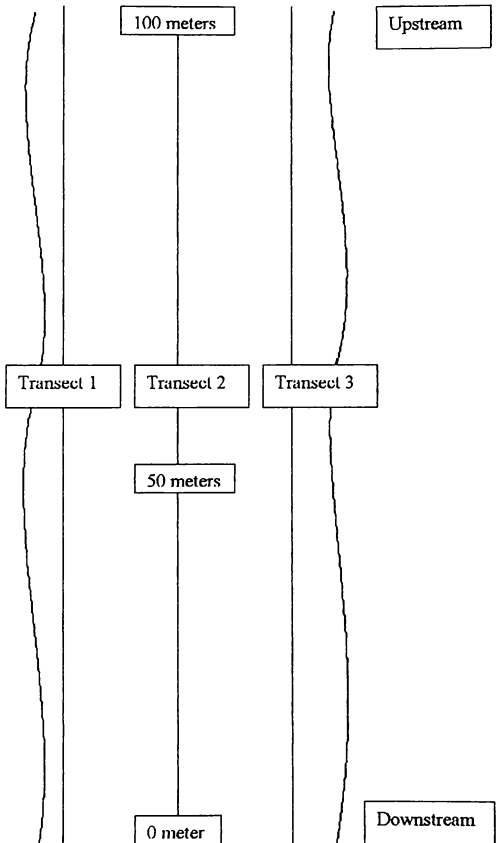


Figure 4. Contour of Boac River along Barangay Binunga (Station 1) showing the positions of the transect line

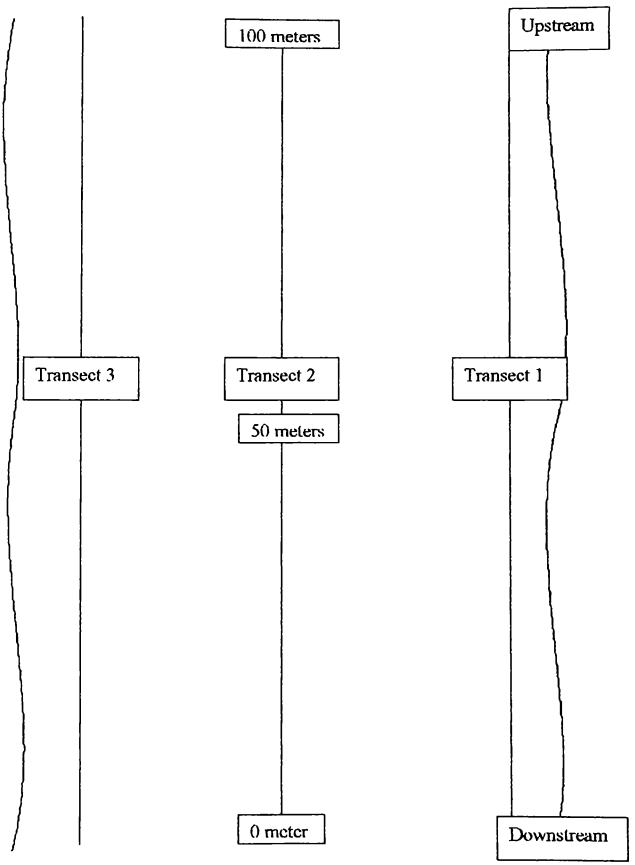


Figure 5. Contour of Boac River along Barangay Lupac (Station 2) showing the positions of the transect line

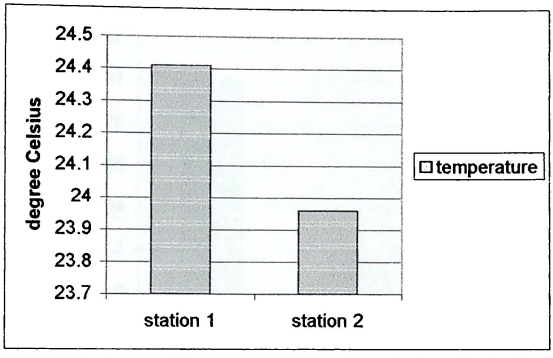


FIGURE 6. Average Temperature of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

