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ABOUT THE COVER



The cover features human hair, a potential sorbent material for oil spill removal. Hair is the only human body part that continually grows, degenerates, and miraculously grows again throughout life. While it is composed of dead cells in its cuticle, the presence of biochemical and hydrophobic properties exemplifies its functionality as a sorbent. Hair can be a symbol of hope, of life and of better things to come. Despite the adversities life brings, we persevere and stay afloat. To rise above the sea of darkness means to emerge from a catastrophe — even stronger, wiser, and more powerful.

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FOREWORD

From the Campus Director

Celebrating the Research Excellence of Batch 2023, Class Eunoia

It is with great pleasure and immense pride that we present the sixth volume of PubliScience, the Research Journal showcasing the remarkable research works of the graduating Batch 2023 from the Philippine Science High School Western Visayas Campus. This volume stands as a testament to the unwavering pursuit of truth and excellence exhibited by these exceptional young minds.

The research outputs presented within the pages of this journal are a reflection of the countless hours of hard work, dedication, and intellectual curiosity that the members of Class Eunoia have demonstrated throughout their research journey. Their innovative ideas, meticulous data collection, and insightful analyses have culminated in a collection of studies that push the boundaries of knowledge and contribute to the advancement of various scientific fields.

We would be remiss not to acknowledge the invaluable role of our esteemed research teachers and advisers, who have served as mentors, guiding our PisayWVC scholars every step of the way. Their expertise, guidance, and unwavering support have been instrumental in shaping the research capabilities and nurturing the passion for inquiry among our students.

This volume of PubliScience is a celebration of the intellect, tenacity, and collaborative spirit of Batch 2023, Class Eunoia. We are confident that the research showcased here will inspire future generations of scholars and scientists to continue pushing the boundaries of knowledge.

May this journal serve as a lasting testament to the outstanding achievements of our graduating batch and as a reminder of the remarkable potential they possess as they embark on their future endeavors. We extend our heartfelt congratulations to Class Eunoia for their exceptional output in research and wish them continued success in all their future endeavors.

SHENA FAITH M. GANELA

Campus Director III

* * *

FOREWORD

From the Curriculum Instruction Division Chief

My heartfelt congratulations to Batch 2023, Class Eunoia, for their remarkable achievement in publishing *PubliScience: A Research Journal of High School Research*, Vol. 6. This accomplishment stands as a testament of a true Pisaynon that embodies dedication, perseverance, and exceptional scholarly abilities in the field of STEM courses.

This publication of research journals marks a highlight of your academic journey as a Pisay scholar. It demonstrates your proficiency in critical thinking, analytical skills, and commitment to pushing the boundaries of human character and understanding.

The depth and breadth of your research reflect the countless hours of meticulous investigation, thoughtful analysis, steady collaboration with groupmates, and rigorous experimentation or revisions to achieve the goals and objectives of your study. Your valuable findings and insights are poised to impact society, address pressing issues, and catalyze transformative change.

I commend your formidable effort to finish your research. You remain steadfast even at times you feel like giving up. This manifests your relentless pursuit of excellence, integrity, and service. Your success serves not only as an inspiration to your peers but also as a shining example for lower batches of Pisay scholars.

Moreover, let me also extend my heartfelt gratitude to the research teachers, advisers, and external experts who have guided and supported these students throughout their research endeavors. Your expertise, guidance, and unwavering encouragement have played a pivotal role in shaping these bright minds and nurturing their passion for knowledge.

Once again, congratulations to Batch 2023, Class Eunoia, on this extraordinary accomplishment. Your research journals will undoubtedly leave an indelible mark on the academic world, and we are immensely proud of your achievements.

Ingat kayo lagi,

ROLANDO S. LIBUTAQUE
Curriculum Instruction Division Chief

* * *

THE RESEARCH PROGRAM

The RESEARCH PROGRAM is a three-year curriculum aimed at honing the scholars' quality and skills as world-class Filipino scientists. Beginning with Grade 10, the curriculum presents a variety of research principles to cultivate the scholars' expertise in becoming respectable figures in their respective fields.

RESEARCH 1

Research as a subject is introduced in Grade 10. It is the foundational year for aspiring researchers wherein an in-depth discussion of the basics of the Scientific Method and the Research Process is done. The curriculum primarily covers the fundamentals of research such as topic selection, literature search, research design, and paper presentation. Scholars are also trained in writing their research proposals and research papers with general topics provided by the Research 1 teachers. Scholars form groups, called work units composed of at most five members. Research 1 culminates with the paper presentation of the Grade 10 scholars in *Pagsugidadon*.

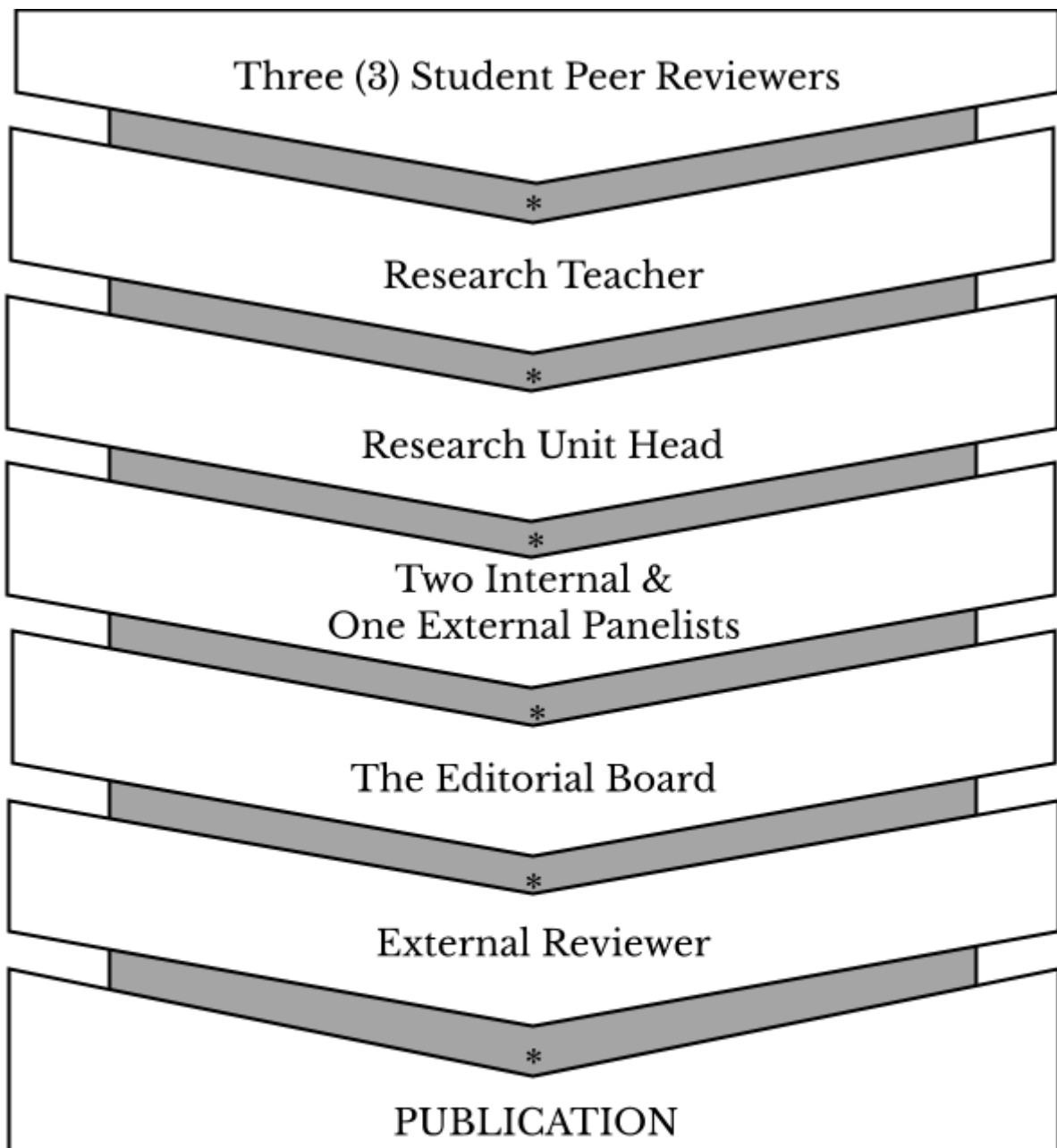
RESEARCH 2

Research 2 is the reinforcement year in Grade 11. During this year level, the writing of the proposal and the research paper are further scrutinized. Each section of a standard research paper: abstract, introduction, method, results, discussion, and conclusion is more pronounced in the syllabus. Research 2 is performed in work units of at most three members. Scholars are allowed to select any topic in alignment with their science options or elective under the supervision of their advisers, propose and defend their proposal to a panel, develop and enhance skills related to the study, perform the method outlined in their proposal, and report their findings in a full-fledged research paper. Research 2 concludes with the presentation of the results in the final defense.

RESEARCH 3

Research 3 is the culminating year of the research curriculum. It is reserved for Grade 12 scholars who organize activities and events that share their respective study's findings, including but not limited to research presentation (*Pagbantala*), poster presentation (*Pagbalandra*), seminar-workshop (*Pahisayod*), and community science conference (*Pagwaragwag*) with more events described at the end of this journal. This very journal is the fruit of the previous two batches' research experience. Research 3 focuses on finalizing the study and networking the results. It focuses on a community-oriented approach to making science more accessible. This is evident in the oral and poster presentations for students and professionals, workshops and seminars for high school students, and the gamification of each study for elementary students during the aforementioned events. Each study is given the opportunity to be published in this journal, provided that they have accomplished the review process outlined in the next page.

The Research Review Process



***Research Adviser**

As the research advisers are co-authors of the journal articles, they are updated with the article or its changes after each round of review.

THE RESEARCH COMMITTEE

The RESEARCH COMMITTEE is tasked with ensuring the quality of all research studies produced by the Batch 2023 scholars, performed from the 10th to the 12th grade. It is headed by the Research Unit Head who oversees and approves all research works, and is composed of research teachers who handle the Research classes for a specific school year and grade level, and research advisers who provide specific guidance, insight, and assistance in a consulting capacity in their fields of expertise. The Science Research Assistants and Specialists manage the unique labs, apparatuses, equipment, and reagents for the conduct of the respective projects of the scholars.

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PAGSUGUIDADON

PAGSUGUIDADON, from the Hiligaynon word *suguid* or "to report", is the culminating event for the Grade 10 Research curriculum. Scholars present and defend their paper to a three-person panel, composed of two invited panelists and a faculty member of PSHS-WVC. The papers are presented in five clusters with each study's overarching theme as the basis of categorization.

PAGSUGUIDADON, from the Hiligaynon word *suguid* or "to report", is the culminating event for the Grade 10 Research curriculum. Scholars present and defend their paper to a three-person panel, composed of two invited panelists and a faculty member of PSHS-WVC. The papers are presented in five clusters, namely: Water Studies, Marine Science, Biology, Plant science, and Development, with each studies' overarching theme as the basis of categorization.

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PAGBANTALA, from the Hiligaynon word *bantala* or “to inform”, is the oral presentation of the scholars’ studies to a panel of experts composed of an invited panelist, an alumni, and a faculty member of PSHS - WVC. For the SY 2022-2023, the studies were presented in 5 clusters namely: Microbiology and Food Science, Material Science, Product Development and Trend Analysis, Computer Studies, and Environmental Science (ordered below left to right, top to bottom).

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THE FINAL DEFENSE

The FINAL DEFENSE is the final step towards the end of the 3-year research curriculum. The scholars invite a three-person panel composed of one external expert and two PSHSWVC faculty to assess the merits and validity of their findings. The final defense panel recommends revisions to the study's manuscript as well as continually review the same until approval.

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PREFACE

We are honored to present the sixth volume of Publiscience, the homegrown journal of PSHS-WVC scholars. This edition showcases the works of Batch 2023 (Eunoia), whose research journey was uniquely shaped by the immediate aftermath of the COVID-19 pandemic. Conducting research during this period meant that certain restrictions were still in place, requiring adaptability, resilience, and creativity from our scholars as they navigated challenges in conducting experiments, gathering data, and collaborating with their peers and advisers.

Keeping true to the spirit of Pagpasanyog—the Hiligaynon word for "innovate"—Batch 2023 continues the legacy of pushing boundaries in scientific research. This year's volume highlights 14 articles, organized into three major clusters: Material and Food Science, Product Development & Trend Analysis, and Environmental Science. These clusters reflect the scholars' commitment to address pressing needs of society, from innovations in sustainable materials and food security, to the development of products that respond to emerging consumer trends, and to advancing solutions for environmental preservation and resilience.

The Editorial Board, alongside the Research Unit, acknowledges the significant role of scientific inquiry in nation-building. Despite the limitations imposed by a transitioning world, the students of Batch 2023 embraced their responsibility as young researchers, producing studies that not only contribute to the growing body of knowledge, but also hold the potential for real-world applications with social, economic, and environmental impact.

This volume comes at a time when the lessons of the pandemic remain fresh in our memories, reminding us of the vital importance of Science and Technology in safeguarding communities and shaping a better future. We hope that through the works presented here, readers may find inspiration in the perseverance and ingenuity of these young scholars, and be encouraged to carry forward the torch of truth-seeking, innovation, and service to society no matter the limitations.

THE EDITORIAL BOARD

* * *

DEDICATION

This journal is dedicated to the mentors and families whose belief in the student-researchers made this work possible, to the young minds who prove that age is never a limitation to discovery, and to the Filipino people, whose perseverance and resilience inspire every page.

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CLUSTER ONE

MATERIAL & FOOD SCIENCE

The papaya structure symbolizes a commitment to exploring preservation methods, a focal point within the realm of food science. The mosaic-style depiction of the papaya is a nod to the investigation into innovative materials like bioplastics, drawing a connection to the study of eggshells. Additionally, the plastic encompassing the papaya signifies the exploration into the world of microplastics within this cluster. Each element of the logo seamlessly weaves together the diverse aspects of research pursuits, creating a visual representation of our multidisciplinary approach to scientific inquiry.

Material science is a multidisciplinary field that delves into understanding the properties and applications of materials. On the other hand, food science focuses on scrutinizing food production, processing, and preservation methods to ensure safety and elevate quality. Studies within this cluster further emphasize areas such as food quality assessment, bioplastics, and microplastics, illustrating the interdependence of the two scientific disciplines in contributing to advancements in materials and food technology.

Mechanical properties of bioplastics of various starch to eggshell reinforcement ratios

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Abstract

Bioplastics are biodegradable polymers derived from the starch of natural and renewable sources such as tuber crops. While it is possible to create bioplastic with cassava starch, the resulting product has high moisture content and poor mechanical properties. In addition, the effects of varying the ratios of eggshell reinforcements on the mechanical properties of cassava-starch-based bioplastics have yet to be studied. The purpose of this study is to determine the optimal ratio of *Manihot esculenta* starch to eggshell reinforcement through comparison treatments and control groups. Unsuitable drying methods, improper storage, and handling caused multiple failed samples. This included the development of molds, samples not drying, and the inability to peel samples from the mold. Further development of better conditions in formulating plastic from cassava starch along with assessment of other properties should be investigated.

Introduction. - Bioplastics include all plastics that are derived from biodegradable resources. The importance of bioplastics lies in their biodegradability and source due to them being mainly composed of biological wastes. The study on bioplastics also has advantages for the environment due to their low carbon footprint and low energy cost in manufacturing [1]. While it is possible to create bioplastic with cassava starch, its unique chemical structure and processing behavior results in a product that has high moisture content and poor mechanical properties as stated by Xie et al. [2].

Existing research utilized cassava starch in bioplastic development with additional reinforcements to strengthen the mechanical properties of their plastics [3,4,5]. These reinforcements increased the tensile strength as well as the biodegradability of their bioplastics based on their results. Furthermore, other studies utilized eggshells for reinforcing their bioplastics from cornstarch and potato starch [6,7]. Results showed that reinforcing bioplastics with eggshells decreased the water absorption and increased tensile strength of the bioplastic. However, the cited studies only used a singular specific ratio during the conduct of comparative analysis between samples, the variation of the ratio of reinforcements and starch composition and the effect of these changes on the mechanical properties of cassava-starch-based bioplastics is yet to be investigated.

Based on Xie et al's [2] study, the creation of a starch-based bioplastic with the integration of a viable plasticizer and reinforcement ratio is necessary. Calcium carbonate or CaCO_3 reinforcements have properties that are

hydrophobic, this in turn causing the bioplastic sample to repel the water [4]. Eggshells contain approximately 95% calcium carbonate and 5% organic materials [19]. Therefore, the presence of CaCO_3 can increase the strength of the mechanical properties of the bioplastic. With the addition of reinforcements, the mechanical properties of the plastic would improve. Studies have stated that the integration of plasticizer and reinforcement is necessary; however, the amount used for these components in respect to the amount of cassava starch may negatively affect its tensile strength and water absorption. Thus, varying the ratios of reinforcements to the matrix is essential to determine how they would change the tensile strength and water absorption of the plastic.

The aim of the study was to determine the optimal ratio of *Manihot esculenta* (cassava) starch to eggshell reinforcement by comparing the water absorption and tensile strength. With this, the objectives of the study were:

- (i) To evaluate the tensile strength of the bioplastic treatment groups containing 10%, 15%, and 30% eggshell reinforcements in comparison to the control group (0% reinforcement);
- (ii) To evaluate the rate of water absorption among the bioplastic treatment groups, 10%, 15%, and 30% reinforcements;
- (iii) To evaluate the tensile strength and water absorption of the various treatment groups and analyze the data using ANOVA or Kruskal-Wallis test if the distribution of the data is not normal; and



(iv) To identify the functional groups present in the various ratios of bioplastic using Fourier-Transform Infrared Spectroscopy (FTIR) spectrometer and compare their spectra.

Methods. - The methods of the study were done in seven steps. These steps consisted of: preparation of materials, formulation of the samples, casting and drying, tensile strength test, water absorption test, and Fourier-transform infrared spectroscopy. The methodology of the study included several changes during the different trials in the formulation of the plastics. All the methods and changes were stated in each step.

Preparation of materials. Medium sized (21 oz.) chicken eggs were utilized as the source for 120 grams of eggshells. The shells were thoroughly washed with distilled water and then dried in a preheated forced-air oven at 60°C for 10 minutes. Once no excess water was observed in the eggshells, these were powderized inside an industrial blender (2.0L Drink Machine; 220 V) for 3 minutes.. Subsequently, the resulting eggshell powder was initially sieved using a mesh size 60 sieve (<0.250 mm), followed by a 30 µm sieve to ensure a uniform and fine particle size.

For the preparation of the cassava starch, the starch was initially sieved using a mesh size 60 sieve before oven drying. The starch was oven-dried for 30 minutes at 60°C using a Biobase BOV-V65F oven of the PSHS-WVC laboratory before it was used for the formulation of the samples.

Formulation of the bioplastic. The conduct of the study involved the following treatment groups:

Control Group = 100: 0 with 5 g starch and 0 g eggshell reinforcement

Treatment 1 = 90: 10 with 4.5 g starch and 0.5 g eggshell reinforcements

Treatment 2 = 85: 15 with 4.25 g starch and 0.75 g eggshell reinforcements

Treatment 3 = 70: 30 with 3.5 g starch and 1.5 g eggshell reinforcements

Starch and eggshell reinforcement were mixed with 70 mL of distilled water. The mixture was then stirred starting from 350 RPM for 2 to 3 minutes until the starch had been dissolved by the water. Five (5) mL of glycerol and 1.5 mL of 0.1 M acetic acid were then added to the same mixture. In a separate beaker, 1.25 g of polyvinyl alcohol (PVA) was placed in a separate beaker and dissolved with distilled water in a 1:24 mass-to-volume ratio. The PVA-water solution was stirred with a magnetic stirrer at 350 RPM until the polyvinyl alcohol was visually observed to be visually observed to be dissolved in water. The contents of the two separate beakers were then combined in a singular 400 mL beaker. The mixture was then heated on a hot plate at an internal temperature range of 60 to 70°C. The content after all the components have been added was stirred

gradually with a magnetic stirrer for 30 minutes. The formulation involving the diluted PVA solution was only used for trials 1 to 4. The rest of the trials followed the same formulation without the polyvinyl alcohol. The solutions formulated during trials 4 to 9 were also subjected to degassing using a Bransonic ultrasonic bath.

Casting and drying of samples. After the mixture was stirred and heated, the mixture was poured into a 15 cm x 8 cm aluminum pan. The initial trial followed this procedure however, further development prompted the researchers to change the container to a glass Petri dish with a diameter of 9 cm. This method was followed for trials 2 and 3. For the succeeding trials, 4 to 9, a plastic petri dish with similar dimensions was utilized in the casting of the bioplastic mixture. Once the mixture was casted into the Petri dish, the samples were subjected to oven drying for 30 minutes at 60°C. After the oven-drying process, the Petri dishes were transferred to a fume hood to be air-dried for a period of 48 hours. Trials 4 to 9 were also sprayed with 99% ethanol to eliminate surface bubbles.

Tensile strength test. After the bioplastic samples had fully dried in their respective molds, a minimum of 100 mm length of sample was required to be tested using the Ametek Brookfield Texture Analyzer for food-grade and low-density samples. It was then cut and peeled from the casting molds. The samples were contained and sealed in a container which was transported to the University of the Philippines Visayas Regional Research Center Food Laboratory for further testing.

Water absorption test. ASTM-D570 was used to measure the percent of water absorption [4]. Samples with dimensions of 1 cm x 3 cm were cut from the bioplastic sheets peeled from the casting mold (i.e., petri dish). These samples were created using a centimeter ruler and were cut from the bioplastic sheet using a scalpel from a dissecting kit. The initial weight of the sample was measured using an analytical balance (KERN ABJ-NM). Then, it was placed inside a 250 mL beaker containing 100 mL of distilled water for 24 hours. Once the immersion period had ended, the sample was cloth-dried until no water could be retrieved from its outer surface. The final weight was recorded using an analytical balance. Similarly, the percentage of water absorption was solved through this formula:

$$WA(\%) = \frac{(FW - IW)}{IW} \times 100\%$$

Where:

WA = Water Absorption

FW = Final Weight of the Sample Post-Immersion

IW = Initial Weight of the Sample Pre-Immersion



FT-IR Spectroscopy. The samples were subjected to FT-IR analysis to determine the presence of bonds and functional groups present. A 1 cm x 1 cm sample was cut from the prepared bioplastic sheets for testing. A Shimadzu IRAffinity-1S FTIR equipped with a QATR 10 was used to scan the samples.

Disposal and safety procedures. Wearing of laboratory personal protective equipment (PPE) was observed during the handling of glassware, equipment, reagents, and samples. Used gloves, unused eggshells, and disposable containers were properly disposed into designated disposal bins inside the chemistry laboratory of PSHS-WVC.

Results and Discussion. - The aim of the study is to determine the optimal ratio of eggshell reinforcement to *Manihot esculenta* (cassava) starch. This section includes the results and key findings from the following tests: tensile strength, water absorption, and FTIR analysis.

Tensile Strength. A total of nine (9) trials of bioplastic samples were created and subjected to a feasibility test for the tensile strength test. The feasibility test has three criteria which need to be met. The samples must: (1) have the prescribed minimum operating length of 100 mm as required by the Ametek Brookfield Texture Analyzer; (2) have an even surface area [8]; and (3) be dry after the conduct of the following drying methods: (i) air-drying - the sample is dry at room temperature (30°C) after 48 hours. (ii) oven-drying - the sample is dry after 30 minutes at a temperature of 60°C inside a biobase forced air oven. In the evaluation of the tensile strength of the produced samples, none of the samples were subjected to the procedure due to the failure to produce a viable material for testing.

The key finding which affected the viability of samples is the occurrence of clumping. The clumping of polyvinyl alcohol granules was observed in the circumference and center of the petri-dish containing samples sourced from trials 2, 3, and 4 of all the prepared reinforced samples. Clumping resulted in the strong adhesion of the samples to the casting mold and the uneven distribution of the polymer throughout the mixture. This defect can be further attributed to the undissolved PVA present in the casting slurry. Studies point out that for the PVA to be dissolved it must be within a temperature range of 60°C to 70°C to avoid hydrolysis and must be at a stirring speed of 200 RPM to minimize bubbling at the surface [9,10]. The clumping of the polymer matrix in the samples can be explained by the uneven distribution of components in the mixing and casting process of the bioplastic [11]. Therefore, factors such as the RPM rate of the magnetic stirrer and the temperature range of polyvinyl substances must be monitored to ensure that it can be incorporated into the mixture into a dissolved form. Failure to take note of these components had led to uneven dissolution of granules. Without samples meeting the aforementioned criteria, the conduct of the tensile strength test was no longer feasible.

Water Absorption. The water absorption test involves the use of ASTM-D570 in order to determine the percent of water absorption. The procedure is used to assess the hydrophobic properties brought about by the eggshell reinforcement [4]. The data analysis process consists of the Shapiro-Wilk normality test followed by the Analysis of Variance with 5% confidence level or the Kruskal-Wallis test depending on the normality of the distribution.

The replicates of the reinforced samples were subjected to the water absorption feasibility test. As adapted from previous studies, the following criteria must be met by the samples prior to the test. The samples must: (1) have a size of 1 cm x 3 cm [4]; and (2) not contain signs of fungal growth as it would affect the water absorption of the samples [12].

A key finding observed during the post-casting phase is the occurrence of glycerol leaching which prevented the drying of the samples within the prescribed time period. The humidity of the storage area of the sample undergoing air-drying is also a factor that contributed to the inability of the samples to dry within the prescribed time. Previous studies such as that of Jones et al. [13] have expressed that glycerol leaching would render samples unsuitable for usage and testing [13]. This phenomena negatively affects the viscoelastic properties of the bioplastic and weakens the hydrogen bonds within the product. While the water absorption test does not depend on the weight of the sample to be utilized but rather the percent increase of the sample under water immersion, the failure to extract suitable samples is a hindrance to perform the test on the prescribed amounts of samples. The conduct of the procedure was limited by the presence of moisture which caused the wetness of the sample, which consequently could not be subjected to the test. Additionally, fungal growth in the sample is another factor that prevented the conduct of the procedure.

Statistical Analysis. With the failure to conduct the tensile strength test and water absorption tests, statistical analysis was not conducted. The two aforementioned tests failed to provide any numerical data because of the insufficient number of samples that could be extracted while meeting the prescribed criteria for each test. As previously mentioned, samples that could meet the required size for the conduct of the tensile strength test were not possible. Additionally, a significant number of samples (i.e., samples 1, 2, 5, 6, 7, 8, and 9) presented mold growth and presence of surface moisture which hindered the conduct of the water absorption test. Crops producing tubers or roots have specific requirements for storage because of their high moisture content (60 to 80%) [14]. Flour with high moisture content will be more vulnerable to mold growth [15]. In line with this, proper storage and drying of the cassava starch must be done in order to prevent mold growth during the formulation and drying of samples. Additionally, ensuring that the samples are fully dry is essential for the tests to be conducted.



FTIR Results. FT-IR spectroscopy was only conducted on the samples containing 10% and 15% eggshell reinforcements and the control group. The results of the various treatments were compared with each other in regard to the identification of functional groups present. The analysis of the spectra was limited to the wavelength of the functional group region. Moreover, FTIR analysis through the identification of the functional groups presence confirmed that the dried product is defined as a bioplastic [11]. The presence of C-H bonds and O-H bonds is brought about by the polymerization of starch and water. The two components undergo polymerization with the addition of heat. This reaction results in the presence of C-H, O-H (carboxylic acid) and O-H (alcohol) functional groups, thus forming polymer chains. The common functional groups reflected by the extracted samples with respective starch-to-reinforcement ratios of 0% (control group), 10%, and 15% reinforcement content indicate the presence of the following bonds: C-H, O-H (carboxylic acid) and O-H (alcohol). The analysis of the spectra was restricted to the region to the left of 1400 cm^{-1} which is defined as the “functional group region”. Meanwhile, the range between 600 and 1400 cm^{-1} is defined as the “fingerprint region”. The interpretation of the results was focused on the “functional group region” as it is where most stretching frequencies occur and the “fingerprint region” was not integrated into the findings since the overlapping of bonds is prone to unreliable interpretation. All functional groups that are relevant to the creation of bioplastic are present within the spectra and peaks have also been observed within the prescribed range.

Recommendations. In order to obtain bioplastic that has better characteristics, the researchers highly recommend to:

- Use a desiccator for sample storage to prevent excess moisture and prevent possible mold growth.
- Explore the effects of other starch to reinforcement ratios in the creation of bioplastic. Further modification of the proportion of reagents such as acetic acid to the volume of the mixture should also be taken into consideration to provide a broader range of options in the optimization of the mechanical properties of the product.
- Refine the air-drying method through storing the samples in an area which prevents the build-up of moisture while simultaneously protecting the contents of the casting mold from contamination.
- Consider factors such as temperature and relative humidity of the working and drying area of the samples inside the laboratory.
- Perform FTIR analysis for samples from various trials to discover trends and the consistency of the data procured; it is also

advised to explore other data sets of wavelengths that could be made to determine the presence of other functional groups.

- Compare FTIR graphs of glycerol and the dried casted mixture to confirm that glycerol leaching has occurred in selected samples that feature branch-like patterns on the surface.

Limitations. The bioplastic samples had high moisture content attributed to poor drying conditions and a lack of appropriate facilities. With this, the samples were not extracted and were not viable to be subjected to the tensile strength testing. In addition, the presence of molds contributed to the reason why the samples were not viable to be subjected to the water absorption test. The data analysis through ANOVA or Kruskal-Wallis test was not conducted due to the absence of quantitative data that had to be collected from the tests. With regard to the FTIR analysis, the data set of the wavelength was limited to the functional group region. From a chemical standpoint, it is limited to the enumeration of functional groups within the said region found during analysis. This is defined as the region to the left of 1400 cm^{-1} in the spectra and is where most stretching frequencies occur. As such, peaks in the fingerprint region were not noted in the presentation of the findings. The absence of a confirmatory test for bioplastics hindered the classification of the produced material to a specific type of bioplastic. This limited the researchers to the evaluation of present functional groups based on the necessary functional groups prescribed for the polymerization and formation of bioplastic [15]. The basis for the functional groups evaluation was the library database of the LabSolutions IR software.

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Abundance of microplastics in a river-estuary along a rural-urban gradient pathway

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Abstract

Microplastics are rapidly accumulating in quantity. Exposure to microplastics can be a threat to ecosystems as mammals ingest 0.1 to 5 grams of microplastics per week. This study sought to determine the abundance of microplastics found along a rural-urban gradient in Iloilo River. Samples were gathered from five sites of differing parameters, treated to remove non-microplastic substances, and identified through a compound microscope. Results showed that the abundance along the river ranged between 1 to 4 particles per liter. The unmonitored rural sites had the highest abundance and the monitored urban sites had the lowest abundance. Additionally, most of the microplastics gathered were in the size range of 150 to 500 μm , transparent in color, and are film morphological type. Investigation of additional parameters like area usage may be needed to understand microplastic abundance patterns as there was no strong correlation between urbanization and microplastic abundance.

Introduction. - Plastic is one of the most widely accessible and mainstream production resources. It is reported that the Philippines uses roughly 59.7 billion sachets and 20.6 billion shopping bags annually [1]. The staggering amount of single-use plastic consumed yearly is one of the greatest obstacles in current efforts in waste management [1].

Microplastics are a type of plastic debris that is less than five millimeters (5 mm) in length, and they originate from the degradation of macro plastics and manufacturing runoffs [2, 3]. Its existence has been seen in the air, waterways, sediments, and in the digestive system of animals [4, 5]. The threat of microplastics has prompted research on the material and its effects on ecosystems and human life [6]. Humans have been heavily exposed to microplastics through ingestion, inhalation, and dermal contact [7, 8]. Ingestion is thought to be the main pathway, due to humans' high trophic level in the food chain [2]. Ingestion allows humans to consume 0.1 to 5 grams of microplastics per week, or 1,000 to 3,000 microplastic particles per year into the body via food products [7]. This may lead to chromosome alteration, cancer, and increased vulnerability to neuronal disorders [8].

Abundance is the measure used to determine how much microplastics are present in the water, usually measured per m^3 or liter [9]. Understanding the microplastic abundance along a river's course is a critical factor in identifying the key sources of microplastic and in developing management interventions. Moreover, the morphological type and the physical characteristics of the microplastics are also important in identifying the possible sources of the microplastics. They are one of the many ways to tell the origins of the plastic as certain

morphological types retain their characteristics despite degradation. A rural-urban gradient pathway is a river with one continuous pathway that crosses through a mixture of rural and urban areas. Rivers in urban areas can contribute to the microplastic concentrations in the ocean, specifically the microplastics found in the surface water since they can easily be transported by tides.

Iloilo City (10.7202° N, 122.5621° E), the provincial capital of Iloilo, Philippines, has a population density of 5,842 people per km^2 [10]. Due to its high population density, the presence of microplastics can pose a hazard to humans and animals alike [11]. The Iloilo River is a river-estuary landmark that spans over 10 km in length [12]. It starts in the municipality of Oton where the surrounding barangays have less than 5,000 inhabitants and thus are classified as rural [13]. The river's surroundings transition from rural to urban as it enters the populated city, thus making it a rural-urban gradient pathway. There is a need for microplastic studies in freshwater bodies, specifically in South East Asian countries, where there is a trend of rapid urban development but poor waste management [14].

This study aims to provide information regarding the abundance of microplastics in the surface water of a rural-urban gradient pathway. The microplastics were identified through sample collection, filtration of microplastics, microscopy, and classification. Additional data such as microplastic physical characteristics and morphological type were also collected. It specifically aims to:



- (i) To quantify the number of microplastics found per area via visual counting;
- (ii) To calculate the abundance (in particles per liter) of microplastics found per site;
- (iii) To determine the most prevalent physical characteristics (size and color) among the microplastics found;
- (iv) To determine the most prevalent morphological type among the microplastics found; and
- (v) To determine the trend line in the abundance of microplastics in different sections of the Iloilo River.

Methods. - The data gathering procedure was divided into four groups: sample collection, sample treatment, sample identification, and data analysis.

Sampling Site. The research study took place in the Iloilo River in Iloilo, Philippines, which is approximately 14.5 km in length. The river's starting point is located in the municipality of Oton. It stretches across the Iloilo city districts and ends at the Iloilo Port located between the Iloilo City Proper and the Lapuz district.

There are three categories for a barangay to be considered urban [13]. The first category of an urban barangay should have at least 5000 inhabitants. The second category requires at least one establishment with a minimum of 100 employees in the barangay. The third category states that there should be five or more establishments with 10 to 99 employees within the two kilometer radius of the barangay hall [13]. Meanwhile, a barangay is considered rural if it does not fit any of the urban criteria.

The Iloilo River is considered a rural-urban gradient pathway. A rural-urban gradient pathway is a body of water that is surrounded by both rural and urban areas. The river's origin point, Oton, is a rural zarea because it has less than 5000 inhabitants. Meanwhile, the Iloilo Port area fits all of the criteria,

and is thus labeled as urban. On the other hand, there is a mixed gradient of urban and rural barangays surrounding the area from the start to the end of the river.

Table 1. Sampling Sites Details

Site	Code	Distance	Coordinates	State of Area
1	U _M R1	1.46 km	10.69479°N, 122.49888°E	Unmonitored Rural Area
2	U _M R2	4.54 km	10.69632°N, 122.52166°E	Unmonitored Rural Area
3	U _M U3	7.76 km	10.70032°N, 122.54170°E	Unmonitored Urban Area
4	MU4	9.67 km	10.70167°N, 122.55886°E	Monitored Urban Area
5	MU5	12.08 km	10.69618°N, 122.57207°E	Monitored Urban Area

Sample Collection. Systematic sampling was used to determine the five general sites, with equal distance between each site as shown in Table 1. Ten liters of water samples were collected from each of the five sites from Iloilo River, Philippines as shown in Figure 1.

The sampling area proper is in the center of the bodies of water: each site was at least 2.4 km away from the other, at least 5 meters away from the riverside, and 0 to 12 centimeters below the surface for each site [15]. Moreover, the weather, time, and pin location of the collection was documented for each site.

The water samples were wet-sieved using stacked mesh sieves (5 mm, 2 mm, 1 mm, 0.3 mm, and 0.15 mm) in order to obtain the particle samples [15, 16]. These were then transported to the lab.

Sample Treatment. Microplastics are removed from the sieve using a vacuum pump with a 0.47 µm pore size filter paper [16]. Next, samples underwent Wet Peroxide Oxidation (WPO). The samples were

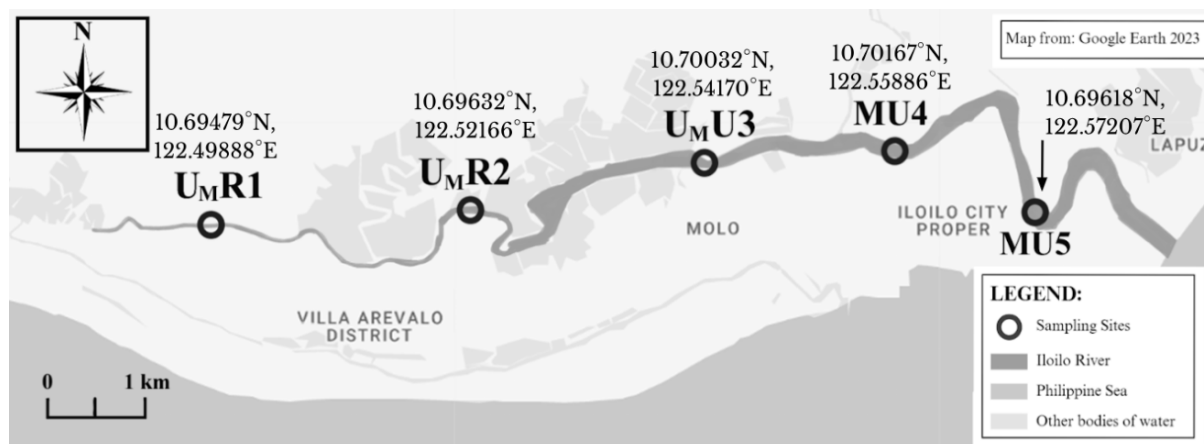


Figure 1. Map of the Iloilo River, Philippines and the five encircled sites (from Google Earth)



mixed with 5 mL of aqueous 0.05 M iron (II) solution and 5 mL of 30% hydrogen peroxide (H_2O_2), and then heated to 75 °C and stirred for 45 minutes at 200 rpm to remove organic material [5, 15].

The remaining particles underwent density separation to remove the inorganic particles with a higher density than plastics. This was done using a 10 mL sodium iodide (NaI) (1.55 to 1.6 g per mL) brine solution and left overnight to settle [17]. Next, a peristaltic pump with a 0.47 μ m pore size filter paper was used to drain the water out of the mixture and left to air dry overnight [5,15].

Sample Identification. The treated samples were individually isolated with tweezers and placed on glass slides for identification. For the smaller samples, the filter paper was placed under the microscope at full brightness in order to observe the particles. A compound microscope at 40x magnification [4] was used to identify its physical characteristics as shown in Figure 2. Free et al.'s [18] table, Lusher et al.'s [19] description, and Dehghani et al.'s [4] study served as libraries for confirmation. This process was done for each microplastic.

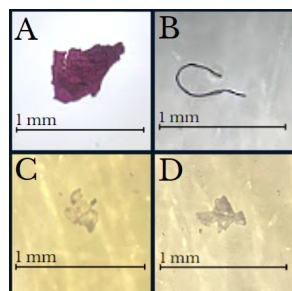


Figure 2. Photographs of different microplastics; (A) Violet fragment, (B) Black fiber, (C&D) Transparent film

The software *ImageFocus4 Version 3.1.2* [20] was used to photograph the particles and used to measure the size of each particle sample. This was done using a 1 mm / 100 div calibration slide for calibration. Samples below 150 μ m were disregarded due to difficulty in identifying their characteristics [21]. The background color of the photos was caused

by the reagent (NaI) during density separation. These shades of yellow are from the differing I2 amounts in the solution due to possible amounts of chlorine in the freshwater.

Data Analysis. The data gathered was analyzed by calculating the abundance per area and determining the trend line. The characteristics and morphological types of the microplastics were placed in bar graphs, while the abundance was shown in a table. A scatter plot was used to show the trend line of the data. No specific statistical analysis test was performed due to the descriptive nature of the study.

The abundance of the microplastics was calculated using the following equation:

$$\text{Abundance} = \frac{\# \text{ of particles}}{10 \text{ L}}$$

Safety Procedure. Face masks, lab gowns, and nitrile gloves were worn for all laboratory procedures with adult supervision.

Results and Discussions - The results show that the number of microplastics found in the river ranged from 9.7 to 38 samples per 10L. Meanwhile, the microplastic abundance has a range of 0.97 to 3.80 par/L. The microplastic abundance average of the rural areas was 3.4 par/L and the average of the urban areas was 1.85 par/L.

Table 2. Microplastic Results Per Sampling Site

Site	U _M R1	U _M R2	U _M U3	MU4	MU5
Number	38	30	30	9.7	13.3
Abundance	3.80	3	3	0.97	1.33
Most Abundant Size(in μ m)	150 to 500	150 to 500	150 to 500	150 to 500	150 to 500
Most Abundant Color	Black	Black	Trans-parent	Black	Black
Most Abundant Morphological Type	Film	Film	Film	Film	Film

Legend: U_M for Unmonitored, M for Monitored. R for Rural, U for Urban. The number indicates the site number.

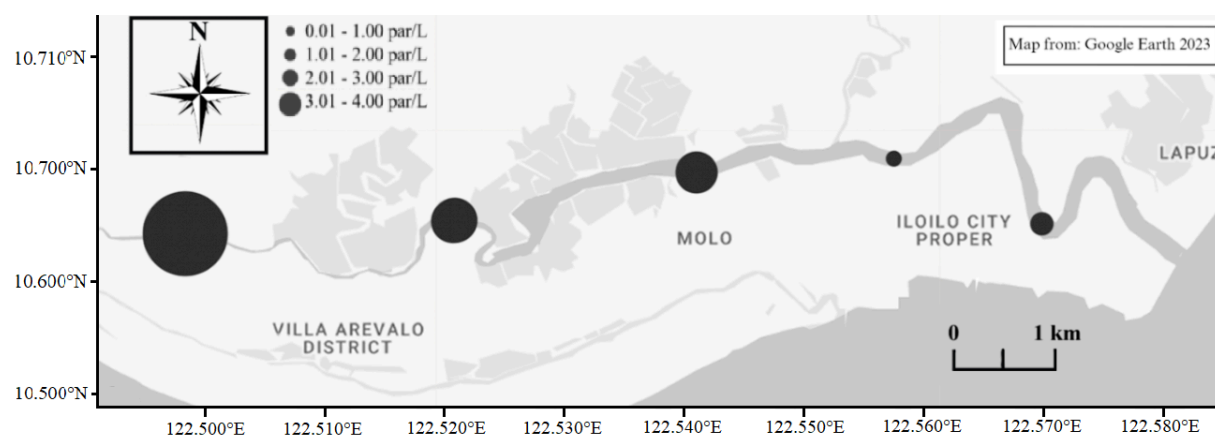


Figure 3. Iloilo River Map with Microplastic Spatial Distribution.



Observations suggest that the site's monitoring status affects the microplastic abundance in the area. The abundance of the Iloilo River has similar values to that of Cañas River (1.58 par/L), Pasig River (3.41 par/L), and Parañaque River (5.02 par/L) [15]. These similarities may be due to their shared history and surroundings. In the study conducted by Osorio et al. (2021), the Cañas river with the least microplastics was far from sources of plastic emissions, while the rivers with higher abundance values were heavily polluted and surrounded by plastic manufacturing industries [15]. On the other hand, the Pasig River, despite being in a polluted area, had a lower abundance due to a rehabilitation program, similar to Iloilo River [15]. However, there are other studies that have lower microplastic ranges than this study; which could have been affected by the difference in water sample amount [5, 15]. The counting of microplastics was limited to microplastics within the size range of 150 μm to 5 mm because the available equipment is not able to handle microplastics less than 150 μm .