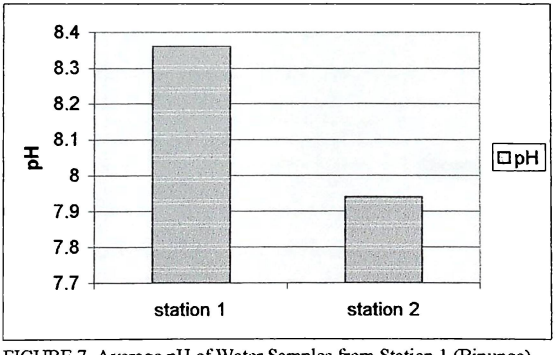


FIGURE 7. Average pH of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

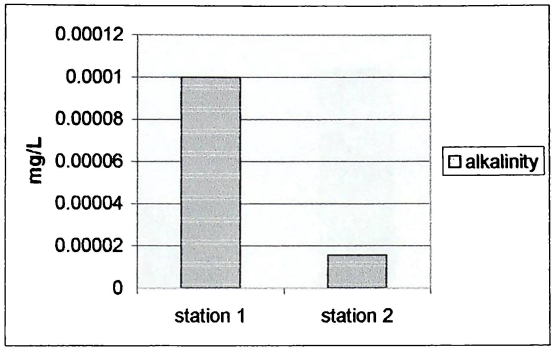


FIGURE 8. Average Alkalinity (mg/L) of Water Samples at Station 1 (Binunga) and Station 2 (Lupac)

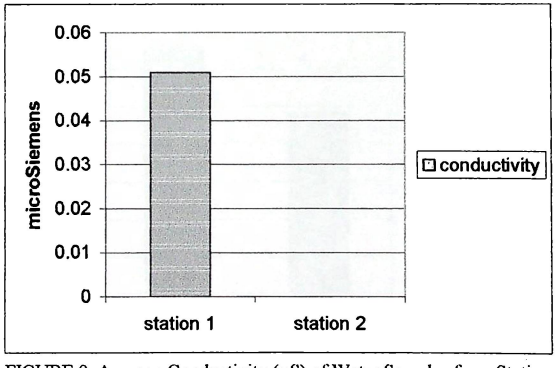


FIGURE 9. Average Conductivity (μS) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

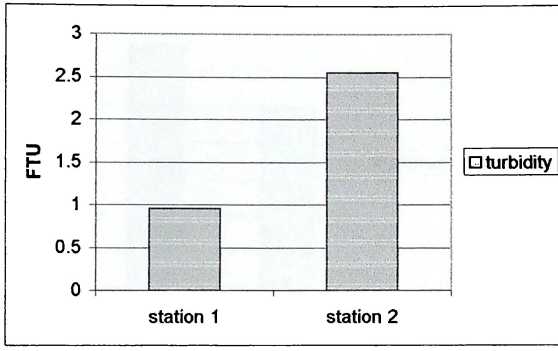


FIGURE 10. Average Turbidity (FTU) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

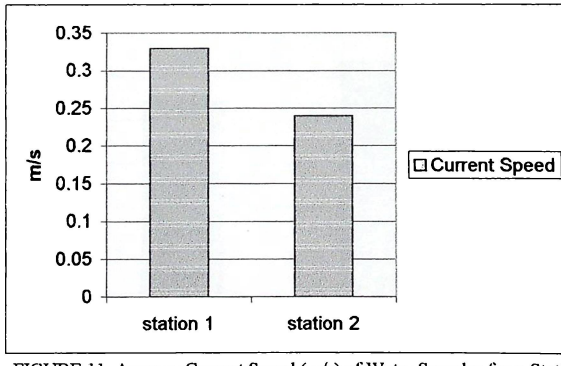


FIGURE 11. Average Current Speed (m/s) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

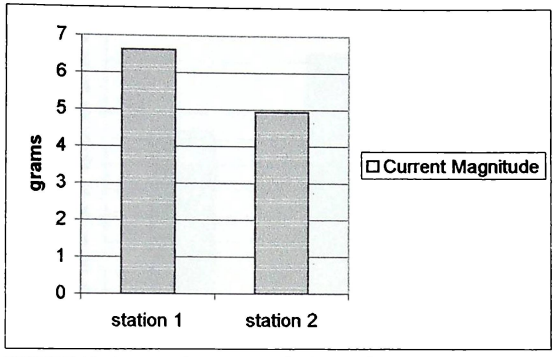


FIGURE 12. Average Current Magnitude (g) of Water Samples at Station 1 (Binunga) and Station 2 (Lupac)

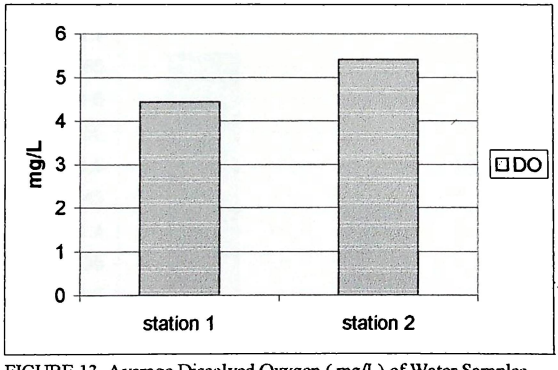


FIGURE 13. Average Dissolved Oxygen (mg/L) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

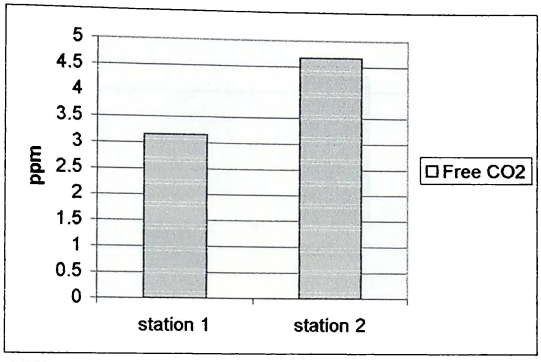


FIGURE 14. Average Free Carbon Dioxide (ppm) of Water Samples at Station 1 (Binunga) and Station 2 (Lupac)

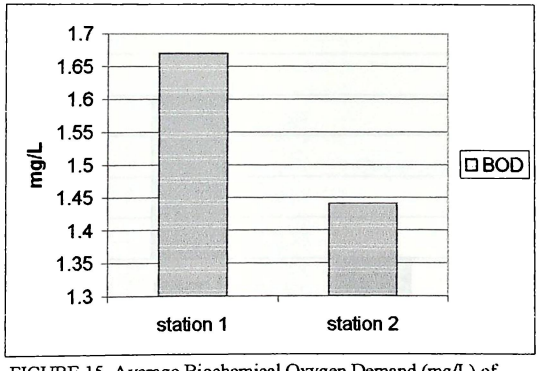


FIGURE 15. Average Biochemical Oxygen Demand (mg/L) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

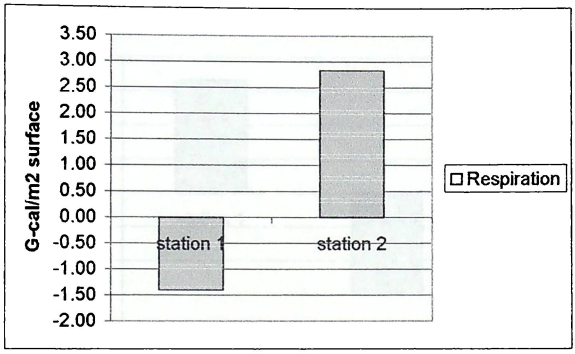


FIGURE 16. Average Respiration (mg/L) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

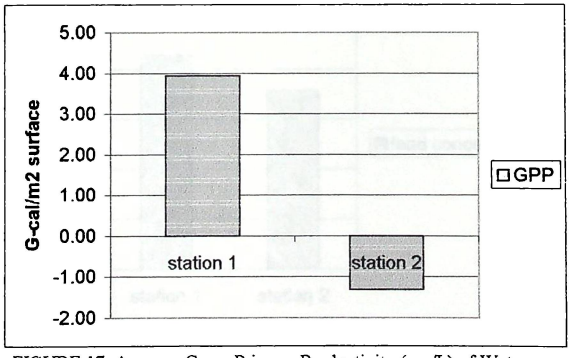


FIGURE 17. Average Gross Primary Productivity (mg/L) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