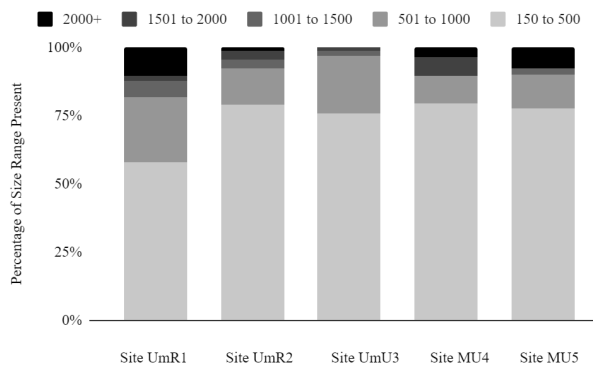


Figure 4. Bar Graph of Microplastic Sizes per site

As seen in Figure 4, the majority of microplastics were characterized within the size range of 150 to 500 μm . It is to be noted that this software provides low quality images, and can lead to inaccurate particle measurements. The results were triangulated to eliminate such limitations. It is hypothesized that the abundance of 150 to 500 μm sized microplastics originated from severe degradation and fragmentation of waste in the surrounding areas. These results align with microplastic findings and observations in the Parañaque River, where their most abundant size range is 250 to 500 μm [15]. It contains a public seafood market - this meant that its main source possibly had more degradable plastic products. The results also align with microplastic findings in the Chi River Basin, which has their most abundant size range at 51 to 500 μm [22]. One of the Chi River Basin sampling sites was surrounded with light industry plants.

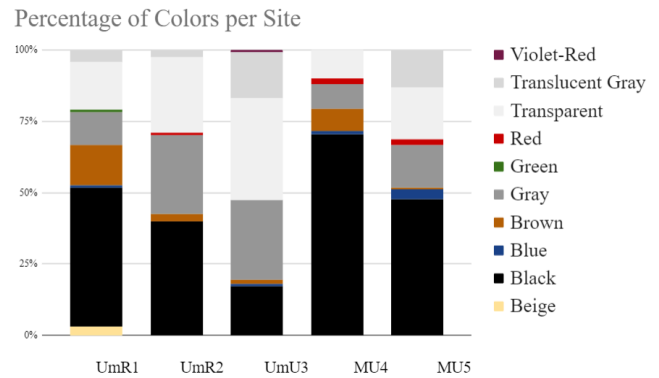


Figure 5. Bar Graph of Microplastic Colors per site

Figure 5 shows that the most prevalent colors among the microplastics found were black, transparent, and gray. This suggests that the majority of the microplastics found can be traced back to plastics of those colors. Although the transparent opacity was also prevalent in other studies, the majority of the surface water microplastic studies had blue and white as their most abundant colors [23, 24].

For studies with vibrant colors common in their findings, it was found that these studies were conducted in rivers lined with industrial and commercial areas where colored plastic is commonly used. This description does not fit Iloilo River's surroundings, and asserts the small percentage of vibrant plastics in the study. Only three out of the five river sites were near industrial and commercial areas (U_{MR1} , U_{MU3} , and $MU5$). U_{MR1} had the most diversity in color. U_{MR2} , a site surrounded by rice fields and the least industrialized, had the least color diversity. Additionally, the abundance of transparent and non-vibrant colored microplastics is due to the microplastic degradation that causes the color to fade overtime [3, 15]. However, the degradation rate of the microplastics found is not constant, as the age of the particles and their duration in the river are uncontrollable variables. Additionally, because the samples are in the surface water, there is a lack of ultraviolet B-rays to initiate the extreme degradation process which can cause the microplastics to compile in the river [3].

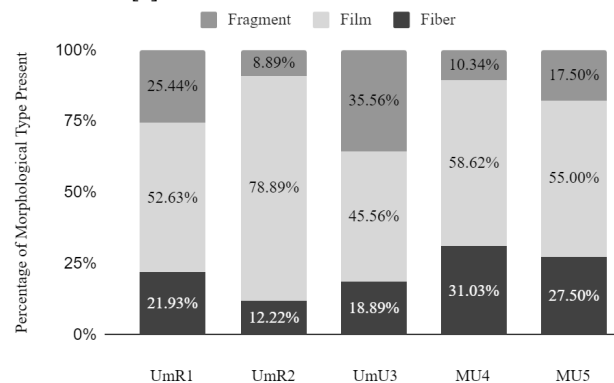


Figure 6. Bar Graph of Microplastic Morphological Types per Site



Only three morphological types were identified across the five sites (film, fragment, and fiber), with film being the most abundant. This aligns with a study in a Mongolian lake; however, their results showed that fiber and fragments were more prevalent [11, 15, 18]. Their findings were caused by waste dumping and plastic manufacturing industries within the area. The Iloilo River, especially in urban protected areas, is mostly free from plastic waste and has little fishery activity. The only macro plastic waste encountered were sachets and plastic bags, which are film types [17], suggesting that the waste surrounding the area influences the prevalence of morphological types found. It also suggests that wrappers, plastic bags, and other film plastics are the main cause of pollution along the Iloilo River. The microplastics found in the river differ from previous microplastic studies in abundance and morphological type due to undetermined factors such as the waste management in the sampling site areas.

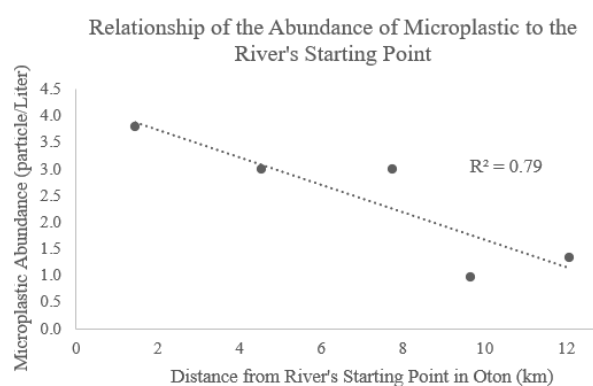


Figure 7. Relationship of the Abundance of Microplastic to the River's Starting Point

Given by the negative trendline, there is an inverse correlation between microplastic abundance and distance from the origin point, indicating that rural areas have less microplastic abundance. This corresponds to a study indicating a positive correlation between high microplastic abundance and lack of solid waste management despite population density [11, 18]. However, the same studies also stated that there is a high positive correlation between microplastic abundance and population density [22, 23]. This has opposite results to our study, as the urbanized and densely populated areas of the Iloilo River are rehabilitated [12]. However, this rehabilitation did not apply to the rural areas, especially in the UMR1 site, where the area was a mix of populated and heavily vegetated, suggesting that the state of urbanization itself may not be a factor in the increase of microplastic abundance in the Iloilo River, but rather the human activities in the affected areas. The unmonitored areas had higher values than the monitored areas. It is to be noted that the number of sites used might have affected the trendline of such phenomena as this study was limited to having only five sites. Additionally, only the population density and visual observation of surroundings were taken into account. Other factors such as waste management practices and regulations of the barangays were outside the scope of the study.

Limitations. The flow rate of the water's current during the collection and its area could not be measured. The water volume (L) was used as a replacement for the collection area measurement. Only ten liters of water were collected per site, and only microplastics within the size range of 0.15 mm to 5 mm were investigated. Due to limited chemical supplies, the reagents used in the Wet Peroxide Oxidation method used in the sample treatment were scaled down; thus, no blank samples were used during the study.

Conclusion. - The abundance of the microplastics throughout the river is 0.97 to 3.8 par/L, with an inverse correlation between microplastic abundance and the distance from the starting point. Microplastics commonly are in gray colors, a size range of 150 to 500 μ m, and a film morphological type. There is a weak correlation between rural-urban and microplastic abundance, but a higher correlation with monitoring status, and thus its lack of waste management.

Recommendations. - A higher quality microscope camera lens is recommended to accurately count a larger microplastic size range. For abundance, future studies should have a higher water volume quantity per site for a more detailed data set. For the color, size, and morphological type, high quality software is recommended for more accurate measurements and identification of the characteristics. It is also noted that the opacity of the microplastic may also be investigated as it could be related to the other characteristics. More sampling sites are needed to provide a more accurate and detailed trendline. Further investigation is needed regarding possible correlations between the abundance in the river and other influencing factors, such as the surroundings' waste management.

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Post-harvest quality assessment of *Carica papaya* L. 'Red Lady' papaya coated with rice bran wax (RBW)

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Abstract

Carica papaya L. fruits are delicate and perishable due to their high water content and would benefit from preservation methods. Waxing is a preservation method that serves as a barrier equivalent to a laminate film on the peel. Rice bran wax (RBW) as a coating has been noted to have delayed the produce ripening process. This study aimed to determine the quality of papaya coated in 15%(T1), 20%(T2), and 25%(T3) RBW emulsions against a control over a time period by assessing %weight loss, pH, fruit color, and decay incidence. Results showed that T1 had the highest weight loss percentage, pH level, and lowest decay incidence out of all treatment groups. T2 had the highest decay incidence, whereas the T3 showed the lowest %weight loss. Results had statistically insignificant differences between all treatments for all parameters. Thus, RBW is not recommended for *Carica papaya* L. fruit preservation.

Introduction. - *Carica papaya* L. fruit is produced in about 60 countries, especially in developing countries such as the Philippines which mainly grows in home gardens or as an intercrop [1,2]. It is delicate and perishable due to its high water content and therefore lags far behind bananas and pineapples in world trade [3]. Papaya shelf-life is crucial as the papayas are stored for 1 to 2 days before being distributed to wholesaler retailers where they must last at least 3 days at the supermarket or retail shop [4]. Current preservation methods that are used in the country are the usage of modified atmosphere packaging (MAP) [5,6] and the use of 1-methylcyclopropene (1-MCP) [7]. Waxing is another method of prolonging a fruit's shelf life by coating it in an artificial waxing material. One such material used for waxing is rice bran wax (RBW) [8,9,10]. This method does not harm the environment and is a cheaper alternative to other preservation practices [11].

RBW has been noted to inhibit ripening while being utilized as a wax coating for produce with it being found to be an effective way to extend tomato shelf-life of up to 27 days [8,9]. Similar results can also be seen with limes, sweet peppers, and cherry tomatoes [8,9]. The common material for waxing is Carnauba wax which must be imported as its source plant *Copernicia prunifera* can only be found in northeastern Brazil [10]. RBW, on the other hand, can be made and procured locally in the Philippines as a by-product of the biowaste of rice milling.

The physical and chemical properties of a fruit can be analyzed to determine or approximate its maturity, namely %weight loss, pH, color, and decay incidence.

Weight loss percentage is an indicator of the fruit dehydration process due to transpiration. Papayas comprise 80 to 85% water making them highly perishable as a high water content makes them highly susceptible to microbial growth [13]. They are also climacteric fruits that continue to ripen and transpire even after harvesting wherein there would be a rapid rise in the rate of oxygen and carbon dioxide exchange [14]. Papayas couldn't replace water that has been lost as water vapor once they are taken off from the main plant thus contributing to the weight loss products will experience. When moisture loss is too high, produce can experience commodity deterioration which includes symptoms like shriveling [15]. Wax coatings like RBW act as a second layer or barrier to retain moisture that could potentially lead to weight loss due to moisture loss [13].

Ripening and subsequently pH control in fruits are very important to prevent color and texture loss [17]. An increase in total acidity observed during ripening is believed to be associated with an increase in free galacturonic acids [18]. Fruits with a pH range of 4.5 or below do not allow the growth of most of the bacteria with exempted examples being molds, yeasts, and aciduric bacteria [19].

Color is one of the first quality attributes a customer can detect in food products [16]. Color change in papayas can be seen as their smooth thin green skin turns yellow or red as it ripens, and their succulent flesh ranges from yellow to orange to red [20]. Therefore, waxing can slow down the ripening process which can be reflected by the color change of the fruits.



Decay incidence is the occurrence of decay symptoms. Such symptoms can be decay and mold, sunken areas on the skin, discoloration, overripeness, softness, scarring of the skin, bruising of flesh, brown spots on the skin, and shriveled appearances [21]. The high moisture content and soft texture of fruit make it susceptible to mechanical injury throughout its production and retail life [14]. Aside from being a protective barrier, wax coatings can also create a non-water-compatible surface that is not conducive to pathogen growth while sealing small cracks and dents in the exocarp to establish a barrier against pathogen entry [23].

There are limited investigations conducted utilizing RBW as the material for waxing on papaya and significantly bigger fruit sizes than sizes found in current RBW studies.

This study's findings will contribute to the enhancement of papaya preservation techniques for producers, particularly in exploring alternative wax materials like RBW, thereby expanding the existing body of research in this field. The additional information on RBW provided by this study may encourage other researchers to further investigate RBW or present different methods for using it as a wax coating.

This study aimed to determine the quality of *Carica papaya* L. 'Red lady' papaya coated with RBW. The study specifically aimed to:

- (i) measure the papaya fruits' percentage weight loss, pH level, fruit color, decay incidence, and mean values of the treatment groups [(T1) RBW: 15% (w/v), (T2) RBW 20% (w/v), (T3) RBW 25% (w/v)] and the control group;
- (ii) compare the papaya fruits' percentage weight loss, pH level, fruit color, decay incidence, and mean values of the treatment groups and the control group; and
- (iii) determine if there is a statistical difference in the mean percentage weight loss, mean pH level, mode of fruit color, and mode decay incidence of papaya between the treatment and control groups.

Methods. - This study used an experimental approach to examine the quality of Red Lady papaya. The study lasted four weeks, with one and a half weeks allotted for material procurement and authentication and setup preparation, another one and a half weeks for data collection, and the final week used for value computation and data analysis. Each papaya was given a code and was randomly assigned to a group. There were three experimental groups and one control group, with each group having three replicates as per the standard control of the Randomized Complete Block Design (RCBD) with a total of nine papayas per group and a total of 36 papayas overall. The experimental phase was conducted for 9 days, and an assessment of the fruit color was done daily during the whole duration of the data-gathering period. The weight was measured

on day 0 to get the initial weight and on day nine to get the final weight. The pH and decay were analyzed on the last day of the data-gathering period.

Sample Collection. Samples of the papayas were collected from Spring Bloom Farms, Pavia, Iloilo. They were noted to be unripe based on the color maturity index of Basulto et al. [20]. Samples were picked based on the following criteria: (i) must be Red Lady variety with certification from the Department of Agriculture Western Visayas (DA - WV); (ii) must have no decay sign; (iii) must have no pests; and (iv) must not be shriveled.

Wax Preparation. RBW coating emulsion was prepared using a method adapted from Abrihami et al. [10]. The RBW was melted using the double boiler method. This method utilizes the heat of trapped steam between two pots to melt solid wax. A small pot containing the RBW was placed inside a larger pot that was partially filled with water. Using a burner, the water was boiled into a simmer. As adapted from Abhirami et al. [10], the amounts used for the treatments are the following: 15% (T1), 20% (T2), and 25% (T3) were 600 g, 800 g, and 1,000 g of RBW respectively. The hot wax was added to a bucket with 300 mL of emulsifier Polysorbate 80 (Tween 80) and 4 L of hot distilled water, homogenized using a stand mixer for 10 minutes at 18,000 rpm. The treatments were quantified using weight per volume (w/v), which was determined by the ratio of the wax weight to the water volume.

Waxing. The papayas were divided into three blocks with 9 papayas per block. The dip coating method was used to apply the wax on the papayas wherein the whole fruit was dipped in the emulsion for 3 minutes. After waxing, the papayas were left to dry for 5 hours and transferred to their assigned tables. A mosquito net was suspended on each table to prevent insects from contaminating the samples.

%Weight loss. For the weight loss percentage determination, the samples were weighed before (day 0) and after (day 9) storage. The equation for calculating the percentage of weight loss given below was based on the study of Zhang et al. [8]; where m and m_0 are the final and initial weights of each papaya fruit, respectively.

$$\%weight\ loss = (m_0 - m) (m_0^{-1})$$

Fruit color. The fruit color of the papayas was observed and documented every 5 pm from day 1 to day 9. The color change of the papaya was based on the maturity index of Maradol papaya in the study of Basulto et al. [20] (See Figure 1).





Figure 1. Maturity index of Maradol papaya [20]

pH determination. A sample of their mesocarp or the fleshly middle layer of the fruit's pericarp was fed into a juicer. The pH value of the obtained solution was measured with a pH meter.

Decay Incidence. In this study, papaya is considered to be experiencing decay when the visual signs of quality loss can be seen on the exocarp or the outer layer skin of the fruit [19]. One of the symptoms of plant disease is fruit spots, definite and localized areas of softening discoloration, and disintegration of tissue [21]. These spots can merge to form rot. Any fruit with visible microorganism growth is also considered decayed.

Decay incidence was based on the visual observation of decay spots recorded using the method of Cao et al. [24]. Their four-grade scale is as described: 0 = no decay; 1 = slight decay, covering up to 25% of the fruit surface; 2 = moderate decay, covering >25% but <50% of the fruit surface; 3 = severe decay, covering >50% of the fruit surface. Results will be expressed as a decay index after using the following formula as used by Cao et al. [24]:

$$DI = \frac{(1 \times N_1 + 2 \times N_2 + 3 \times N_3) \times 100}{(3 \times N)}$$

where DI is the decay index, N is the total number of fruits, and N_1 , N_2 , and N_3 is the number of fruits showing slight decay, moderate decay, and severe decay, respectively.

Data Analysis. Data were plotted using Google Docs and Google Sheets before being processed with the Statistical Package for the Social Sciences (SPSS) ver.28 program. To determine whether the data are statistically significant, one-way ANOVA was utilized at a 95% confidence interval for the parametric data of weight and pH. At the same time, the Kruskal-Wallis H test was used for the nonparametric data of color and decay incidence.

Safety Procedure. Polysorbate 80 poses physical hazards and potential health effects to researchers. It may cause skin and eye irritation. The heated emulsion of RBW, Polysorbate 80, and distilled water may cause burns during the waxing process. To avoid these, proper and cautious handling of the substance was always observed.

Results and Discussion. - The study aimed to determine the quality of *Carica papaya* L. coated with different concentrations of RBW by assessing their weight loss, pH level, fruit color, and decay incidence.

Weight loss analysis. All samples had weight loss. Among the treatment and control groups, treatment 3 yielded the least mean percentage weight loss at 18.54%, followed by control (18.68%), T2 (21.11%), and T1 (21.58%). It could be inferred that T3 allowed for the lowest transpiration rate and water content loss. This may be due to the concentration of the RBW or material component of the film which affects the water vapor permeability properties of the wax [25]. Similarly, the study of Jutamongkon et al. [9] reported that higher RBW concentrations resulted in less weight loss in tomatoes. Zhang et al. [8] also found that RBW-coated cherry tomatoes had a significantly lower weight loss compared to the control group. Percentage weight loss is an indicator of the fruit dehydration process due to transpiration. It can be used as a representation of a way to determine coating efficiency in the preservation of fruit quality [10].

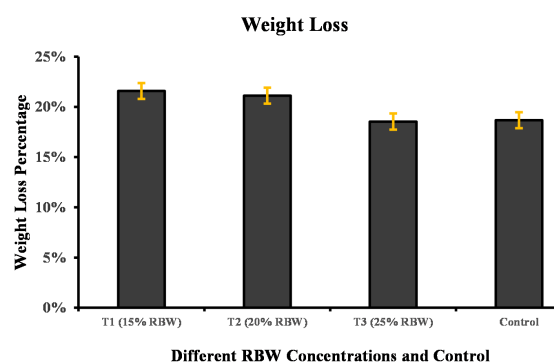


Figure 2. Mean percentage weight loss of the groups

However, one-way ANOVA results revealed that there was no statistically significant difference between the treatment and control groups ($F(3,32)=0.757$, $p=0.527$). The weight loss of the coated fruits was not significantly different from the control group. Furthermore, after the means of Day 1 and Day 9 of each treatment and the control group underwent a paired t-test, it was found that RBW neither slowed down nor sped up the weight loss rate. This indicates that there is not enough evidence to prove that a relationship between RBW coatings at different concentrations and weight loss of fruits exists, which may be attributed to the small sampling size. It is to note as well that there are only two data points observed on day 0 and day 9 which could not be represented entirely and thus inconclusive.

pH analysis. It is observed that all groups have yielded a pH value that is between 5 and 6. The mean pH values of the T1 papayas fall under the pulp's standard pH, which is between 5.5 and 5.9 [26]. The rest of the treatments and the control group fall a little lower than the range stated.



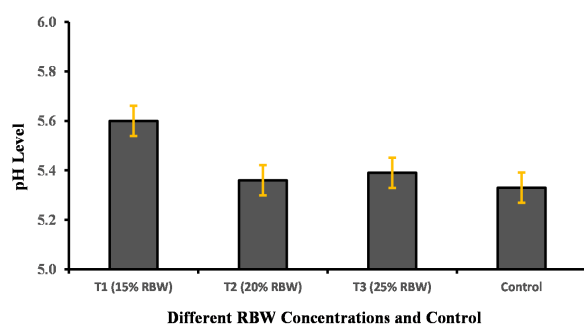


Figure 3. Mean pH levels of the treatments and the control group

One-way ANOVA results revealed that there was no statistically significant difference between the treatment and control groups ($F(3,32)=0.987$, $p=0.411$). This suggests that with or without wax, the pH level of the papayas relatively stayed within the normal range. The results of this analysis denote that RBW did not significantly change the pH of the papaya.

Batista-Silva et al. [27] claimed that the organic acid content of fruits decreases with maturation due to the breathing process or sugar conversion. This results in a rise in pH as the acidity of the fruit decreases. In a study conducted by Gomez et al. [28], it was noted that papayas in the mature green stage were more acidic. However, papayas at the intermediate and ripe stages had less acidity and were found to be sweeter than green papayas. The acidity is low because the papayas in the different treatment groups and the control group have a pH level below but near neutral.

Fruit color analysis. A higher ranking in the color scale means there is a higher number of papayas observed that had higher valued scores on the papaya maturity index. This corresponds to how far along the papaya is in its ripening based on the visual evidence of its pericarp color.

T1 (15% RBW), T2 (20% RBW), and the control group showed similar progression in color wherein they consistently had a color score mode of 2 for the first five days and it increased to 3 on the sixth up until the seventh day. The fruit color on days 8 and 9 was not recorded anymore due to the presence of decay obscuring the color of the papayas. There was no statistically significant difference between the change in fruit color of the treatment groups and the control group as determined by the Kruskal-Wallis H test in the SPSS software. However, the fruit color of treatment 3 was not recorded due to it being obscured by the wax. The results show that the different concentrations of wax did not greatly affect the change in color of the treatments in comparison to the control group. It can be inferred that the RBW did not alter the respiration rate to the extent of significance.

Decay incidence analysis. T1 showed the least decay percentage while the higher RBW concentration tied for the highest decay percentage. This ranking is also reflected in the modes of the decay scores of each treatment (Figure 4).

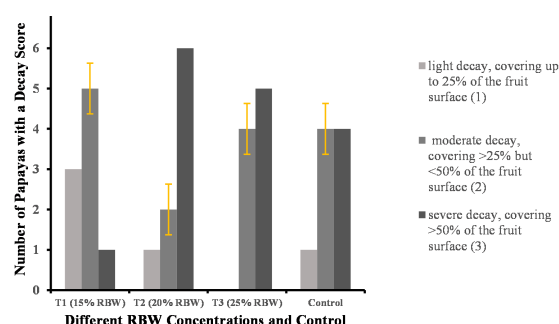


Figure 4. Decay index score of the treatments and control group.

Table 1. Decay index percentages and description of the treatments and the control group

Treatment	Decay Index Percentage	Description
Control	56.70%	severe decay
(T1) RBW: 15% (w/v)	43.20%	moderate decay
(T2) RBW 20% (w/v)	62.10%	severe decay
(T3) RBW 25% (w/v)	62.10%	severe decay

The Kruskal-Wallis H test resulted in no significant differences ($h = 7.179$, $p = .066$, $df = 3$) between the 3 treatments and control for decay incidence. This indicates that coating *Carica papaya* L. 'Red Lady' Papaya with RBW has no significant effect on inhibiting microbial growth or decay symptoms. Waxing creates a hydrophobic film barrier on the surface of the fruit [29], which blocks out pores in the cuticle of the exocarp for less water vapor loss [30]. This could mean that RBW is also sealed in possible moisture which is conducive to microbial growth as water is essential for the normal body functioning of organisms [23]. Although not part of the study's parameters, it has been observed that treated papayas' mesocarp can be considered unripe inside for having firm flesh that would have been softening due to ripening [31]. The flesh is also lacking in the bright orange color that ripened papayas have [19].

Papayas may also be more susceptible to fungal invasion during ripening as their normal range of pH, which the papayas of the study have, is lower than that of the pH range of 4.5 or below which helps in inhibiting the growth of most of the bacteria in fruits [32]. It is also suggested that as the pH of the tissue increases, skin layers soften, soluble carbohydrates build-up, and defense barriers weaken which could explain the eventual microbial growth, discoloration, and sunken areas observed on the papayas [31].



Limitations. It is to note that temperature was excluded as a variable in the experiment as of the time the study was conducted, there was not any available equipment for it and was deemed an uncontrolled variable. It could be that heat from the wax, despite being let cool, influenced the progression of the papaya quality.

Conclusion. - The results obtained from each parameter showed that there was no significant difference in weight loss, pH, fruit color, and decay incidence between the treatment groups and the control group.

Recommendations. - It is recommended to use an advanced tool or software such as ImageJ to measure the total area of decay and the fruit color of the papaya. The use of a homogenizer is also advised to homogenize the papaya flesh in measuring the pH level. Furthermore, it is advised to replace the Brand X used by the study with a self-produced RBW as well as the characterization of said RBW. The addition of parameters to be analyzed such as firmness, ethylene production, titratable acidity, flesh characterization, microbial infestation, and soluble solids content is also recommended to examine further the ripening of the fruit physically and chemically. The cosmetic attributes that wax coatings can provide for papayas can also be investigated for consumer preferences.

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CLUSTER TWO

PRODUCT DEVELOPMENT & TREND ANALYSIS

The flask illustrates the pivotal role of product development, particularly in conjunction with chemical experimentation. Adjacent to the flask orbits a satellite, symbolizing the expansive reach of data acquisition inherent in the field of product development. These symbols, along with the portrayal of space within our universe, suggest that the impact of studies centered on trend analysis and product development transcends the earth, giving emphasis on the significance of these disciplines in the field of research.

Cluster 2 is a compilation of research studies that address the development of new products and the trends of historical data. Studies under product development involve designing, creating, and testing a product's efficiency to be presented as an alternative to commercially available goods. Studies on trend analysis, on the other hand, examine the significant trends and changes in historical statistical data to provide valuable insights into how these aspects impacted various important geographic features in the country.

Assessment of lead concentration in surficial sediments of an island harbor estuary in Western Visayas, Philippines by flame atomic absorption spectrophotometry (FAAS)

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Article Info	Abstract
Submitted: July 24, 2023 Approved: Dec 15, 2023 Published: Dec 31, 2023 Keywords: heavy metals anthropogenic activities lead contamination Sediment analysis Flame Atomic Absorption Spectrophotometry	Lead contamination is an emerging problem in the Philippines due to marine activities such as boating and commercial fishing in most coastal areas like MacArthur's Wharf in Guimaras. The aquatic environment's health is assessed by considering sediment quality through Flame Atomic Absorption Spectrophotometry (FAAS). Four surficial sediment samples were collected at 0 m, 25 m, 50 m, and 75 m away from the innermost sections of the docking area of the wharf, and the Pb concentrations were 23.66 ppm, 15.34 ± 1.07 ppm, 12.31 ± 1.07 ppm, and 11.80 ± 1.07 ppm, respectively. All samples fulfilled the permissible lead concentration in sediments by the National Oceanic and Atmospheric Administration (NOAA) at <30.24 ppm, and the U.S. Environmental Protection Agency (U.S. EPA) at <40 ppm, implying that MacArthur's Wharf, Guimaras, is within the acceptable environmental standards.

Introduction. - Heavy metal (HM) contamination of aquatic ecosystems is developing into a possible global issue due to its hazardous impacts on the environment and public health [1]. Heavy metals are elements with high atomic weights and densities that pose a danger even at low concentrations [2]. In certain amounts, some play a vital role in the biochemistry and physiological functions of plants and animals but can be harmful to these organisms when exceeding the threshold value [2]. The study by Astatkie et al. (2021) [3] stated that surficial sediments may act as an adsorptive basin, especially for metals that exceed the threshold value and do not naturally degrade [4]. Thus, sediments are used as environmental indicators for the assessment of metal pollution in bodies of water [5].

All potential causes of sediment contamination with heavy metals include anthropogenic activities, such as dumping of domestic waste, drainage system inefficiencies, and natural occurrences like rock corrosion and weathering [3]. Lead (Pb) is a non-essential metal and one of the most hazardous and toxic contaminants in the environment [6]. It is largely found in the oil and gasoline industries [2,7]. One study on the analysis of the water column of Iloilo-Guimaras Port concluded that the exceeding amounts of Cd, Cr, and Pb could be mainly attributed to oil spillage from motor boats [16]. Shipping activities and marine traffic in ports reportedly have increased the flux of Pb into the marine environment [8].

In maintaining proper and balanced physiological functions in aquatic species, heavy metals play vital roles at trace levels or in small amounts [2,9]. Water bodies with excessive levels of heavy metals, however, harm aquatic life [2]. Later on, HMs like Pb could contribute to the long-term poisoning of the food chain [6]. Pb is found to be potentially carcinogenic to humans and animals, inducing damage to the brain, kidneys, liver, digestive system, endocrine system, and reproductive system [10].

One of the main wharves in Guimaras, MacArthur's Wharf, formerly known as "Buenavista Wharf," with coordinates of 10.6870° N, 122.6173° E, is located in the Iloilo Strait and is used to transport people, goods, and products to and from the island for industrial and commercial purposes, as well as to dock boats when they are not in use or require repair. Given their significance for international trade and economic activity, seaports have evolved into a coordinated land-sea region that is heavily influenced by human activity. Consequently, anthropogenic causes such as marine traffic, fishing, ship maintenance, and commercial activities may release pollutants into nearby seas and sediments. High Pb concentration in a port in Misamis Occidental was attributed to shipping and other anthropogenic activities in the area [10].

In addition, both residential and commercial buildings line the waterfront. According to the classification of water bodies and usage of marine waters of the Department of Environment and Natural Resources (DENR) Environmental Management Bureau, the surrounding waters of the



wharf are categorized as Class SC which includes fishery water, recreational water, and marshy and mangrove areas. It has beneficial uses including boating and the propagation of fish and other aquatic resources intended for commercial and sustenance fishing.



Figure 1. The docking area (encircled) of boats in MacArthur's Wharf, Guimaras

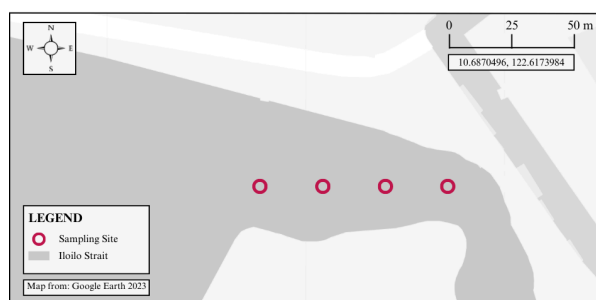


Figure 2. A close-up map of the docking area and the sampling sites (from Google Earth)

There are no sediment quality guidelines in the Philippines, but there are available standards developed by the National Oceanic and Atmospheric Administration (NOAA) [10], and the U.S. Environmental Protection Agency (U.S. EPA). Sediment Quality Guidelines (SQGs) are numerical chemical concentrations intended to be either protective of biological resources, predictive of adverse effects on those resources, or both. Heavy metal concentrations in the samples collected from the study area are assessed by comparing them with sets of SQGs. The study referred to two SQGs, the U.S. EPA and the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment [11,12].

The investigation of heavy metals in surficial sediments is beneficial in assessing the anthropogenic and industrial impacts posed by pollution on water ecosystems. Heavy metals, like lead, are known to atomize with good efficiency with either N_2O or acetylene flame type with FAAS detection limits. A detector receives a light beam from a cathode lamp directed through the flame. The absorbed light is measured to compare with the light wavelengths that originally passed through the sample. The principle is that since the light beam has the same wavelength as the metal being observed, the absorbed light energy represents the concentration of the metal in the sample [13]. FAAS is also known for its low operational costs and good analytical performance. Therefore, in this study, surficial sediments were gathered in the docking

area of MacArthur's Wharf. Then, they underwent pretreatment and acid digestion before conducting the FAAS to determine the concentration levels of the heavy metal Pb.

The study aimed to determine Pb concentrations and its pollution and toxicity state in the surficial sediments of the docking area of MacArthur's Wharf, Buenavista, Guimaras with the following objectives:

- (i) To determine the concentration of Pb in the surficial sediments of MacArthur's Wharf, Buenavista, Guimaras by FAAS; and
- (ii) To assess the detected concentrations of Pb if it is within the permissible levels as set by the EPA Toxicity Classifications and the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment.

Methods. - The study adopted a descriptive approach designed to assess whether the concentration of heavy metal Pb in the surficial sediments of the docking area of MacArthur's Wharf, Buenavista, Guimaras is within the permissible levels set by U.S. EPA and NOAA. The methodology is comprised of five parts: collection, pretreatment, digestion [14], preparation of the calibration curve, and FAAS analysis [15]. Surficial sediment samples were collected during the dry season from four separate sampling areas: 0 m, 25 m, 50 m, and 75 m from the innermost section of the docking area, the farthest that pump boats are stationed. The samples were then pretreated and digested before being analyzed through FAAS [14,16].

Collection of Sediment Samples. The collection of sediment samples was done in January during the dry season. Four sampling sites with 25-m intervals from end to end of the docking area of the wharf surrounded by residential areas were marked: 0 m, 25 m, 50 m, and 75 m. Around 500 g of the upper 5 cm surficial sediment layer of each marked collection area was collected with a separate plastic spoon for each area and transferred to a decontaminated zip lock bag. The sediment samples were then kept in a styrofoam box filled with ice while being transported to the Philippine Science High School - Western Visayas Campus (PSHS-WVC) laboratory.

Pretreatment of Sediment Samples. Upon arrival at the laboratory, the sediment samples were then oven-dried at $50^{\circ}C$ for 24 hours, grounded to ensure homogeneity, and sifted through a 3-mm sieve (or ASTM sieve size No. 16-8) to separate coarse-grained sediments and concentrate dust particles in this fraction that may contain high levels of heavy metal [14].

Acid Digestion. Acid digestion was then done to the sediment samples following the U.S. EPA Method 3050B: Acid Digestion of Sediments, Sludges, and Soil [16].



Preparation of Calibration Curve. Pb solutions with concentrations of standard true values 0.05, 0.10, 0.30, 0.50, and 1.0 ppm were prepared following the standard addition method. The standard curve was created using the absorbance values measured for the working standards. It showed the relationship between the absorption of monochromatic light in the spectrophotometer and the known Pb concentration.

FAAS Analysis. The Pb concentrations in the sediment samples were then analyzed using the Shimadzu AAS AA-7000F model with Lamp ID: Pb-1, wavelength of 283.3nm, slit width of 0.7nm, lamp Mode: BGC- D2, and low peak at 10mA. It uses an acetylene gas flow rate of 2.0 L/min and a support gas flow rate (compressed gas) of 15l/min. For each sample, the instrument performed two replicate analyses. The average of these replicates was subsequently calculated and utilized in assessing the sediment quality by established SQGs.

Data Analysis. The concentrations in ppm of analyte Pb in the sample were compared with the permissible concentrations set by the U.S. EPA Toxicity Classifications and the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment [11,12].

Safety Procedure. Possible harm from inhalation of fine sediment samples was mitigated by wearing safety gear such as safety goggles, face masks, and gloves. Handling of strong acids with fumes was done in a fume hood. The experiment was conducted with the guidance of a laboratory supervisor.

Results and Discussion. - The yielded actual concentrations slightly deviated from the standard target values of the calibration curve due to an inaccuracy during the preparation of the standard solutions.

Table 1. Target standard concentration, generated actual concentration, and absorbance values of lead as yielded from the FAAS

Target Standard Concentration (ppm)	Actual Concentration (ppm)	Absorbance
0.05	0.0247	0.0265
0.10	0.1105	0.0282
0.30	0.3325	0.0326
0.50	0.4839	0.0356
1.00	0.9986	0.0458

Nonetheless, a straight line was approximated through the data points using linear regression, and its equation was best described as $y = 0.0198x + 0.0260$. The line has a slope of 0.0198 and an r^2 value of 0.9983 from a linear fit.

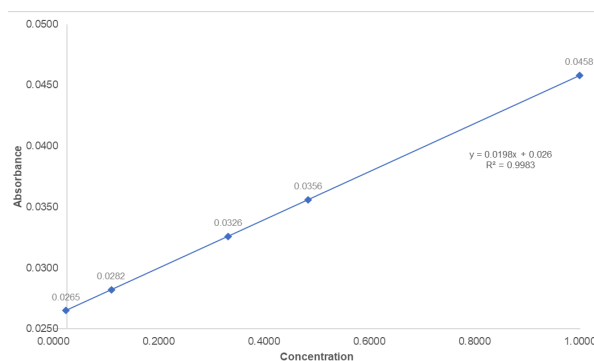


Figure 3. Standard Curve for Lead Concentration Analysis

The Pb concentrations were calculated by substituting their measured absorbance values into the equation of the standard curve. The instrument-run replicates of unknown concentrations of Pb are shown in Table 2.

Table 2. FAAS yielded concentration and absorbance of lead from samples with two instrument runs each.

Sediment Sample	Absorbance	Concentration (ppm)
1	0.0307	23.66
	0.0307	23.66
2	0.0289	14.58
	0.0292	16.09
3	0.0283	11.55
	0.0286	13.06
4	0.0281	10.54
	0.0286	13.06

The statistical analysis of the Pb concentrations, including the mean and standard deviation is presented in Table 3. These values were calculated using the results from the two instrument-run readings of each of the four samples.

Table 3. Mean and standard deviation of the two instrument-run readings of each sample.

Sediment Sample	Mean (ppm)	SD (ppm)
1	23.66	0.00
2	15.34	1.07
3	12.31	1.07
4	11.80	1.78

The average lead concentrations in the samples were assessed with the SQGs: U.S. EPA and NOAA Screening Quick Reference Table for Inorganics in Marine Sediment. For samples 1, 2, 3, and 4, the values are 23.66, 15.34, 12.31, and 11.80 ppm, respectively. The U.S. EPA provides three classifications for Pb concentration ranges: non-polluted, moderately polluted, and heavily polluted with values of less than 40, 40 to 60, and greater than 60 ppm. NOAA's SQGs for lead in



marine sediment provided values of 30.24, 46.70, 112.0, and 218.0 ppm for Threshold Effect Limit (TEL), Effects Range Low (ERL), Probable Effect Limit (PEL), and Effects Range Median (ERM).

Table 4. NOAA and US.EPA Classification of Heavy Metal Concentrations in MacArthur's Wharf

Heavy Metal	NOAA (ppm)				EPA (ppm)		
	TEL	ERL	PEL	ERM	Non-Polluted	Moderately Polluted	Heavily Polluted
Pb	30.24	46.70	112.0	218.0	<40	40-60	>60

The lead concentrations in the docking area of MacArthur's Wharf were found to decrease with increasing distance from the innermost section. Sediment sample 1, located at 0 m from the innermost portion of the docking area, exhibited the highest concentration of lead with a value of 23.66 ppm. Such results concurred with the study of Qian et al. (2015) [17] as it was observed that high concentrations of toxic metals are commonly found in sediments near industrialized coastal areas. Pb in the sampling areas may be particularly attributed to domestic waste and run-off from surrounding residential areas, fishing boats and vessels, and passenger boats plying and stationed in the area [18]. Furthermore, studies have found that HM levels were significantly higher during the dry season in both water and sediment samples due to decreased water activity resulting in sediment accumulation [19]. In contrast, sample 4 showed the lowest amount since it was located further away from commercial and residential areas. However, the researchers were unable to collect sediment samples from other sampling sites, such as in commercial areas where frequent shipping activities occur.

The observed lead concentrations from all four samples were well within the permissible levels and complied with the standards set by the U.S. EPA and NOAA. According to the U.S. EPA toxicity classification, all sediment samples were found to be non-polluted as their concentrations were determined to be less than the set value of 40 ppm. For the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment, the TEL, with a permissible level of lead at 30.24 ppm, is the level of sediment contamination at which benthic organisms begin to exhibit toxic responses. The PEL is the concentration at which the majority of benthic organisms exhibit toxic responses and has a permissible concentration of 46.70 ppm. Harmful effects on the surrounding environment are rarely observed at concentrations below the ERL value of 112.0 ppm, while concentrations above the ERM value of 218.0 ppm frequently result in harmful effects. Concentrations between ERL and ERM are those in which harmful effects would occasionally occur. The determined concentrations of all four samples were below both the TEL and ERL, indicating that benthic organisms in the area have not exhibited toxic responses, and harmful effects are rarely observed.

Pb in the sampling areas may be attributed to several sources, including domestic waste and run-off from surrounding residential areas, fishing boats and vessels, and passenger boats plying and stationed in the area. Sediments serve as an adsorptive sink wherein heavy metals and other particles accumulate as they get quickly removed from the water body [20, 21]. The Second State of the Coasts of Guimaras 2018 has reported total and fecal coliforms that exceeded the standard provided by the DENR for Class SC bodies of water [22]. Though their presence and contamination may suggest exceeding levels of Pb, detected Pb concentrations were well within the permissible levels. The State of the Coasts report also monitored the physicochemical properties of water, such as pH, temperature, and dissolved oxygen. It supported the current study's findings that the water quality standards were satisfied, and it suggested that heavy metals not be contaminated.

Few studies have addressed heavy metal pollution assessments in sediments in the Philippines. Although heavy metals are naturally occurring elements, anthropogenic activities such as mining and smelting operations, industrial production and usage, home and agricultural use of metals, and transportation are the main causes of environmental contamination and human exposure [10]. Bacteria can be used as heavy metal concentration bioindicators and thus as indicators of water and sediment quality [23]. The observed lead concentrations that are within permissible levels may oppose the monitored exceeding coliform levels that would otherwise suggest also exceeding levels of heavy metal concentrations. However, these low concentrations of heavy metal may be attributed to the nearby mangrove forestation.

One factor that may have affected the low presence of lead in the area is the nearby mangrove forestation which is approximately 30 m to 70 m away from the docking area. Studies have found that the roots of certain mangrove species have a high potential for absorbing heavy metals and could serve as a natural phytoremediation treatment [24]. However, current monitoring of the mangrove forestation of the area and its physicochemical properties was not taken into account, thus their relationship with the observed lead concentrations cannot be determined for certain.

Domestic waste and run-off due to industrial activities contributed to the high lead concentration in the innermost section of the docking area of the sample site. The low lead concentration of some parts may be attributed to the nearby mangrove forestation where the study of Nazli and Hashim (2010) [24] found that the roots of some mangrove species have a high potential for absorbing heavy metals and could have served as a natural phytoremediation treatment. In addition, the found lead concentrations that are within permissible levels may oppose the monitored exceeding coliform levels that would otherwise suggest also exceeding levels of heavy metal concentrations. All four samples were able to fulfill the permissible lead concentration set



by the U.S. EPA and NOAA, implying that the sampling location, MacArthur's Wharf docking area, is not polluted with lead, benthic organisms in the area have not exhibited toxic responses, and harmful effects are rarely observed.

Limitations. Due to the rapid return of high tide upon arrival at the docking area, the researchers were unable to collect the intended three replicates per sample area distance (right side, left side, center), and only managed to collect samples from the center section of the docking area. Second, statistical analysis tools were not utilized for the assessment of the detected concentrations of Pb for any significant differences if it is within the permissible levels.