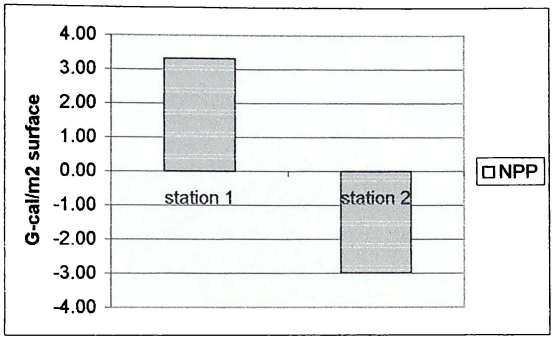


FIGURE 18. Average Net Primary Productivity (mg/L) of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

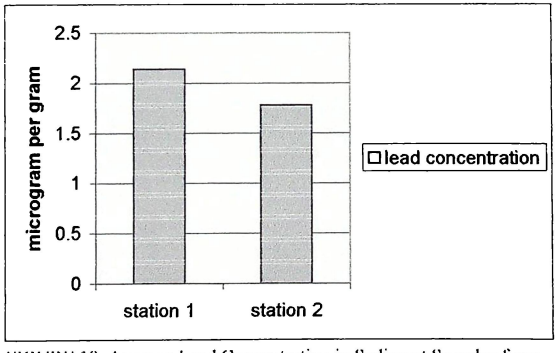


FIGURE 19. Average Lead Concentration in Sediment Samples from Station 1 (Binunga) and Station 2 (Lupac)

PLATES

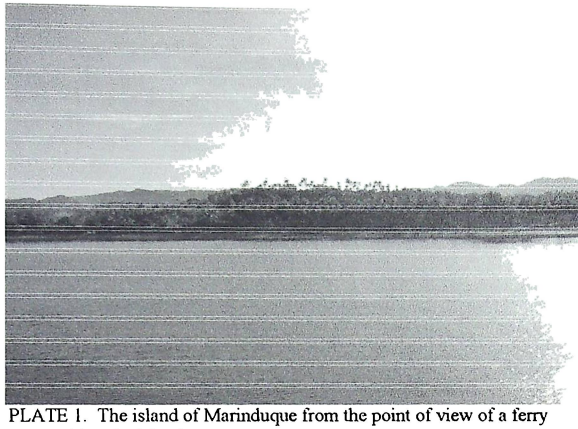


PLATE 1. The island of Marinduque from the point of view of a ferry approaching the island

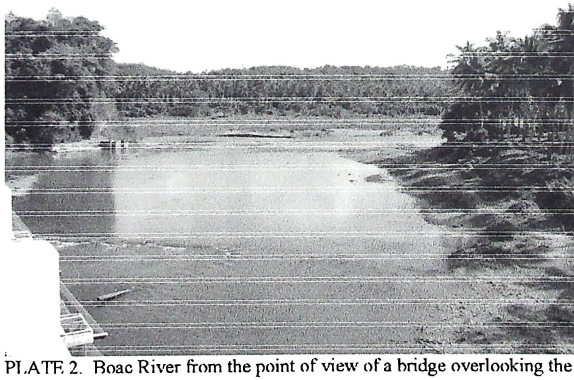


PLATE 2. Boac River from the point of view of a bridge overlooking the river

PLATE 3. Boac River showing contour of the river

PLATE 4. Hanna HI8014 multi-tester meter used to measure temperature (°C) and pII of water samples

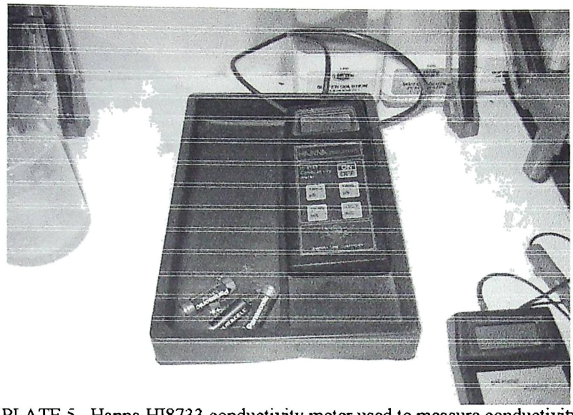


PLATE 5. Hanna HI8733 conductivity meter used to measure conductivity (μS) of water samples