Conclusion. - The results obtained from the FAAS analysis showed that all four samples were able to fulfill the permissible lead concentration set by NOAA (at <30.24 ppm) and the U.S. EPA (at <40 ppm). Sediment sample 1 contained the highest lead concentration of 23.66 ppm. Samples 2 through 4 had concentrations of 15.34 ± 1.07 ppm, 12.31 ± 1.07 ppm, and 11.80 ± 1.07 ppm, respectively. The findings imply that MacArthur's Wharf, Guimaras, is not polluted with lead.

Recommendations. - The researchers recommend identifying a schedule for lower tides to have more time to collect samples from the docking area (right side, left side, center). It is also recommended that the researchers utilize statistical tools such as independent samples t-test for their assessment of the detected concentrations of Pb for any significant differences if it is within the permissible levels.

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Physicochemical properties of *Artocarpus heterophyllus* peels packaging paper coated with fish gelatin-palm wax-lemongrass oil

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Article Info	Abstract
Submitted: June 29, 2023 Approved: January 17, 2024 Published: February 25, 2024 Keywords: jackfruit paper coating FTIR spectroscopy water absorption tear resistance	Paper demand in the Philippines is increasing by 2.5% each year since 2016, including packaging paper. To address this demand, paper made from <i>Artocarpus heterophyllus</i> peels (AHP) has been used for packaging but it had low water barrier properties. A coating composed of fish gelatin, palm wax, and lemongrass essential oil (GPL) increases the physical, mechanical, and functional properties of paper. This study aims to determine the physicochemical properties of packaging paper made out of AHP coated with GPL. This includes water absorption, tensile strength, and chemical composition. Results showed that the water resistance of AHP-GPL was weaker than other packaging papers. The tear index was lower than kraft but possessed similar values with other non-wood papers. Attenuated total reflectance - Fourier Transform Infrared Spectroscopy (FTIR) results revealed that the peaks closely correspond to cellulose, which is a primary component of paper. This study concludes that AHP-GPL does not comply with paper packaging standards in water absorption and tear index.

Introduction. - The total annual demand for paper in the Philippines has increased by 2.5% every year since 2016, with the packaging paper industry experiencing a high growth rate [1]. Packaging paper possesses low moisture resistance due to its composition, allowing moisture to pass through and contaminate the contents [2] easily. To combat this weakness, coatings are added to increase their water barrier and mechanical properties [2].

Artocarpus heterophyllus (AH), commonly known as jackfruit, holds significant importance as a valuable crop in the Philippines [3, 4]. AH peels are often discarded as solid waste. According to the Philippine Statistics Authority [5], an average of 2,406 metric tons of AH waste was produced from 2019 to 2021 per year. The biodegradation of AH peels through anaerobic digestion produces air pollutants such as methane and carbon dioxide [6].

Lothfy et al. [9] tackles the use of *Artocarpus integer* peels as paper, and are compared to the standards of commercial paper. Results present that it has good mechanical properties but possesses low wet tensile strength, strain, and tensile energy absorption characteristics comparable to wood-based paper. It does not tackle other parameters such as biodegradability and water absorption. The use of *Artocarpus heterophyllus* paper (AHP) in packaging could be increased by enhancing its current features by addressing the weakness revealed in prior studies and boosting water resistance and other characteristics. Syahida et al. [7] conducted a study on the effects of kraft paper coated with an

FG-PW-LEO (GPL) coating. The coating was made out of fish gelatin (FG), palm wax (PW), and lemongrass essential oil (LEO). FG has great potential for application as a paper coating due to its biodegradability and good film-forming properties [8]. PW is preferable due to its low cost, high availability, nontoxicity, excellent hydrophobicity, and biodegradability [7]. The lemongrass essential oil will act as the antioxidant property of the coating. The results prove that GPL coating can improve the water barrier, biodegradability, and mechanical properties of paper.

The validity of materials is often confirmed through Attenuated total reflectance - Fourier transform infrared spectroscopy (ATR-FTIR). Studies [10] use ATR-FTIR spectroscopy to characterize and identify functional groups found not only in paper [11,12] but also in its components such as cellulose and lignin [13,14].

Based on the standards of the Technical Association of the Pulp and Paper Industry (TAPPI) 441, water absorption is evaluated by measuring the weight of water absorbed in a period of time using a Cobb tester. Syahida et al. [7] tested the water absorption of kraft paper with GPL coating. The coated kraft paper had lower water absorption values which indicates better water resistance [7].

Meanwhile, tear resistance evaluates the strength of a paper [15]. The study of Lothfy et al. [9] measured the tear index of *Artocarpus integer* paper. The value of the tear index they obtained was lower



than the commercial paper they compared. The tear index can be obtained by dividing the tearing resistance by the grammage of the paper [15].

Exploring the capabilities of AHP with different coatings and studying more parameters can help determine the most effective coating that can amplify the properties of the AHP. The study's outcome can provide additional information about more ways to reuse AH wastes rather than letting AH cause pollution. In addition, this can determine if AHP-GPL can help address the rise of paper demand. It can also encourage and further the development of AHP as an alternative packaging material. Moreover, this can help the environment by turning *Artocarpus heterophyllus* peels into paper rather than letting them biodegrade and cause pollution

This study aims to determine the physical and mechanical properties of packaging paper made out of *Artocarpus heterophyllus* peels (AHP) coated with Fish Gelatin-Palm Wax-Lemongrass Oil (GPL) and to be compared with the respective kraft paper standards. Testing the AHP coated with GPL coating (AHP-GPL) will help evaluate if the GPL coating can address the low barrier water properties of the AHP paper and determine if it can be on-par or even better than the given standard for papers.

Specifically, the aims of this study are to:

- (i) identify functional groups found within the AHP produced via Attenuated Total Reflectance Fourier-Transform Infrared (ATR FTIR) spectroscopy, and ensure the validity via comparison to literature;
- (ii) measure the water absorption (WA) of GPL-coated AHP (AHP-GPL) via the Cobb Test, and compare to corresponding standards; and
- (iii) determine the tear resistance (TR) of AHP-GPL by using a tear tester, and calculate the TI for comparison to existing literature.

Methods. - Papermaking followed a modified soda pulping process to extract pulp from *Artocarpus heterophyllus* peels [9]. The mold and deckle used are 27 cm by 22.5 cm in length and width, allowing each sheet of paper to form one sample for the Cobb test. The preparation of the coating was made in the same process as in Syahida et al. [7] which consists of FG, PW, and LEO as its key ingredients. GPL coating will then be applied to the created paper samples.

In total, 10 sheets of AHP-GPL were created. Five samples were used for the Cobb test, each measuring 12.7 by 12.7 centimeters in length following the recommended dimensions of the sample by Central Philippine University (CPU) - Packaging Engineering Laboratory. For the tear resistance (TR), five sheets of paper were delivered to the CPU - Packaging Engineering Laboratory for testing.

Preparation of the AHP-GPL. Creating the GPL-coated *Artocarpus heterophyllus* Peel Paper to be used for sample testing involved four steps: formation of paper from AH peels, verification of the AHP, creation of the coating, and the application of GPL coating to the AHP. Paper creation was based on Lothfy et al. [9] with modifications to produce ten sheets of 27 by 22.5 cm AHP. The process began with AH peel drying where the researchers used the laboratory oven from the Philippine Science High School - Western Visayas Campus (PSHS-WVC) heating room, the peels were dried for four hours, at 70° Celsius. The resulting dried peels underwent the soda pulping process, by boiling the peels with 16% (w/w) NaOH for 1 - 2 hours. The resulting pulp was cleaned and dried, then placed in the mold and deckle to form a sheet of paper. The paper in the mold dried after 24 hours. The GPL coating and application were similar to Syahida et al's [7] where a coating made from FG, PW, and LEO is applied to the paper samples.

FTIR Spectroscopy. FTIR Spectroscopy was performed using the Shimadzu IRAffinity-1S at the PSHS Chemistry Instrument Room. The Attenuated Total Reflectance (ATR) accessory of the Shimadzu IRAffinity-1S was used to enhance the surface sensitivity of the machine, leading to more accurate results. Ten scans were performed to ensure the accuracy of the spectra and were set to absorbance, where the peaks were shown going upwards. The range of the scanned spectra was from 700 to 4000 cm^{-1} . The paper composition was confirmed by comparing the spectra to existing literature. [10,13,16].

Water absorption. Five samples of AHP-GPL measuring 12.7 by 12.7 centimeters in length, as recommended by the CPU's Packaging Engineering Laboratory, were used for the measuring of WA. The resulting data were expressed in the standard Cobb Value units: g/m^2 .

$$\text{Cobb Value} = (W_f - W_i) \times 100$$

W_i is the initial weight of the paper after the pouring of water and W_f is the final weight of the paper before the pouring of water.

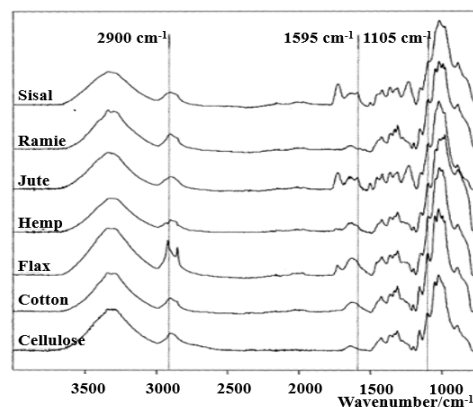


Figure 1. FTIR spectra of cellulose fibers from [10]



Tear Resistance. After submission to CPU's Packaging Engineering Laboratory, three sheets of the sample material with dimensions of 7.62 by 6.35 centimeters were torn together through a fixed distance using the pendulum of an Elmendorf-type tearing tester in the cross direction, following the standard of ASTM D689. The process was repeated once again in the machine direction. The work done in tearing was measured by the loss of potential energy of the pendulum. The resulting data was measured in grams-force indicating tearing strength (*gf*). Tear index was then calculated by dividing the average tear resistance of the sample by its grammage.

$$\text{tear index} = \frac{\text{average tearing force (gf)} \times 9.81}{\text{average grammage (g/m}^2\text{)}}$$

Data Analysis. The WA of AHP-GPL was submitted to laboratories for testing and as such, required no further calculations before data analysis. The data was compared to related literature to assess the quality of the two parameters.

Safety Procedure. To ensure safety from possible hazards, proper laboratory procedures were observed by the researchers. Proper laboratory equipment and protective clothing were worn during the handling of chemicals such as NaOH. During the data-gathering process, the Science Research Assistant (SRA) of PSHS-WVC and the research adviser supervised the researchers to ensure their safety.

The proper disposal of the excess materials after the conduct of the data-gathering process was observed. The NaOH used during the soda pulping process was stored in a plastic container as advised by the SRA and was then stored in the Chemistry Laboratory. To avoid clogging the drains of the laboratory, the researchers wait for the palm wax to solidify before scraping and disposal through the garbage gin.

Results and Discussion. - FTIR Spectroscopy. The AHP spectra matched the functional groups of cellulose, hemicellulose, and lignin, which are key components of paper. Hydroxyl and methyl bands were found in the single bond area while several tiny sharp peaks were found in the double and triple bond areas. In the fingerprint area, overlapping peaks are widespread and include large ranges and small sharp peaks, most of which are related to the components of the paper. The most significant functional groups of the paper are -OH, -CH, C=O, and C-O. Majority of the peaks in the spectra correspond to cellulose (3036 to 3639, 2800 to 3000, 1779 to 1596, 1173 to 840), while the sharp peaks in the single and triple bond region are attributed to lignin's functional groups. The most significant functional groups for paper, according to Munajad et al. [12], are -OH (3700 to 3000 cm^{-1}), -CH (3000 to 2700 cm^{-1}), C=O (1700 cm^{-1}), and C-O (1500 to 900 cm^{-1}). These functional groups coincide with those of cellulose, hemicellulose, and lignin, which are the main components in paper [11,14]. Furthermore,

paper contains more cellulose than lignin due to the removal of lignin and other additives during the papermaking process [11] with short, sharp peaks caused by the functional groups of lignin (1499 to 1596; 2397 to 2192; and 2134 to 1870 cm^{-1}) [16, 17].

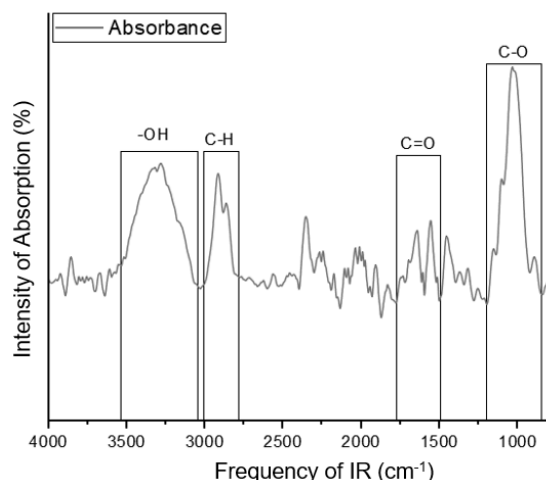


Figure 2. FTIR Spectra of uncoated AHP with the functional groups of paper indicated.

Water Absorption. Laboratory results by CPU - Packaging Engineering Laboratory showed that the Cobb Test of the first three samples had an average water weight of 135 g/m^2 . Meanwhile, two of the five submitted samples failed during testing due to leakage. Two of the submitted samples that failed due to leaking may be caused by multiple factors. Lack of equipment in papermaking can lead to an inconsistent thickness around the paper as mechanical papermaking equipment provides a more even pulp distribution [18]. In addition, microscopic holes can occur during the papermaking process, as they cannot be seen by the naked eye.

The water resistance of AHP-GPL is lower than kraft paper, which possesses a water weight of $40 \pm 5 \text{ g/m}^2$. A lower water weight value means it has a better water resistance property [7].

Table 1. Cobb test results of AHP-GPL.

Specimen	Weight of water in g/m^2 (Cobb Value)
Sample 1	103
Sample 2	141
Sample 3	161
Sample 4	(Failed)
Sample 5	(Failed)
Std. Deviation	29.5
Average	135 ± 5



Tear Resistance. The average force required to tear the three samples of AHP-GPL is 87.105 gf. This is converted to millinewtons and divided by the grammage such that the tear index of AHP-GPL is calculated to be 6.117 mN.m²/g.

Table 2. Tear test results of AHP-GPL

Sample	Tearing Force (g)	
	Cross Direction	Machine Direction
1	80.00	80.00
2	96.00	101.3
3	101.3	64.00
Std. Dev.	11.10	18.73
Average	92.44	81.77

This is higher than AHP with no coating, which has a tear index of 0.16698 mN.m²/g, which might indicate GPL coating's tear resistance-improving properties [9]. However, the increase was not enough to be comparable to kraft paper. Kraft paper is often used for high-tensile packaging applications and has a minimum tear index of 8-10 mN.m²/g [19, 20, 21]. A factor that can be taken into account is the difference in grammage between the AHP-GPL and kraft paper. The grammage of kraft paper is 70 g/m² [20], while the calculated grammage of AHP-GPL is 139 g/m². The tear index is also similar among other non-wood fiber papers such as kaun straw, chia, and mustard stalks, which have a tear index of 6.23 mN.m²/g, 5.9 mN.m²/g, 5.9 mN.m²/g respectively [22]. The AHP-GPL has lower mechanical strength than paper made from unbleached kraft pulp, possibly due to the soda pulping process [23]. Although, the TI of AHP-GPL is comparable to other chemical pulps such as softwood sulphite, hardwood sulphite, and hardwood sulphate pulps [15].

Limitations. The tensile strength test cannot be performed due to the lack of an available Universal Testing Machine (UTM). Therefore, tear resistance was the alternative parameter that the researchers tested. Handmade papermaking methods were also utilized, causing inconsistencies in the texture and thickness of the paper created. Furthermore, the unavailability of libraries meant that the assignment of peaks was limited, leading to the reliance on pre-existing literature for FTIR spectroscopy data analysis. Due to the distance of FPRDI, the researchers are unable to conduct the testing of tensile strength in person.

Conclusion. - AHP-GPL packaging paper did not meet the physicochemical standards of other packaging materials and non-wood fiber papers. ATR FTIR spectroscopy showed that AHP contains functional groups present in cellulose, hemicellulose, and lignin, which are major components of paper. However, AHP-GPL had a water absorption Cobb value of 135 g/m², which is inferior to other

packaging papers. AHP-GPL's tear index was 6.117 mN.m²/g, lower than kraft paper but higher than AHP without GPL coating, on par with other non-wood fiber papers like kaun straw, chia, and mustard stalks.

Recommendation. - The results of this study may be improved by using a papermaking method that reduces the chance of micro punctures from occurring. The use of equipment dedicated to papermaking can improve the quality of the created *Artocarpus heterophyllus* peel paper, having a more consistent texture and thickness in each area. This can also avoid unnecessary creases and unevenness in the paper. Additional methods during the papermaking process such as pulp beating or adding additives in the pulp can also benefit the properties of the samples. Exploration of different bio-based coatings can also help test the properties of AHP. The tensile strength of the AHP-GPL should also be investigated to obtain a more comprehensive understanding of the mechanical strength of the paper. Additionally, FTIR spectroscopy should also be performed on the coated AHP. Other parameters for packaging paper such as porosity, oil resistance, and burst index should also be tested.

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Determining Forest Cover Change In National Greening Program Sites In A High Conservation Priority Area By Utilizing Remote Sensing Techniques

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Article Info	Abstract
Submitted: Jun. 27, 2023 Approved: Jan. 24, 2024 Published: Apr. 5, 2024 Keywords: QGIS NGP remote sensing forest cover reforestation	Deforestation in the Philippines resulted in a reduction in forest cover to just 10% of its original size in recent decades. To address deforestation, the Philippine government introduced the National Greening Program (NGP) and the Enhanced National Greening Program (ENGP). However, earlier studies have found that previous evaluations of these initiatives failed to sufficiently assess their impact on forest cover in the respective implementation areas. Thus, this study utilized Remote Sensing techniques to evaluate the effects of these programs in Brgy. Minoyan, Murcia, Negros Occidental (123.1199°E, 10.4983938°N), which is the largest NGP/ENGP planting site in Western Visayas, a region categorized as "highest conservation priority". The implementation of ENGP increased forest cover by 223.9 hectares and a decrease in grasslands and barren land by 192.2 ha and 31.8 ha, respectively. These findings indicate an increase in forest areas highlighting the program's effectiveness.

Introduction. - Deforestation has been a pressing issue present in the Philippines [1]. Its prevalence is evidenced by the fact that the country's forest cover has significantly decreased in past decades, as the forest cover in the country now only represents 10% of its original size [2]. This decrease in forest cover due to deforestation may cause a multitude of negative impacts on the environment such as biodiversity loss, exacerbation of climate change, depletion of water and food resources, and an increase in poverty [3].

In line with these issues, the government launched the National Greening Program (NGP) in 2011 under Executive Order 26 series of 2011. This program involved planting seedlings across the country from the year 2011 up to 2016. The underlying state policy of this initiative is to achieve sustainable development in the forestry sector by addressing poverty reduction, food security, biodiversity conservation, and climate change adaptation and mitigation. This was later followed by the Enhanced National Greening Program (ENGP) which aimed to expand upon the initiatives of the NGP throughout the years from the year 2016 up to 2028. These programs aim to bring back the vegetative cover of the country and to achieve impacts more than reforestation in line with the aforementioned underlying state policy. Moreover, the NGP and ENGP initiatives also align with Goal 15 of the United Nations Sustainable Development Goals, which aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land

degradation and halt biodiversity loss as it focuses on reforestation and sustainable forest management [4]. As the NGP and the ENGP aimed to bring reforestation to the Philippines, it is increasingly important to assess whether the activities have reached their desired impacts. In fact, Perez et al. [2] stressed the importance of the comprehensive monitoring of the forest cover changes associated with the program to improve assessment of the successes of these activities. Included in the sites for the implementation of the NGP was a bamboo plantation area in Brgy. Minoyan, Murcia, Negros Occidental, established in the year 2020 at the Bago River Watershed Reserve. The aforementioned NGP site is noteworthy as it is the largest in Western Visayas, wherein forest fragments are considered global centers of endemism and biodiversity [1]. This makes these forest fragments fall into the highest priority for conservation, according to the International Union for Conservation of Nature.

Considering the importance of monitoring the forest cover change associated with the greening programs, the researchers sought to determine the change in the forest cover throughout the implementation of these greening programs with the use of Remote Sensing (RS). This study is especially important as there have not been good ground confirmations of the reported successes in the areas of activities of the NGP and the ENGP [2]. The researchers utilized RS in determining the forest cover change, which is a technology and science used to observe, measure, and map objects on Earth's surface from a distance [5]. Although



Greening Program sites traditionally use Key Informant Interviews and Focus Group Discussions to determine the forest cover in a given area, the researchers utilized RS as it was recognized that remote sensing could be beneficial in measuring vegetation growth in those sites [6].

Given the benefits of RS and the importance of monitoring the ENGP, this study aims to:

- (i) Calculate the area of different land cover classes in the study site in 2020 and 2023 through the use of the Normalized Difference Vegetation Index and QGIS Tisler 3.24 and;
- (ii) Determine the percent change of the cover of different land cover classes in the study site throughout the implementation of the ENGP by using the percent change formula.

Methods. - The study is descriptive and it aims to evaluate and compare the change in forest cover in Brgy. Minoyan, Murcia, Negros Occidental, and measure the change brought upon by the ENGP on the forest cover in the area.

Study area. Negros Occidental (10.2477° N, 122.9888° E) is classified as a first-class province, and prioritizes the advancement of sustainable agricultural practices, while also emphasizing the safeguarding of its primary watersheds. The province encompasses 792,607 hectares of land. Out of this, 68% or 540,385.62 hectares are categorized as Alienable and Disposable Land, and the remaining 32% or 252,221.38 hectares are classified as Forestland [7]. Negros Island, as a whole, is one of the regions that encounter severe flooding, super typhoons, drought, biodiversity loss, and other natural disasters. These problems are further aggravated by the absence of integrated planning, coupled with insufficient capacity and dedication of local government units to include biodiversity conservation in local development and land use planning at the municipal, city, and provincial levels [8]. Furthermore, these problems also demonstrated the importance of strict implementation and monitoring of environmental activities conducted within the region. Upon consultation with the DENR, it was discovered that there are several NGP planting sites in Western Visayas, the largest among these is situated at Brgy. Minoyan, Murcia, Negros Occidental, a site established in the year 2020 in which bamboo species are the planted commodities. The planting site in the mentioned location is the chosen study site, as its massive area makes it ideal for RS as it allows for more training points. The study area included the implementation sites of the ENGP in Brgy. Minoyan, Murcia, Negros Occidental (123.1199°E, 10.4983938°N; 123.1895739°E, 10.5588658°N). The site used for the study was composed of a 547-ha reforestation site and a 100-ha reforestation site at the Bago River Watershed Reserve (Figure 1 & 2).