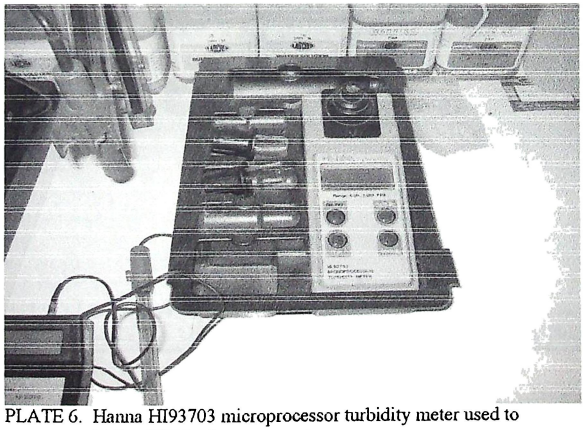


PLATE 6. Hanna HI93703 microprocessor turbidity meter used to measure turbidity (FTU) of water samples

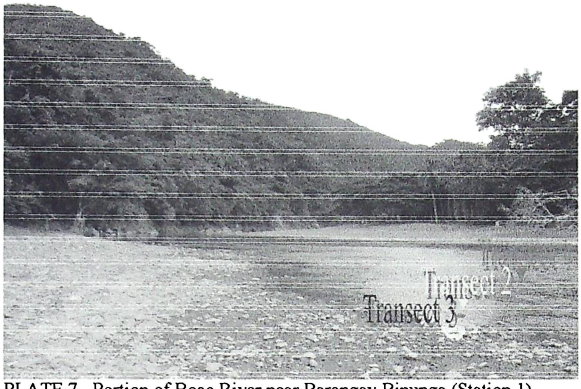


PLATE 7. Portion of Boac River near Barangay Binunga (Station 1)

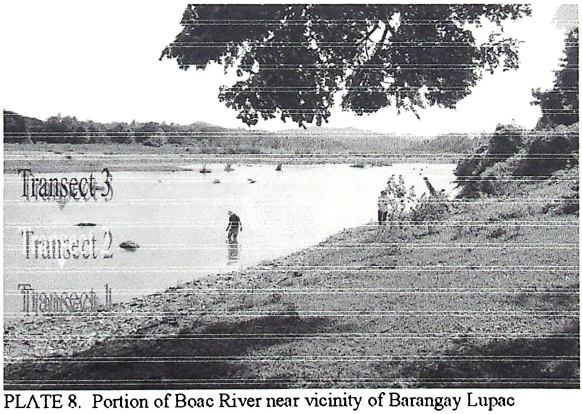


PLATE 8. Portion of Boac River near vicinity of Barangay Lupac (Station 2)

TABLES

TABLE 1. Mean Values of the Physico-chemical Properties of Water Samples from Transects 1, 2, and 3 in Station 1 (Binunga) along Boac River

PARAMETER	STATION1: BINUNGA								
	TRANSECT 1 (1A)			TRANSECT 2 (1B)			TRANSECT 3 (1C)		
	0m	50m	100m	0m	50m	100m	0m	50m	100m
Temperature (°C)	24	25	24	25	24.67	24.67	24.33	24	24
Ph	8.81	8.56	8.74	8.22	8.47	8.77	7.99	7.84	7.87
Alkalinity (mg/L)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Conductivity (μS)	0.10	0.03	0.33	0	0	0	0	0	0
Turbidity (FTU)	0.60	1.15	2.26	0.89	0.61	0.88	1.41	-	0
Current Speed (m/s)	0.32	0.16	0.29	0.71	0.22	0.27	-	-	-
Current Magnitude (g)	7.85	4.3	-	-	-	11.9	5.75	3.35	-
Free CO_2 (ppm)	2.67	3.00	2.33	3.67	3.00	3.33	3.33	3.33	3.67

TABLE 2. Mean Values of the Physico-chemical Properties of Water Samples from Transects 1, 2, and 3 in Station 2 (Lupac) along Boac River