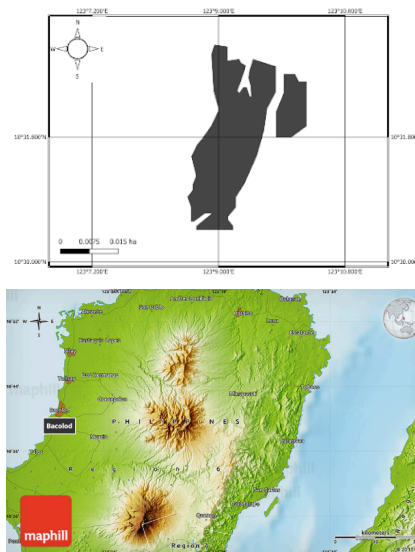


Figure 1. (top) Study area at Negros Occidental and (bottom) corresponding satellite image (MapPhl, 2011).

Satellite image collection. Using the Google Earth Engine, satellite imagery of the study site was obtained from Landsat 8. This also included the preprocessing of the images through a script in Google Earth Engine. This included cloud masking, temporal filtering, and mosaicking. The cloud coverage was set to 20% as was used by Dida et al. [9], and only the image with the lowest cloud cover satisfying the minimum threshold was considered.

Generation of Normalized Difference Vegetation Index. Using QGIS and the Semi-Automatic Classification(SCP) plugin. An NDVI image of the site was made through the use of the Band Calc function of the SCP plugin. For the raster calculation of the bands, the formula used for Landsat 8 is:

$$(NDVI)_{LandSat8} = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$$

Land Cover Classification. Through the Supervised Classification technique, the area was classified into different land cover classes. This included the setting of the Regions-of-Interest (RoIs) and processing the training points through the Spectral Angle Mapping (SAM) Algorithm.

Supervised classification included the setting of Regions-of-Interests (RoIs) through the use of the SCP plugin in QGIS [10]. The RoIs were classified into three predetermined classes, namely: Barren Land, Grasslands, and Forest as was adapted from Negassa et al. [11] and Adhikary et al. [12] as these were the observed classes in the study site.

Through the use of the SCP plugin in QGIS, each pixel of the study site was automatically classified through the SAM Algorithm in which each pixel was evaluated to the class it is most likely to be a member of [13].



Sieving. Through QGIS, the classified image was then processed through the Sieve tool. The sieve tool removed groups of 2 pixels or less from the image, this was done after visually assessing the impact of the number selection on the image [14] in order to reduce noise and achieve a better visual representation of the classification map [15].

Classification Report. A classification report of the classified image was generated through the SCP plugin in QGIS [16]. This report calculated the class statistics specifically: the area (in percentage) of each class in the study site classification map.

Data Analysis. An adapted version of the percent rate formula was used to analyze the raw data and determine the percentage of change for the program. The different percentage changes of each land classification's cover from 2020, the year that the study site was established, to its current state in 2023 was computed.

Safety Procedure. Potential safety hazards present in the study were the overuse of computers and improper posture while using computers. These hazards could have potentially given eyestrain and headaches, and musculoskeletal issues respectively. In order to combat this, proper safety procedures were exercised, such as following the 20-20-20 rule (a 20-second break every 20 minutes, to view an object 20 feet away) [17] and taking frequent short breaks from using computers. Furthermore, all data collected for this research was sourced from reliable and publicly accessible outlets. The data acquisition process was entirely conducted online, ensuring no harm to individuals or animals, and no parties were adversely affected during the course of this study.

Results and Discussion. - The study aimed to determine the change in forest cover through the implementation of the Enhanced National Greening Program (ENGP) in Negros Occidental, using remote sensing techniques. To determine this change, the area cover of different land cover classes in the study site in 2020 and 2023 was calculated through the use of the Normalized Difference Vegetation Index and QGIS software, and the percent change of the cover of different land cover classes in the study site throughout the implementation of the ENGP was determined using the percent change formula. These objectives were attained through Landsat satellite image collection using the Google Earth Engine; the generation of NDVI Images, land cover classification, generation of classification report using the SCP plugin in QGIS; sieving in QGIS; and the use of the percent change formula.

The land cover of each year was found using Landsat images using the Google Earth Engine, from where images of each year were then processed through the generation of NDVI Images, land cover classification, and sieving. The data was finally found using the generation of a classification report for each respective year. In the year 2020, barren lands comprised 113.0 hectares or 17.5% of

the entire plant site, while grasslands comprised 433.0 hectares or 66.9% of the entire plant site, and forests comprised 101.0 hectares or 15.6% of the entire plant site. Meanwhile, in 2023, barren land comprised 81.2 hectares or 12.6% of the entire plant site, while grasslands comprised 240.9 hectares or 37.2% of the entire plant site, and forests comprised 324.9 hectares or 50.2% of the entire plant site. This shows that in 2020, grasslands occupied the largest area in the plant site, followed by the barren land, while forests accounted for the smallest portion. By 2023, there was a shift, with forest cover increasing to occupy the largest portion, followed by grasslands, and then barren land accounted for the smallest portion.

Table 1. The area of the different land cover classes in 2020 and 2023 in hectares (ha).

	2020	2023
Forest	101.0	324.9
Grassland	433.0	240.9
Barren Land	113.0	81.2

Table 2. The area of the different land cover classes in 2020 and 2023 in percent (%).

	2020	2023
Forest	15.6	50.2
Grassland	66.9	37.2
Barren Land	17.5	12.6

The percent change in different land classes throughout the implementation of the ENGP in the study site was determined using the percent change formula. The formula was applied to the different classes, comparing their values between the start of the ENGP in the site in 2020 and its most recent state in 2023.

During the implementation of the Enhanced National Greening Program (ENGP) in the study site, it was found that there were negative percent changes in barren land and grassland of -28.1% and 44.4%, respectively, while the forest class showed a positive percent change of 221.8% (Table 3).

Table 3. Summary of percent change (%) from the establishment of the site in 2020 to the current state of the site in 2023.

	Forest	Grass-land	Barren Land
2020 to 2023	221.8	-44.4	-28.1



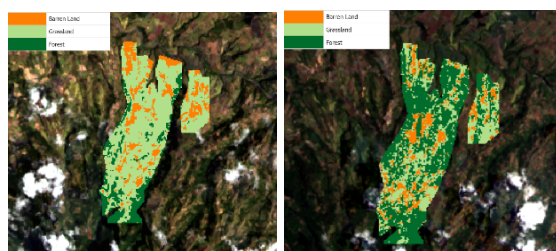


Figure 2. (left) Classified Study Site in 2020 and (right) Classified Study Site in 2023.

Through these results, it was observed, through the years of implementation of the ENGP in the study site that there was an increase in the percentage of the area that was covered by forest, demonstrating the positive effect the program had on the forestation site. The results of the study show that NDVI can be utilized in order to find the different land cover classes in the study site. This finding is in line with the study of Baloloy (2014), who found that NDVI has been a reliable indicator for spatiotemporal analysis of vegetation change. Given these results, it was found that through RS methods information about the land cover classification of the study site in the years 2020 and 2023 were obtained. This resultant information however was limited as only satellite images from Landsat were used which may lead to less accuracy.

The results of this study show that during the implementation of the greening programs, there was an increase in the growth of forests in the study site. The results of this study show that during the implementation of the ENGP in the study site forest cover increased while grasslands and barren land decreased. These changes show that the program has had a positive effect on forest cover in the study site. However, these results are contrasting with those of Perez et al. [2], wherein it was found that greening programs had no particular effect on forest cover in the greater Luzon area. These results may be contrasting due to underlying factors creating differences in the respective study sites, factors such as the availability of resources in the study site, specifically the availability of light, space, soil nutrients, and water; and physical conditions of the study site, specifically: elevation, topography, and climate conditions [19]. Moreover, the results of this study are limited as the researchers did not conduct the reclassification method in the SCP plugin and an accuracy assessment was not conducted.

Through the use of RS techniques, the change in forest cover in hectares throughout the implementation of the ENGP in Negros Occidental was determined. Moreover, NDVI was used to determine the change in forest distribution at the study site, supplementing the lack of studies on the implementation of the ENGP. In this study site, RS was successfully used to determine forest cover change in the area, showing that in future forestation measures, RS can be utilized to supplement data gathered from ground truthing.

Limitations. The resultant data from the research was solely utilized to determine the change brought about by the ENGP in the specific study site, rather than all unique and potential sites in the nation. In this study, the site utilized had only been established in the year 2020.

As a result, the research did not include the years that corresponded to the implementation of NGP (2010-2016) and part of the ENGP (2016-2019), as the study site was yet to be a part of both programs. Moreover, an accuracy assessment was not conducted due to the lack of necessary data. Finally, the study only focuses on the time span during which the ENGP was implemented in the study site and does not take into account any other anthropogenic or natural events in the area as its focus was the ENGP and its effects on the study site, and the study area used for the study was restricted to the given shapefile obtained from the Department of Environment and Natural Resources (DENR) Region VI, and only the bounds within this shapefile were considered the study site.

Conclusion. - From the year 2020 to 2023, the predominant class in the area changed from grassland in 2020 to forest cover in 2023. Moreover, in this span, barren land and grassland both decreased, while the forest cover in the study site increased. This shows that during the years of the implementation of ENGP, there was an expansion of forest cover in the area and that this was a result of the ENGP.

Recommendations. - For future research, the use of other satellite images may lead to increased accuracy compared to using only Landsat satellites. It is also recommended that future studies use datasets supplemented by images from other free satellites, such as Sentinel and MODIS. Furthermore, an accuracy assessment can be conducted to supplement their findings. Finally, utilizing the reclassification method in the SCP plugin is proposed to account for the redistribution of classes, thereby further supporting and substantiating the results of future studies.

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Trend analysis of drought indicators in terms of rice yield for drought identification in a Type III climate area in Central Philippines

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Article Info	Abstract
Submitted: May 29, 2023 Approved: Jul 31, 2023 Published: Dec 31, 2023 Keywords: increasing temperature rice yield drought indices potential evapotranspiration precipitation	The most utilized drought indices are the Standard Precipitation Index (SPI) and the Standard Precipitation Evapotranspiration Index (SPEI), which are based on precipitation and temperature data. As tools that utilize a combination of meteorological data, this could provide a means to monitor and forecast drought conditions in relation with agriculture. Thus, this study aims to analyze the trend of SPI and SPEI for drought identification in terms of rice yield in Roxas City, Philippines, which is a Type III Climate area. Annual climate parameters (mean, minimum, and maximum temperature, precipitation, and potential evapotranspiration) were run through the Mann-Kendall test to determine trend significance, and rice yield was tested for correlation to SPI and SPEI. It was found that neither of the drought indices had a specific monotonic trend on a 12-month timescale. Rice yield had a weak negative correlation with SPI ($r = -0.050$) and a weak positive correlation with SPEI ($r = 0.065$), depicting the indices as weak agricultural indicators. However, other studies have found that this correlation is much stronger on a shorter timescale.
Introduction. - Rice was the most commonly consumed food item in the Philippines in 2021, with a roughly 110 million population having a 133 kg per capita rice consumption [1]. This is further supported by the increase in volume of the country's rice output, with 19.07 million metric tons produced in 2018 [2,3]. However, when compared with other Asian countries such as Vietnam, China, Thailand, Indonesia, and India, the Philippines had the second least annual yield [4]. As an agricultural country, continuous monitoring of the current strategies' effectiveness is important. Information about the country's yield-climate relationship can provide a basis for projecting the impact of future climate change [2,5]. The threat climate change brings to the agricultural sector heightens with the foreseen increase in the frequency and severity of extreme weather events such as droughts and floods [6,7]. Climate change and variability are leading factors that affect rice yield, with each 1°C temperature increase leading to a six percent decrease in total rice yield [8,9]. Moreover, water availability below the optimum requirement for the full expression of yield potential leads to drought stress [10]. Ray et al. [11] investigated the relationship between rice yield and annual temperature extremes and found that temperature changes resulted in a -0.02 percent change in rice yield in the Philippines. However, Prabhakorn et al. [12]	stated that a shorter time step would better represent crop sensitivity to climate at each growth stage. Among the climatic variables, temperature and precipitation are the two fundamental variables commonly used as indicators for changes in climate [13]. In contrast, Vogel et al. [9] revealed that temperature-related indicators have a stronger predictive capacity for rice yield compared to precipitation-related indicators. The present study addresses this by using annual temperature extremes to investigate the effect of temperature on rice yield. Researchers often select precipitation-based indices because of their calculation convenience and standardization with respect to available data [14]. They also often base the selection of the drought index on its advantages in other regions. Pei et al. [15], however, suggest that different natural characteristics of different regions may contribute to the poor classification of drought. Furthermore, drought indices in general have a strong connection with agriculture. In the Philippines, PAGASA (Philippine Atmospheric, Geophysical, and Astronomical Services Administration) only uses the Standard Precipitation Index (SPI) to monitor drought events, which only takes precipitation into account. However, the Standardized Precipitation Evapotranspiration Index (SPEI), specifically, is more accurate than the SPI in terms of describing drought events because it takes temperature into consideration [12,16]. This study was formed to



analyze the trend of two drought indices and correlate each index with the rice yield in a Type III Climate area, as identifying the variations between the drought indices and their characteristics was deemed to require further analysis by Pei et al. [15]. A Type III Climate area is defined by PAGASA [17] as one where the seasons are not very pronounced, with a short dry season lasting only from one to three months, either during the period from December to February or from March to May. It shares similarities with a Type I climate due to its short dry season; however, the season differences in Type I are more pronounced [17]. This study, therefore, has the potential to contribute valuable insights into the application of drought indices in Type III climate areas.

The Philippines' current water infrastructure has previously been identified as deficient in the National Climate Change Action Plan for 2011–2028 [18]. The findings of this study will improve understanding of the relationship between drought and rice yield, making it important to the country's agricultural research and climate change management plans. While current research and development focus on the creation of new technologies in agriculture, this study's focus is still in line with the recommended management practices for rice production in Asia [19].

The study aimed to determine the relationship between the drought indices SPI and SPEI and rice yield from 2005 to 2020. This is mainly due to the limitations of data availability for the rice yield data; the study was limited to 16 years only, from 2005 to 2020.

Specifically, the study aimed to analyze the trend of SPI and SPEI for drought identification in terms of rice yield in a Type III Climate area from 2005 to 2020 through the following objectives:

- (i) compute for the annual mean, minimum, and maximum temperatures of Roxas City from the daily data;
- (ii) compute for the annual precipitation of Roxas City from the daily data;
- (iii) compute for the annual Potential Evapotranspiration (PET) of Roxas City;
- (iv) compute for the annual Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) of Roxas City;
- (v) compare the graphs of the annual SPI and SPEI of Roxas City at the given timescale; and
- (vi) correlate the annual rice yield with the annual SPI and SPEI classifications of Roxas City.

Methods. - The methodology for this study was adapted from Prabnakorn et al. [12] and Pei et al. [15]. These studies provided the basis for conducting the Pearson Correlation and the Mann-Kendall tests,

respectively. Data was requested from identified government agencies (PAGASA and the Capiz Provincial Agriculture Office), and missing data were imputed using multiple imputation. SPI, SPEI, and statistical calculations from the meteorological data were conducted in the R environment version 4.1.2. Their yearly averages were taken using the total annual rice yield data. Pearson's correlation was then employed to identify whether linear relationships existed between the drought indices and rice yield.

Study Area. The study area of Roxas City, Capiz (11°36'00.72"N 122°44'58.74"E) was selected based on the completeness of the available climate and agricultural data. It is within a 25-kilometer radius from its weather station seen in Figure 1. Of the two PAGASA weather stations in Western Visayas, the Roxas City station had the more complete data. Additionally, the study area is a Type III climate area with its dry season that lasts from February to April [17].



Figure 1. 25-km radial scope of the weather station's climate data

Tabulation and Imputation of Datasets. The raw data were tabulated in Google Sheets; however, there were missing values. In order to identify the data's missingness, the Little's Missing Completely At Random (MCAR) Test was used on the meteorological dataset. After identifying it as Missing Not At Random (MNAR), it was imputed with the random indicator method using the Multivariate Imputation by Chained Equations (MICE) algorithm.

Conduct of SPI and SPEI Analysis. The SPI expresses the amount of precipitation over time, while the SPEI calculates the difference between the cumulative precipitation and PET. The code for the SPI and SPEI analyses was adapted from Beguería and Vicente-Serrano [20]. PET was calculated using the Thornthwaite [21] equation, which is ideal when only temperature and precipitation data are available. Other equations, such as those of Hargreaves [22], also utilize temperature and precipitation; however, they returned a value of infinity when tested with the data, which was not considered significant.



$$PET = 1.6b\left(\frac{10T_m}{I}\right)^a$$

Where:

b is the total monthly daylight hours divided by 360

T_m is the monthly mean temperature

I is the annual heat index

a is the empirical constant; cubic function of I

Data Analysis. The resulting values from the SPI and SPEI calculations match a specific SPI and SPEI category that determines drought conditions in an area. This assessment for SPI and SPEI was adapted from Prabnakorn et al. [12] and the Standardized Precipitation Index User Guide of the World Meteorological Organization, respectively. The values from 2005 to 2020 were then graphed to analyze the variations.

Table 1. Dry and wet conditions corresponding to the seven SPI and SPEI categories.

Value	SPI Category	SPEI Category
≥ 2.00	Extremely wet (EW)	Extreme wet (EW)
1.50 to 1.99	Very wet (VW)	Severe wet (SW)
1.49 to 1.00	Moderately wet (MW)	Moderate wet (MW)
0.99 to -0.99	Near normal (NN)	Normal (N)
-1.00 to -1.49	Moderately dry (MD)	Moderate drought (MD)
-1.50 to -1.99	Severely dry (SD)	Severe drought (SD)
≤ -2.00	Extremely dry (ED)	Extremely drought (ED)

Conduct of the Mann-Kendall Test. To analyze the monotonic trend of the temperature, precipitation, PET, SPEI, and SPI data, the Mann-Kendall Test was conducted using the *MannKendall* function in R Software. The null hypothesis for this test is that no monotonic trend exists, while the alternative hypothesis is that a trend exists.

Conduct of Pearson Correlation. The SPI and SPEI values acquired from the SPI and SPEI analyses, along with the annual rice yield of the study area, were utilized to implement the Pearson Correlation Test using the *cor.test* function in R Software.

Results and Discussion. - The trend analysis done through Mann-Kendall showed that temperature and PET were both increasing, while precipitation showed no monotonic trend. A significance level of 95%, or a p-value of 0.05, was

presumed. The table below summarizes the results of the Mann-Kendall test.

Table 2. Outputs of the Mann-Kendall test with the climate data.

Dataset	Kendall's tau	2-sided p-value
Mean Temperature	0.205	2.5392e-05
Minimum Temperature	0.314	2.22e-16
Maximum Temperature	0.143	0.0032147
Precipitation	-0.00517	0.91591
PET	0.148	0.0023863
SPI	-0.00846	0.86266
SPEI	-0.0404	0.40647

Based on the values found in Table 2, the minimum temperature and mean temperature were the variables that exhibited the two most significant increasing trends. Their positive tau values indicated an increasing trend, with the strength of it increasing as it got closer to 1. Maximum temperature and PET also displayed a significant increasing trend. Precipitation was the only single climate variable that displayed no monotonic trend from 2005 to 2020. The SPI and SPEI values of Roxas City were also run through the Mann-Kendall Test in RStudio to assess whether a monotonic upward or downward trend exists in their generated graph of values. The results imply that no significant upward or downward trend exists among the annual SPI and SPEI values of Roxas City from 2005 to 2020.

SPI and SPEI Variations

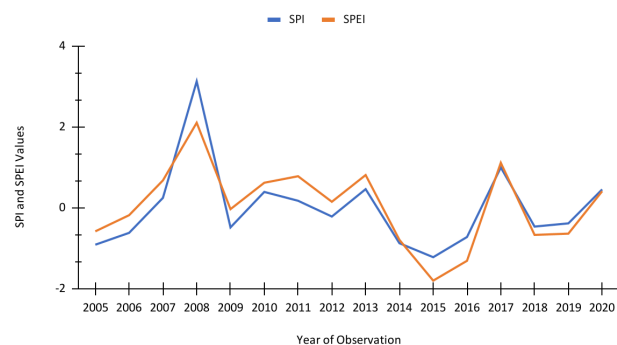


Figure 2. Combined graph of the annual SPI and SPEI values of Roxas City from 2005 to 2020.

The values of temperature and precipitation were compared with the climatological normals for Roxas City from 1991 to 2020 from Figures 3 to 6. The average values of mean, minimum, and maximum temperature from 2005 to 2020 all exceeded their respective climatological normals.



This indicates a warming trend within this timespan. Figure 7 shows the annual PET trend, while Figure 8 shows the annual time series of rice yield.

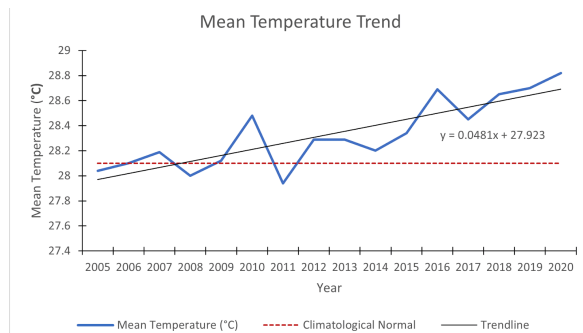


Figure 3. Graph of the annual mean temperature trend in Roxas City from 2005 to 2020.