PARAMETER	STATION 2: LUPAC								
	TRANSECT 1 (2A)			TRANSECT 2 (2B)			TRANSECT 3 (2C)		
	0m	50m	100m	0m	50m	100m	0m	50m	100m
Temperature (°C)	24.00	24.00	23.67	24.00	24.00	24.00	24.00	24.00	24.00
pH	8.05	8.05	8.04	8.04	8.00	7.85	7.93	7.81	7.66
Alkalinity (mg/L)	0	0	0.00001	0.00004	0.00003	0	0.00004	0.00002	0
Conductivity (μS)	0	0	0	0	0	0	0	0	0
Turbidity (FTU)	2.26	2.77	3.81	3.46	2.38	2.54	1.56	1.44	2.69
Current Speed (m/s)	0.14	0.18	0.12	0.23	0.37	0.24	0.48	0.31	0.12
Current Magnitude (g)	2.7	4.13	3.6	9.9	-	-	6.6	-	2.69
Free CO_2 (ppm)	4.67	5.67	6.00	4.00	3.33	6.00	3.67	4.67	4.00

TABLE 3. Average Values of Physico-chemical properties of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

PARAMETER	STATION 1 (BINUNGA)	STATION 2 (LUPAC)
Temperature (°C)	24.41	23.96
pH	8.36	7.94
Alkalinity (mg/L)	0.0001	1.56E-05
Conductivity (μS)	0.051	0
Turbidity (FTU)	0.96	2.55
Current Speed (m/s)	0.33	0.24
Current Magnitude (g)	6.63	4.94
Free CO_2 (ppm)	3.15	4.67

TABLE 4. Mean Values of the Productivity of Water Samples from Transects 1, 2, and 3 in Station 1 (Binunga) along Boac River

PARAMETER	STATION 1: BINUNGA								
	TRANSECT 1 (1A)			TRANSECT 2 (1B)			TRANSECT 3 (1C)		
	1	2	3	1	2	3	1	2	3
DO (mg/L)	-	5.2	-	5.2	3.4	3.2	3.7	5.2	5.1
BOD (mg/L)	-	2.5	-	2.7	1.1	1.95	0.65	1.40	1.40
Respiration	-	0.83	-	0.44	-5.39	-9.08	-5.78	10.34	-1.27
Gross Primary Productivity	-0.44	1.27	6.60	-	-	-	2.94	11.17	2.09
Net Primary Productivity	-	0.44	-	-	-	-	0.83	8.69	3.3

Note: Water samples were collected using composite sampling.
Productivity values were in G-cal/m^2 surface.

TABLE 5. Mean Values of the Productivity of Water Samples from Transects 1, 2, and 3 in Station 2 (Lupac) along Boac River

PARAMETER	STATION 2: LUPAC								
	TRANSECT 1 (2A)			TRANSECT 2 (2B)			TRANSECT 3 (2C)		
	1	2	3	1	2	3	1	2	3
DO (mg/L)	5.40	4.62	5.60	4.62	5.32	5.30	5.50	6.20	6.10
BOD (mg/L)	1.70	0.57	1.54	0.32	1.42	1.35	1.65	2.40	2.00
Respiration	3.74	-0.44	5.78	5.06	-2.81	2.92	4.13	5.89	1.27
Gross Primary Productivity	11.65	0.00	4.57	2.09	-7.7	-3.3	5.89	0.44	-2.09
Net Primary Productivity	-5.37	0.74	-1.24	-2.97	-4.87	-6.19	2.09	-5.78	-3.3

Note: Water samples were collected using composite sampling.
Productivity values were in G-cal/m^2 surface.

TABLE 6. Average Values of the Productivity of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

PARAMETER	STATION 1 (BINUNGA)	STATION 2 (LUPAC)
DO (mg/L)	4.43	5.41
BOD (mg/L)	1.67	1.44
Respiration	-1.41	2.84
Gross Primary Productivity	3.93	-1.31
Net Primary Productivity	3.31	-2.99

Note: Water samples were collected using composite sampling.
Productivity values were in G-cal/m^2 surface.

TABLE 7. Concentration of Lead (μg/g) in the Water and Sediments of Boac River at Station 1 (Binunga)

		STATION 1: BINUNGA								
		TRANSECT 1 (1A)			TRANSECT 2 (1B)			TRANSECT 3 (1C)		
	Sample#	1	2	3	1	2	3	1	2	3
Water samples (μg/g)	Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sediment samples (μg/g)	Lead	2.35	1.84	1.89	2.56	0.32	2.58	2.92	2.37	2.45

Note: Water and sediment samples were collected using composite sampling.
Lead content in water was not detected (ND) for amount of lead was below the detectable range of 0.94 μg/g.

TABLE 8. Concentration of Lead (μg/g) in the Water and Sediments of Boac River at Station 2 (Lupac)

		STATION 2: LUPAC								
		TRANSECT 1 (2A)			TRANSECT 2 (2B)			TRANSECT 3 (2C)		
	Sample#	1	2	3	1	2	3	1	2	3
Water samples (μg/g)	Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sediment samples (μg/g)	Lead	1.85	1.54	2.29	1.59	1.68	1.58	2.26	1.53	1.72

Note: Water and sediment samples were collected using composite sampling.
Lead content in water was not detected (ND) for amount of lead was below the detectable range of 0.94 μg/g.

TABLE 9. Average Values of Lead Concentration in Water and Sediment Samples from Station 1 (Binunga) and Station 2 (Lupac)

LEAD CONCENTRATION (μg/g)	STATION 1 (BINUNGA)	STATION 1 (LUPAC)
Water	ND	ND
Sediment	2.14	1.78

Note: Water and sediment samples were collected using composite sampling.
Lead content in water was not detected (ND) for amount of lead was below the detectable range of 0.94 μg/g.

TABLE 10. Range Values of Physico-chemical Properties of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

WATER QUALITY ANALYSIS	STATION 1	STATION 2	NORMAL RANGES
Temperature (°C)	24 – 25	23.67 – 24	25.0 – 32.0
pH	7.84 – 8.81	7.66 – 8.05	6.5 – 8.5
Alkalinity (mg/L)	0.0001	0 – 0.00004	below 500
Conductivity (μS)	0 – 0.33	0	10 – 1,000
Turbidity	0 - 2.26	1.44 – 3.81	1 – 1,000
Current Speed (m/s)	0.16 - 0.71	0.12 - 0.48	1 – 21.54
Current Magnitude (g)	4.3 – 11.9	2.69 – 9.9	-
Dissolved Oxygen (mg/L)	3.2 – 5.2	4.62 – 6.20	3.0 –5.0
Free CO_2 (ppm)	2.33 – 3.67	3.33 – 6.00	0.5 – 8.5
BOD (mg/L)	0.65 – 2.7	0.32 – 2.40	1.0 – 5.0

TABLE 11. Range Values of Respiration and Productivity of Water Samples from Station 1 (Binunga) and Station 2 (Lupac)

MEASUREMENT OF PRODUCTIVITY	STATION 1	STATION 2
Respiration (G-cal/m^2 surface)	-9.08 – 10.34	-2.81 – 5.89
Gross Primary Productivity (G-cal/m^2 surface)	-0.44 – 11.17	-11.65 – 5.89
Net Primary Productivity (G-cal/m^2 surface)	0.44 – 8.69	-6.19 – 2.09

TABLE 12. Range Values of Lead Concentration (μg/g) in Water and Sediment Samples from Station 1 (Binunga) and Station 2 (Lupac)

LEAD ANALYSIS	STATION 1	STATION 2
Water samples	ND	ND
Sediment samples (μg/g)	0.32 – 2.92	1.53 – 2.29

Note: Water and sediment samples were collected using composite sampling.
Lead content in water was not detected (ND) for amount of lead was below the detectable range of 0.94 μg/g.

APPENDIX A

Flame Atomic Absorption Spectrophotometry

Samples will be required to be in liquid form. Any solid material will be liquified using some form of extract or digest protocol. The liquid sample will be aspirated then mixed with combustible gases as an aerosol. With a flame of temperature ranging from 2100 to 2800 degrees Celsius, the mixture will be ignited. A lamp whose cathode is made from the same element being determined will release a light beam that will pass through the flame into a monochronometer and detector. Free, unexcited ground state atoms of the element absorb light at characteristic wavelengths; this reduction of the light energy at the analytical wavelength is a measure of the amount of the element in the sample.

The main principle in any atomic absorption spectrophotometry is the reduction of the solution into atoms during combustion. These atoms absorb specific wavelengths being emitted by a cathode lamp are equivalent to the amount of element vaporized in the flame.