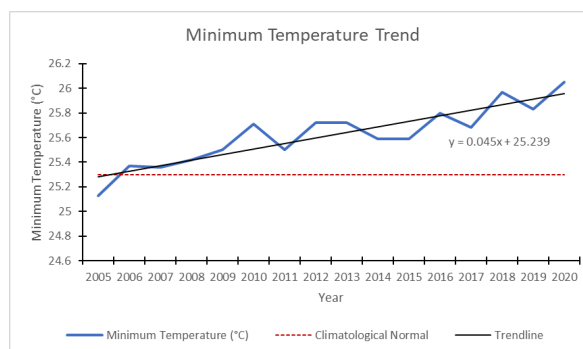


Figure 4. Graph of the annual minimum temperature trend in Roxas City from 2005 to 2020.

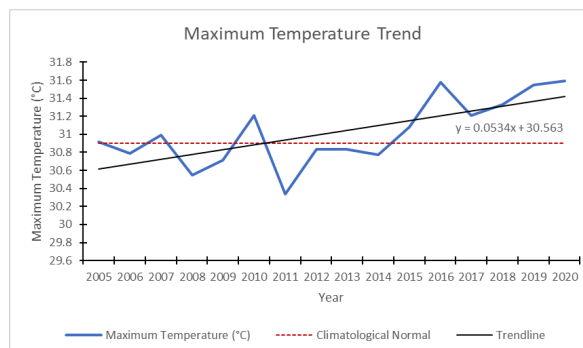


Figure 5. Graph of the annual maximum temperature trend in Roxas City from 2005 to 2020.

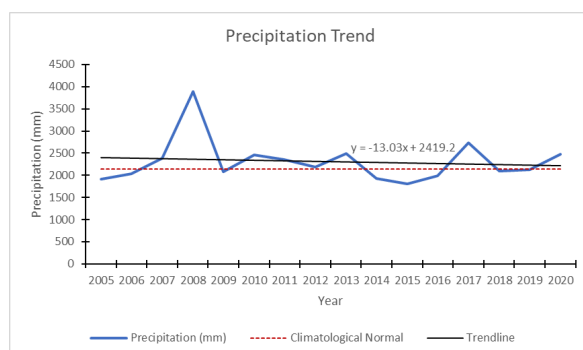


Figure 6. Graph of the annual precipitation trend in Roxas City from 2005 to 2020.

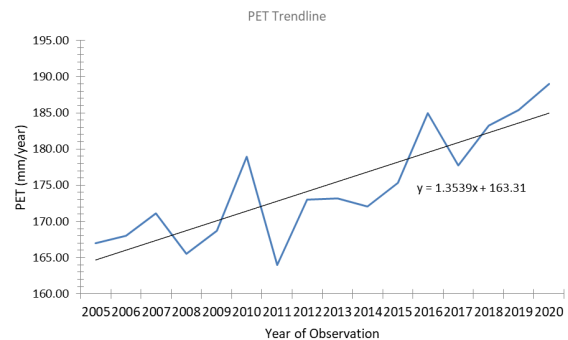


Figure 7. Graph of the annual potential evapotranspiration trend in Roxas City from 2005 to 2020.

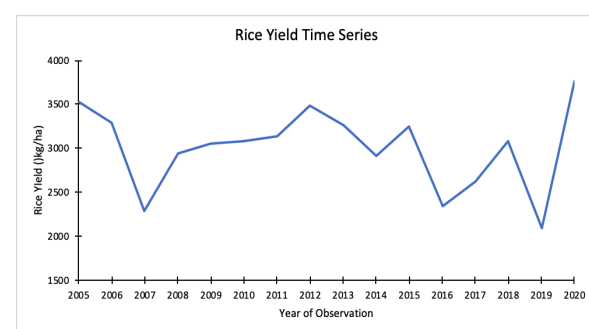


Figure 8. Graph of the annual rice yield trend in Roxas City from 2005 to 2020.

The Pearson correlation coefficient conducted between annual yield and SPI resulted in an r-value of -0.04972216 or -0.050, and the Pearson correlation coefficient between annual yield and SPEI is 0.06546188 or 0.065.

Pearson correlation coefficient values range from -1 to 1. If interpreted, Zvizdojevic and Vukotic [24] describe the major cut-offs as:

- 1 - a perfectly negative association between two variables
- 0 - no association between two variables
- 1 - a perfectly positive association between two variables



Furthermore, a positive Pearson correlation coefficient reflects that the two variables are directly proportional, while a negative Pearson correlation coefficient reflects that the two variables are inversely proportional. However, given the low correlation values, this would imply that the association between the drought indices and rice yield has no significant linear relationship or is nonlinear.

Some scientific evidence points towards temperature as the climate variable that holds significant influence over rice yield [25]. The results of the current study, however, show that despite the significantly warming mean, minimum, and maximum annual temperatures, rice yield trends still remain without a constant pattern. Interestingly, the study's precipitation trend was also neither significantly increasing or decreasing. As SPI and SPEI showed no significant upward or downward trend during the study period either, annual temperature and precipitation data alone may not be enough in characterizing rice yield trends.

Identifying and comprehending the risks that climate change poses to vulnerable sectors such as agriculture is critical for authorities to implement timely mitigation efforts. The weak correlations between rice yield and drought magnitudes for Roxas City suggest that drought magnitudes as measured by SPI and SPEI may not be a significant indicator of rice yield in some areas. Although the current impact is low, the influence on rice yield may be more serious in the future if temperatures continuously rise to a level that negatively targets specific growth stages of rice.

Limitations. In understanding the results of the correlation between the rice yield and the drought indices, factors such as irrigation and hybrid rice varieties were not considered in this study; the rice data utilized both rainfed and irrigated agricultural practices, which may have an effect on the rice yield data. These external factors that contribute to the growth stages of rice were not defined in this study, which looked at rice yield alone.

Conclusion. - The two drought indices have weak relationships with annual rice yield in Roxas City, Capiz. Annual SPI displayed a weak negative relationship, and annual SPEI displayed a weak positive relationship. Furthermore, both SPI and SPEI may not be strong predictors for rice yield.

Recommendations. - The applicability of SPI and SPEI may vary depending on the area's climate type [15], thus it would be ideal to look into other climate types as well. Other drought-sensitive crops may have higher linearity with the aforementioned drought indices. Conducting studies with the 30-year standard reference period would be more ideal to compare to climatological normals, and specifically for the rice yield data, it is recommended that the data be detrended in consideration of crop damage reports and other humanitarian influences in the analysis. Seasonal variations would be better observed on higher temporal resolutions (i.e. quarterly average) and may be given better analysis

through the implementation of an autocorrelation analysis. Lastly, future analyses may want to consider the type of relationship between drought indices and rice yield aside from the linear level.

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Determining the Impact of the COVID-19 Lockdown on Mangroves of a Class C Coastline in Iloilo City, Philippines through Remote Sensing

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Article Info	Abstract
Submitted: Jun. 27, 2023 Approved: Oct. 22, 2023 Published: Dec. 31, 2023 Keywords: QGIS mangroves pandemic remote sensing COVID-19 lockdown	The growth of mangroves is negatively impacted by human activity; however, lockdowns were imposed across the Philippines during the COVID-19 outbreak, resulting in a decrease in human activity. This study determined the lockdown's impact in terms of the decrease in human activity on the mangroves in the Batiano River, Iloilo City, Philippines. The mangrove area was mapped yearly from 2017 to 2021 using the Quantum Geographic Information System (QGIS). Percent changes in the area every year were computed and showed results of 0.57%, -0.09%, 2.22%, and 1.08% in 2018 to 2021 respectively, compared to the immediate previous years. The marked increase from 2019 to 2020 can be attributed to mangrove cutting prohibition and preservation by the Department of Environment and Natural Resources (DENR). The percent change from 2020 to 2021 is higher compared to the years with no interventions and lockdowns, but cannot be attributed to the lockdown alone.

Introduction. - Mangroves are types of trees that grow near bodies of water, such as rivers, seas, and other coastal areas. These types of trees are in decline due to anthropogenic factors which include conversion of the area to fish and shrimp ponds and urban development, which occupy the area of mangrove forests; logging (both legal and illegal), which reduces mangrove forests; and pollution [1,2]. The area that mangroves occupy in the Philippines has diminished from 500000 ha in 1918 to 120000 ha in 1994 because of natural and anthropogenic factors [3]. There have been multiple efforts to restore the mangrove forest cover in the country, done by the government and non-government organizations (NGOs), but until now, the mangrove forest cover has continued to be in danger [4]. However, in March 2020, lockdowns were implemented all over the country, which restricted going out unless necessary [5]. Land, water, and air pollution, which are some factors in the decline of mangroves, have decreased during the lockdown period, as shown in the studies by Aunan et al. and Diraviya et al. [6,7]. As it has been established that mangroves are also greatly affected by human activities and pollution, mangrove forests can be another metric by which the effect of the lockdown can be measured. In this study, the possible impact of the lockdown on the mangroves in the Batiano River, Iloilo City was determined by mapping using the Quantum Geographic Information System (QGIS) software [8]. The Batiano River is home to several marine species, with 16 of the 35 species of mangroves found in the Philippines, and is also significant for the fishing industry of the city, making the site significant for this study [9,10]. This study determined the impact of the lockdown on *Avicennia marina* mangroves in the Batiano River, Iloilo City in 2017, 2018, 2019, 2020, and 2021 by calculating the

area of mangroves each year and comparing the percent changes for every two years to analyze the trend in mangrove growth pre and post-lockdown.

With this, the study specifically aimed to:

- (i) determine the area of mangrove cover (10° 41' 31"N to 10° 41' 18"N and 122° 33' 00"E to 122° 33' 13"E) in the Batiano River, Iloilo City during 2017, 2018, 2019, 2020, and 2021 using QGIS;
- (ii) solve for the percent change in the area of mangrove cover yearly; and
- (iii) compare the percent changes of the aforementioned years.

Methods. - The methodology consisted of four major steps: gathering and georeferencing the satellite images of the chosen study site every year from 2017 to 2021 using Google Earth Pro and Smart GIS; mapping the mangroves by tracing them using polygons; calculating the mangrove area via the drawn polygons; and analyzing the data by comparing the percent changes during each year.

Study site. Iloilo City is a highly urbanized city in Western Visayas. The city is significant in providing function to the region for trade and commerce, education, research, and tourism. Furthermore, all of the barangays and districts comprising the city have also been classified as urban [10].

This study's chosen sampling site is located in the Batiano River, Iloilo City, Philippines (from 10° 41' 31"N to 10° 41' 18"N and from 122° 33' 00"E to 122° 33' 13"E). The Iloilo-Batiano River System falls under the



classification of Class C, which can be fishery water, recreational water for boating and fishing, or agriculture, irrigation, and livestock watering. This makes the river significant to the aquaculture, boating, and agriculture industries of Iloilo City [11]. The mangrove forest is also directly adjacent to a coastal community. Moreover, the rivers are home to 16 out of the 35 species of mangroves found in the Philippines, including one rare species [10]. The local government of Iloilo City declared through Executive Order 055 - Series of 2020 that the city would be put under enhanced community quarantine (ECQ) during 2020, making the chosen site suitable for assessment of the effects of the lockdown. The site's satellite image for the year 2021 is shown in Figure 1.

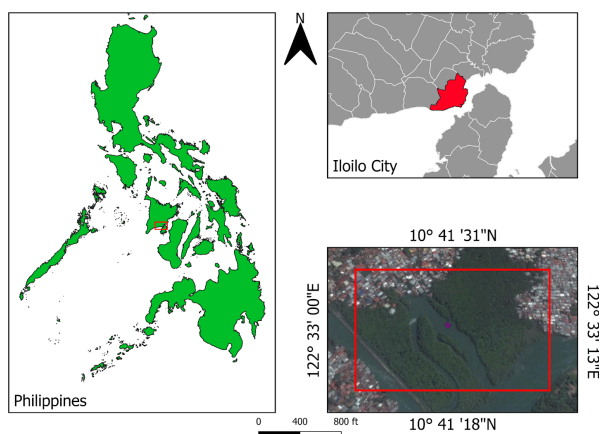


Figure 1. Study Site in the Batiano River, Iloilo City, Philippines.

The site was visited by researchers to determine the human activities, and mangrove tree planting and fishing were observed. The captain of the community was interviewed, and it was confirmed that the aforementioned activities were paused during the lockdown. The mangrove species used for tree planting in the area was confirmed to be *Avicennia marina*. Due to the area of mangroves being adjacent to a community, there was also a significant amount of trash found in the mangrove area and in the river. Shown in Figure 2 are the images taken during the inspection of the Batiano River and its mangroves.

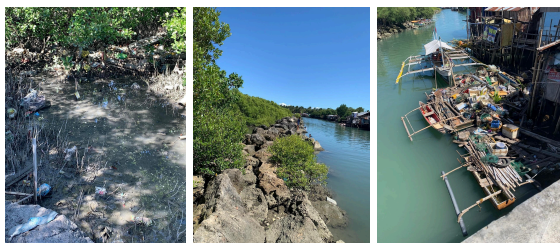


Figure 2. Mangrove area in the Batiano River.

Collection and Georeferencing of Satellite Images. One satellite image was collected each from April 27, 2017; February 9, 2018; March 2, 2019; April 18, 2020; and April 30, 2021. The images were obtained from Google Earth Pro version 7.3.2, an application that contains features such as being able to obtain a

satellite view of an area at different dates by changing the time. The satellite images needed for each date were then georeferenced in Smart GIS version 23.02.

Mapping of Mangrove Area. Before the mapping process, a site inspection was done to ensure that the plants being mapped are mangroves. The georeferenced satellite images' mangrove area was manually mapped in QGIS version 3.28.1 by tracing the area using a polygon and turned into a shapefile layer. If the mangrove areas were scattered, multiple polygons were created for each mangrove patch.

Calculation of Mangrove Area. After the tracing was completed, the attribute table of the shapefile layer was opened, and a new field was added, which served as the column for each polygon's area. The field calculator was then opened, and the command '\$area' was inputted, which automatically calculated the area size of each polygon. The given area sizes were then added to obtain the total area of the mangroves during the given year.

Data Analysis. The percent change in mangrove area cover was calculated. Next, the percent changes were then compared and the trend in the change of mangrove forest cover was observed. It was then analyzed whether or not the change in the mangrove area was affected by the lockdown. This is further explained in the discussion section.

Computing for the Percent Change in Mangrove Forest Cover. The percent change is the percentage of increase or decrease of mangroves in an area for the given year compared to the previous year. The percent changes were calculated using the formula:

$$\Delta\% = \frac{\text{Final Area} - \text{Initial Area}}{\text{Initial Area}} \times 100\%$$

The final area is the area of mangrove cover in a given year and the initial area is the area of the mangrove cover in the preceding year. A positive percentage indicated an increase in area while a negative percentage indicated a decrease.

Analyzing the Trend of Percent Changes. The percent changes that were calculated were used to assess the possible effects of the lockdown by analyzing the trend. The percent changes in the area both before and during the lockdown were compared.

Safety Procedure. This study mainly involved the use of digital data; therefore, the possible hazard that was foreseen was the radiation from the computers. This was mitigated by limiting the time spent facing computers, and while unnecessary, anti-radiation glasses were also reserved to be worn for protection in case problems arose when facing the computer during the data gathering procedure in the computer software. Furthermore, during the site inspections, there was a companion of legal age present in order to secure the site inspection process.



Results and Discussion. - The mangrove forest of the Batiano River, Iloilo City (from 10° 41' 31"N to 10° 41' 18"N and from 122° 33' 00"E to 122° 33' 13"E) was mapped from 2017 to 2021. Shown in Figure 3 are the mapped areas of the mangrove forest, where the change in the area throughout the years can be visualized with the initial year 2017 and the final year 2021.

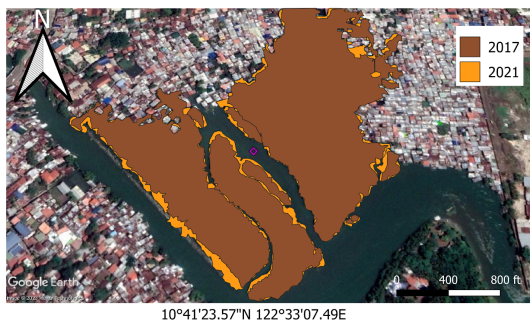


Figure 3. Change in mangrove forest cover, 2017 to 2021.

The areas calculated from the mangrove forest cover of the Batiano River, Iloilo City, Philippines, were 89283.79 m² (April 27, 2017), 89787.33 m² (February 9, 2018), 89707.32 m² (March 2, 2019), 91695.85 m² (April 18, 2020), and 92684.52 m² (April 30, 2021). Using the data gathered from the mangrove forest's area, the percent changes for every year were calculated. Percent changes in area were 0.57% from 2017 to 2018, -0.09% from 2018 to 2019, 2.22% from 2019 to 2020, and 1.08% from 2020 to 2021. A change of less than one percent was seen from 2017 to 2019, while an increase of more than one percent was seen from 2019 to 2021, with the highest increase from 2019 to 2020. Shown in Figure 4 is the trend of change in mangrove areas during the years 2017 to 2021.

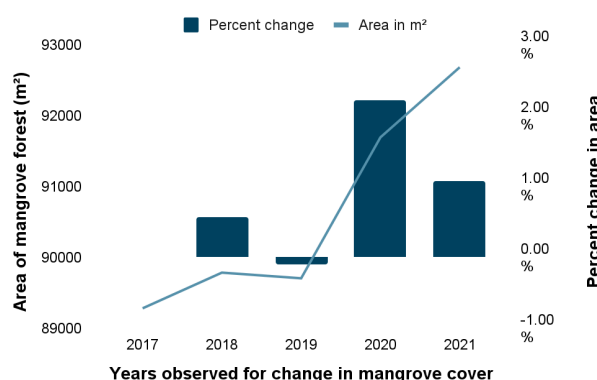


Figure 4. Area (in m²) and percent change of mangrove cover in the Batiano River, Iloilo City, Philippines, 2017 to 2021.

Mangrove area growth from 2017 to 2019 was gradual, despite other human activities present in the area potentially impacting the mangrove forest, due to the area's mangrove tree planting initiative that started in 2016. The gradual increase in the area can be attributed to the time mangroves take to grow, which is usually ten to twenty years until they fully mature [12]. Moreover, the *Avicennia marina* species

of mangrove grows in sandy, muddy, and coralline rock substrates [13]. The area's substrate is muddy, as observed from visiting the site, which is suitable for the species of *Avicennia marina*. This could have contributed to the area consistently increasing throughout the years except from 2018 to 2019. Common human activities that impact mangroves are those that require utilization of the forests' area, such as the expansion of aquaculture, tourism, and coastal development [2]. Moreover, mangroves are also used as resources, such as wood for construction and fuel [4]. However, this is not the case for the mangroves in the Batiano River, as the human activities found on the site do not involve the destruction of mangroves, like fishing and mangrove tree planting. Lastly, the decrease in area from 2018 to 2019 could likely be a personal error due to the methods being done manually.

An increase of 1988.53 m² or 2.22% occurred from 2019 to 2020. Additional information about the activities on the mangroves in the Batiano River, Iloilo City was gathered for possible explanations of the marked increase in area. There were mangrove tree planting activities that started in 2016 by the community's local government, and the prohibition of the cutting of mangroves in 2019 based on Republic Act No. 7161. There was also an intervention by the Department of Environment and Natural Resources (DENR) to preserve the mangroves in the area, which occurred from 2019 to 2020. When human activities are persistent, action toward the restoration of mangroves is needed to combat the impact of human activities.

There was a 1.08% or 988.67 m² increase in the area of mangroves from 2020 to 2021, which was during the lockdown. This can also be attributed to the intervention of the DENR and the adopted ordinance. However, the mangrove tree planting paused during the lockdown. This left the mangroves to just grow naturally, causing a slower increase in the mangrove forest's area. Nevertheless, there were no other human activities ongoing due to the lockdown. This might have contributed to faster growth than in 2017 to 2019. Additionally, studies have shown that improvements in environmental conditions were caused by the restriction of human activity due to the lockdown, shown in indicators of air quality and water quality [8,15]. However, the same cannot be concluded for mangroves, as there are other factors, such as mangrove tree planting, that may impact the mangrove forest differently, and changes in mangroves take longer to be noticeable [13].

The lockdown only had a partially positive impact on mangroves, as before the lockdown was imposed, other factors already had a positive impact. Improvements in environmental conditions during the COVID-19 lockdown did not take effect as quickly in mangroves as it did in pollution, due to reforestation efforts being present, which already helped the mangrove forest's conditions before the lockdown. With that, any increase or decrease in the area of mangrove cover in the Batiano River cannot be solely attributed to the lockdown.



Limitations. The limitations of this study mainly focus on its methodology. First, the availability of satellite images was limited, which specifically led to one of the images being low quality, making it prone to personal errors. Second, the mangrove forest cover was only monitored for the total area occupied, which could be different when it comes to its vegetation and colonization rate. Third, although the area was visited to ensure that the plants seen in the satellite images are indeed mangroves, it cannot be assumed for the whole area. Some parts of the forest are too far to be visited, which makes it difficult to determine whether there are other plants growing adjacent to the mangroves. Lastly, the years used for comparing the trend of growth before and during the lockdown only generalized the years in which the lockdown occurred, not the actual time frame of the lockdown.

Conclusion. - Generally, there was an increase in the mangrove area from 2017 to 2021, with a marked increase from 2019 to 2020. Although during the lockdown, there was an increase in area, it is not as high as the increase in the preceding year. Thus, the increase cannot be solely attributed to the lockdown, but prior human interventions such as mangrove tree planting, regulations to protect the mangroves, and government interventions were able to contribute to the increase in the area of mangrove forest cover.

Recommendations. - Satellite images from Google Earth Pro were used for mapping, but other satellite websites could be used for image collection so that the satellite images to be used are ensured to be available and high quality to avoid errors in future studies. Due to the limited available images, not all months had satellite images in Google Earth Pro version 7.3.2. Determining the conditions of a mangrove forest could be done by using other assessments, such as colonization rate, which indicates how quickly mangroves occupy a new area, and vegetation index, which determines the density and vegetation of plants in an area based on their color. Selecting an area without rehabilitations for mangroves can determine the impact of the lockdown better. Focusing on changes that occurred monthly instead of annually could be done in future studies to have a clear comparison of the change that occurred before and during the lockdown. Other parameters such as land pollution and grassland vegetation could also be compared. Lastly, no satellite images for the year 2022 were available on Google Earth Pro, which made this study unable to describe the status of mangrove forests after the lockdown; therefore, it is recommended that studies in the future investigate the trend of mangrove area change post lockdown.

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CLUSTER THREE

ENVIRONMENTAL SCIENCE

The greenness of the plant symbolizes growth and progress towards exploring agricultural wastes for environmental science. Trapped inside are the contaminants and pathogens present in our water sources portrayed by the droplet shape, thus providing great capacity for new sorbent materials. Repurposing agricultural wastes offers a sustainable solution to both waste management and oil spill remediation, productively addressing two major environmental issues. Overall, this symbol is a testament to the scientific investigation of the unlimited potential roles of agricultural wastes and the importance of environmental preservation for the community.

Cluster 3 encapsulates the essence of environmental science research, particularly in repurposing sugarcane bagasse, rice residues, and pineapple leaf fibers in diesel oil recovery. Oil sorption studies involve the submersion of sorbents in the oil sorbate to test their ability to absorb or adsorb the molecules into their matrix. Alongside water quality analyses, these studies attempt to address the long-term detrimental impact of pollution in the environment, consequently affecting ecosystems. These studies are dedicated to future research that will uncover the potential of agricultural wastes for the preservation of the environment.

Diesel oil sorption potential of sugarcane bagasse incorporated with human hair

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Abstract

Sorbents remove pollutants by absorption, adsorption, or both. Sugarcane Bagasse (SCB) has excellent sorption ability, but it can acquire water in its pores, limiting its field application in oil spills. Due to the high oleophilic and hydrophobic properties of human hair (HH), the study aimed to determine the sorption percentages of SCB incorporated with HH of varying ratios in diesel oil. Three treatments with the ratios (1:1), (1:3), and (3:1), and three controls were subjected to 60-minute sorption tests by placing sorbent samples on oil-seawater mixtures. Kruskal-Wallis H Test and the Mann-Whitney U test revealed significant differences among groups. An equal ratio of SCB and HH had significantly the highest percent sorption, likely due to the lignocellulosic content in SCB and the lipid layer in HH. Cellulose in SCB is suspected to promote water absorptivity and consequently, percent water sorption, while the hydrophobicity of HH possibly caused low percent water sorption. The synthetic sorbent pad exhibited the highest percent oil sorption, which can be attributed to its hydrophobicity, oleophilicity, and large surface area. The incorporation of HH in SCB shows favorable results in diesel oil removal, specifically in an equal ratio. With this, the study can be a basis for the establishment of sorbents incorporating SCB and HH.

Introduction. - The Philippines, being an archipelago, relies heavily on maritime transport for movement, including motorized “pump” boats or *bangkas* powered by diesel-powered outriggers, where spillage usually occurs during refueling and bilge discharge [1]. Vessels caused more than half (55.15%) of the oil spills in the country between 1975 and 2019, and more than three-fourths of which were Tier 1 oil spills (between 1 to 10,000 liters) [2].

Various methods and technologies such as chemical treatment, bioremediation, and physical remediation like skimmers, booms, and sorbents have been applied in the recovery and remediation of oil spills [3,4]. Sorbents are materials used to remove or recover pollutants by absorption, adsorption, or both [5]. Absorption involves the oil penetrating the pore spaces of the material, while adsorption only entails physical accumulation on the surface of the adsorbent [6,7,8].

Effective sorbents should have high hydrophobicity, oleophilicity, uptake capacity, and appropriate efficiency in oil recovery, retention, reusability, and biodegradability [9, 10]. Based on these criteria, synthetic sorbents are the most widely applied materials but they are not advantageous economically and environmentally, hence there is a rising trend in publications on oil spill cleanup and alternatives [11]. Specifically, there is a growing interest in natural sorbents [11,12,13] due to their accessibility, low costs [11,14]; biodegradability, and non-toxicity [3]. However, a disadvantage for most

natural materials is low hydrophobicity which reduces potential oil uptake due to competition between seawater and oil molecules [3,11].

Studies [15,16,17] have investigated the sorption ability of various natural materials such as raw sugarcane bagasse (SCB), specifically for oil. It is a fibrous agricultural by-product obtained after sugarcane is crushed for juice extraction [16,18].

SCB and its derivatives have been studied as potential adsorbents in both their raw and modified forms [19]. Ali et al. [15] found that SCB exhibits excellent sorption capacity, exceeding 10 g/g, however, its oil-to-water sorbency ratios were considerably low. SCB can still acquire water in its pores despite having a strong high affinity for oil, which hinders its field application. Ifelebuegu and Momoh [18] reported that the high oleophilicity and hydrophobicity of human hair (HH) resulted in increased oil adsorption and decreased water adsorption once integrated with coconut coir. In order to increase usability of SCB, the current study used SCB with added HH, which are agricultural and human waste, respectively. SCB may be more effective in oil spills with reduced water sorption ability [17] and increased oil sorption capacity by incorporating HH in 1:3, 1:1, and 3:1 ratios [18].



In addition to the multiple studies on SCB [6,16,22] and HH [20,21,23] for oil sorption, this research may offer additional insight into oil spill removal, sorbent materials, and the potential of agricultural waste. The abundance and low-cost of raw lignocellulosic materials and HH are favorable for practical applications and clean-up efforts, specifically in oil-water separation [11,24,25].

The study aimed to determine the sorption percentages of SCB incorporated with HH in varying ratios (1:1, 1:3, 3:1) in diesel oil using 60-minute sorption tests. Specifically, it aimed to:

- (i) measure and compute the mean percent sorption (PS) (%), mean percent oil sorption (POS) (%), and mean percent water sorption (PWS) (%) of each treatment and control group;
- (ii) compare the mean PS, mean POS, and mean PWS of groups using the Kruskal-Wallis H test; and
- (iii) determine which pairs of means are statistically different using the Mann-Whitney U test.

Methods. - The methodology is divided into five (5) parts: preparation, sorption, separation of oil and seawater, computation of parameters, and statistical analysis. The estimated duration of the experiment was four weeks, which included periods for procurement, data gathering, and data analysis.

Preparation. SCB and HH were washed and soaked in distilled water, respectively, and dried under sunlight. SCB was sieved to a particle size of 0.25 mm and randomized using the coning and quartering method. A total of 4 g for each sorbent group (excluding sorbent pads) were wrapped in polypropylene fabric for easy retrieval after sorption. A 3-D sphere was used to shape and pack sorbent bags with consistency and minimal disparity.

The oil-seawater mixtures composed of 200 mL of seawater and 20 mL of diesel oil were prepared in 600 mL beakers and measured with a calibrated toploading balance (Sartorius QUINTIX1102-1S).

Sorption. The sorption test was performed by subjecting the wrapped SCB + HH (1:1) sorbent to the surface of the oil-seawater mixture and allowing it to float freely, following the American Society for Testing and Materials (ASTM) F726-99 - Standard Method for Testing Oil Spill Sorbents [5.] After 60 minutes, the sorbent was removed and drained in a basket for 2 minutes. Finally, the resulting sorbent was weighed using a calibrated analytical balance (KERN ABJ 320-4NM). The same procedures were done for the remaining treatment (1:3 and 3:1) and control groups (SCB only, HH only, and sorbent pads). Six samples were tested for each group. To control the substance sorbed by the polypropylene fabric used to wrap the treatments, six samples of empty polypropylene bags of the same dimensions as those used in wrapping the sorbents were subjected to the same procedures and same

experimental conditions. The average weight of the substance sorbed by the empty bag was subtracted from the weights of the sorbent samples.

Separation of Oil and Seawater using Decantation. To obtain POS and PWS values, the remaining oil-seawater mixture was transferred to a separatory funnel, where the mixture was left to rest. The seawater layer was first collected, followed by the oil layer. The separated remaining oil and seawater were individually weighed using a toploading balance.

Computation of Parameters. All variables were measured in grams. PS is the ratio of the substance sorbed by the sorbent to the initial substance in the oil-seawater mixture, disregarding the effect of the polypropylene fabric. It was computed with the formula [20]:

$$PS = \frac{W_a - W_b - W_s}{O_t + W_t} \times 100\%$$

where:

W_a is the weight of the sorbent after sorption,
 W_b is the weight of the sorbent before sorption,
 W_s is the weight of the substance sorbed by the polypropylene fabric,
 O_t is the initial weight of the oil in the oil-seawater mixture, and
 W_t is the initial weight of the seawater in the oil-seawater mixture

The POS is a ratio of oil sorbed to the initial oil in the oil-seawater mixture, disregarding the effect of the polypropylene fabric. It was computed with the formula:

$$POS = \frac{O_t - O_r - O_s}{O_t} \times 100\%$$

where:

O_t is the initial weight of the oil in the oil-seawater mixture,
 O_r is the weight of the oil remaining in the beaker after sorption, and
 O_s is the average weight of oil sorbed by the empty polypropylene bags.

The PWS is the ratio of seawater sorbed to the initial seawater in the oil-seawater mixture, disregarding the effect of the polypropylene fabric. It was computed with the formula:

$$PWS = \frac{W_t - W_r - W_w}{W_t} \times 100\%$$

where:

W_t is the initial weight of the seawater in the oil-seawater mixture
 W_r is the weight of the seawater remaining in the beaker after sorption; and
 W_w is the average weight of seawater sorbed by the empty polypropylene bags.



For the group sorbent pads, the same formulae were used, but O_s and W_w had no values.

Statistical Analysis. The computed mean values of each group for each parameter were analyzed using the Kruskal-Wallis H test. The Mann-Whitney U test was made to identify which pairs of means were statistically different. All tests were performed using Statistical Package for the Social Sciences (SPSS) (Version 28.0.0.0, IBM SPSS Statistics).

Safety Procedure. Precautionary measures for transport, storage, handling, first aid, personal protective equipment, and disposal were observed and implemented. Diesel oil was placed away from items that can create possible hazards. Safety glasses with side shields, aprons, boots, air-purifying respirators for organic vapors (Elastomeric Half Facepiece Respirators), and gloves were worn throughout the data gathering. Lastly, liquid substances and sorbent waste were handed over to Caltex Station Tabuc Suba and PSHS WVC's Research Assistants, respectively, for proper disposal.

Results and Discussion. - The treatment with an equal ratio of SCB and HH had significantly the highest mean PS and PWS, while the control group sorbent pad had significantly the highest mean POS.

Percent Sorption. The mean PS between the treatment and control groups was significantly different using the Kruskal Wallis H test ($H(5) = 26.8393$, $p = <0.001$). The Mann-Whitney U test revealed that the pairs of means that showed statistical differences were T1 and T2, T1 and C2, T1 and C3, T2 and C1, T2 and C2, T3 and C1, T3 and C2, T3 and C3, C1 and C2, and C1 and C3.

Table 1. The Mean Percent Sorption of Treatment and Control Groups.

Group	Mean Percent Sorption (%)
T1 (1 SCB: 1 HH)	16.5783 ± 4.97
T2 (1 SCB : 3 HH)	9.2233 ± 3.78
T3 (3 SCB: 1 HH)	12.9033 ± 1.73
C1 (SCB only)	16.1600 ± 1.08
C2 (HH only)	1.7700 ± 1.90
C3 (Sorbent Pad)	3.9117 ± 0.28

The mean PS of T1 (1 SCB: 1 HH) is significantly higher compared to the PS of T2 (1 SCB : 3 HH), C2 (HH only), and C3 (Sorbent Pad), while it is comparable to the PS of T3 (3 SCB: 1 HH) and C1 (SCB only). This may be attributed to the higher SCB content comprising T1 (1 SCB: 1 HH), T3 (3 SCB: 1 HH), and C1 (SCB only). SCB contains a carbon percentage greater than 50%, providing an initial indication of high lignocellulosic content [18]. SCB is a combination of 40-45% cellulose, 20-30% lignin, and 30-35% hemicellulose [26,27]. Since the groups contain 50% or more SCB, it is supported by its main constituents and polymeric structures, which have a strong influence on the adsorption capacity [28].

The PS of T1 (1 SCB: 1 HH) can also be attributed

to the presence of keratin and cuticles covered by a layer of lipid (18-methyleicosanoic acid), which contributes to the hydrophobic and oleophilic characteristics of HH, hence, the ability to sorb large quantities of oil from aqueous solution [29,30,31]. However, despite its porous structure [32], rough texture, large surface area, and the presence of amine (NH-), hydroxyl (OH), sulfide group, S-S, carboxyl group, C-O, and carbonyl (C=O) groups on its surface [21,30,31], which are factors for high sorption affinity of HH, C2 (HH only) shows the lower than expected sorption affinity for HH (Table 1) in contrast to the recommendation of Ifelebuegu and Momoh [18]. Another mechanism may have been involved in T1 leading to improved distribution because SCB particles and/or HH fibers might be optimally more separated in the 50% mixture.

C1 (SCB only) had a significantly higher mean PS compared to T2 (1 SCB : 3 HH). Surface morphology of the sorbent material is a factor that affects oil adsorption [9]. The rough exterior of SCB [15] provides more active sites for oil adsorption which is desirable and linked to high sorption capacity. Moreover, the oil adsorptivity of a natural sorbent is directly dependent on its active surface area [34,35]. Given that the SCB content was reduced when comparing C1 and T2 as well as SCB having better sorption than HH when comparing C1 and C2, it can be implied that reducing the SCB content also diminishes the sorption potential.

C1 (SCB only) had a significantly higher mean PS compared to T3. It can be speculated that this was contributed by SCB's high water absorptivity [18]. It was observed during the experiment that most samples of T3 (3 SCB: 1 HH) and C1 (SCB only) sank to the bottom of the beaker. This phenomenon is in accordance with the study of Ali et al. [15] and supported by Chau et al. [36], where it was stated that when enough water is absorbed, natural cellulose-based absorbents would sink.

Moreover, T3 (3 SCB: 1 HH) was significantly higher than C2 (HH only), an indication that the incorporation of HH to SCB is better compared to HH alone. T3 (3 SCB: 1 HH) is also significantly higher than C3 (Sorbent Pad), suggesting the potential of the sorbent when compared to commercially manufactured sorbent pads. Additionally, C1 (SCB only) is significantly higher than C2 (HH only) and C3 (Sorbent Pad), which means that SCB exhibits better PS compared to the sorbent material HH or sorbent pads. Similar to the previous discussion, these may be attributed to the higher SCB content comprising T3 (3 SCB: 1 HH) and C1 (SCB only) [16].

The treatment and control groups (excluding C3 (Sorbent Pad) which were laid in sheets) were wrapped with a polypropylene fabric using a 3-D printed sphere to maintain consistent bulk density among samples. Bulk density is also a key factor in determining sorbent porosity and sorption capacity. It indicates how much weight of material could be packed per unit volume and is used to determine how much material can fit in the container [37].



Paulauskienė et al. [38] found that sorbents with high sorption capacity exhibit low bulk density values, since in theory, lower bulk density defines higher porosity. To achieve similar packing space and bulk density across samples, a 3D-printed sphere was used to determine the tightness and amount of space the sorbent bags of the treatment and control groups (excluding C3 (Sorbent Pad)) would have.

Percent Oil Sorption. Kruskal-Wallis H test showed a statistically significant difference between the treatment and control groups ($H(4) = 15.413$, $p = 0.004$). Using the Mann-Whitney U test, C3 (Sorbent Pad) was statistically different from all treatment and control groups as it had significantly the highest POS (excluding T1 (1 SCB: 1 HH)) from the parameter.

Table 2. The Mean Percent Oil Sorption of Treatment and Control Groups, excluding T1*.

Group	Mean Percent Oil Sorption (%)
T2 (1 SCB : 3 HH)	2.45 ± 1.28
T3 (3 SCB: 1 HH)	1.07 ± 0.78
C1 (SCB only)	1.94 ± 1.03
C2 (HH only)	5.63 ± 5.91
C3 (Sorbent Pad)	59.70 ± 7.47

*T1 was excluded from the POS data analysis due to insufficient number of samples.

It was also found that C3 (Sorbent Pad) had the significantly highest mean POS, which may be due to synthetic sorbents having good hydrophobic and oleophilic properties [24] and high sorption capacity [4]. Sorbent pads are made from engineered polymers with a high surface area, a factor that promotes sorption [39]. Additionally, C2 (HH only) had a large standard deviation (Table 2) which may be due to the small sample size of the study.

Percent Water Sorption. Kruskal-Wallis H test showed a statistically significant difference between the treatment and control groups ($H(4) = 14.601$, $p = 0.004$). The Mann-Whitney U test showed that the mean PWS of C2 was significantly lower than those of other treatments – T1 (1 SCB: 1 HH), T2 (1 SCB : 3 HH), T3 (3 SCB: 1 HH), and C1 (SCB only). Furthermore, T1 (1 SCB: 1 HH) had significantly higher PWS compared to T2 (1 SCB : 3 HH) (Table 3).

Table 3. The Mean Percent Water Sorption of Treatment and Control Groups, excluding C3**.

Group	Mean Percent Water Sorption (%)
T1 (1 SCB: 1 HH)	36.65 ± 7.34
T2 (1 SCB : 3 HH)	15.97 ± 13.30
T3 (3 SCB: 1 HH)	30.71 ± 6.65
C1 (SCB only)	29.76 ± 4.35
C2 (HH only)	2.09 ± 1.64

**C3 was excluded from PWS data analysis due to significant outliers.

C2 (HH only), sorbents containing only HH, had significantly lower mean PWS than the other groups. The low sorption of water can be attributed to the hydrophobic property of HH, which is contributed by the layer of lipid that shelters keratin and the cuticle [6] and its affinity for oil [40,41]. In

comparison to T1 (1 SCB: 1 HH), T2 (1 SCB : 3 HH), T3 (3 SCB: 1 HH), and C1 (SCB only), the absence of SCB in the C2 (HH only) group entails a lack of potential water absorptivity, whereas SCB is highly capable of 400% to 700% water absorptivity [17].

It was also found that T1 (1 SCB: 1 HH) had a significantly higher mean PWS than T2 (1 SCB : 3 HH). The difference could be explained by the high water sorption capacity of SCB [7, 17] combined with the hydrophobicity of HH [6]. Comparing the two groups, T1 (1 SCB: 1 HH) has one more gram of SCB and one less gram of HH than T2 (1 SCB : 3 HH). It follows that T1 (1 SCB: 1 HH) is able to absorb more seawater. It can be noticed that groups containing 50% or more SCB are comparable and have a mean of 29% PWS or more. This may be due to the SCB's natural sorption capabilities.

Limitations. Considering that this study was conducted at the height of the pandemic, the organic materials were sun-dried instead of oven-dried due to feasibility concerns, specifically, limited access to equipment. Variations in room temperature may have occurred due to ventilation at the data collection site.

Conclusion. - The PS, POS, and PWS of SCB incorporated with HH in varying ratios in diesel oil were investigated to determine its applicability as an oil spill sorbent.

SCB when incorporated with HH resulted in the highest PS and PWS, which can be attributed to the combination of the water absorptivity of SCB and the oleophilicity of HH. In regards to POS, sorbent pads exceeded all other treatment and control groups consisting of organic materials possibly due to its high surface area and synthetic nature.

This study can serve as a basis for the formulation of SCB with HH as viable oil sorbents in diesel oil removal, and when comparing the treatments of the study, an optimal sorbent ratio would be an equal amount of SCB and HH.

Recommendations. - Experiments can be conducted within a day to avoid possible influence in the following days or all control groups can be tested per day for a more accurate comparison with the treatments. The polypropylene fabric in the study may have had an effect on the treatments and results, hence efficient methods to disregard its effect can be implemented, along with more replicates. Excess substance caused by weak capillary forces can be excluded from the sorbed substance of the sample.

The weighing of glassware can be done repeatedly and with minimal movement in the surroundings to reduce the chances of error in the resulting measurement. Further research can be done at a microscopic level to establish the synergistic effect of SCB and HH provided that both absorption and adsorption are present. Additionally, adsorption isotherm modeling and kinetic modeling are suggested to determine maximum sorbent uptake and reaction rate. Future studies can also test



variations in oil types and the packing of the materials into the bag. For bulk density, different geometrical shapes can be considered to determine a standard measurement in packing and significant differences with respect to their sorption abilities.

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Comparison of raw rice husk and raw rice straw (*Oryza sativa* L.) for diesel oil removal

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Article Info	Abstract
Submitted: Jul 07, 2023 Approved: Dec 26, 2023 Published: Dec 31, 2023 Keywords: rice husk rice straw sorption diesel oil oil spill	Oil spillages result in detrimental environmental hazards, posing mutagenic and carcinogenic effects. Targeting oil removal and repurposing of agricultural wastes, this study aims to assess and compare the percent sorption of raw rice husk (RRH) and raw rice straw (RRS) for pure diesel oil. A tetrahedral framework in the packing of the sorbents was incorporated to control their bulk density. Results showed that RRH, RRS, and sorbent pad have mean percent sorption of 2.97%, 4.71%, and 7.25%, respectively. The significantly higher mean percent sorption of RRS than RRH can be linked to their porosity, surface roughness, and presence of functional groups and lignocellulosic components. Thus, RRS can better sorb diesel oil than RRH. Although it is not comparable with the commercially-used sorbent pad, the use of RRS is still recommended as an alternative sorbent for oil spill clean-up.

Introduction. - Oil spills may contribute environmental damage to lands and seas that could necessitate years or decades of recovery due to the release of toxic hydrocarbon compounds known as polycyclic aromatic hydrocarbons [1,2]. Among reported spill incidents, diesel constitutes 20% of the encountered oil type that originates from major sources such as power plants and power barges [3]. Consequently, diesel oil, with a density of 0.81-0.84 g/cm³, has been recognized as one of the relevant oils that require oil spill response in the Philippines [3]. Thus, diesel, exhibiting better diffusion and higher penetration in sorbents, has been utilized for evaluating the adsorptive characteristics of sorbents [4,5]. Specifically, the diesel used in this study contains a mixture of paraffins, cycloparaffins, aromatic and olefinic hydrocarbons, and has a density of 0.84 g/cm³ [6].

Various technologies for the removal of organic pollutants have been explored by previous studies, such as oxidation, reverse osmosis, ion exchange, electrodialysis, electrolysis, and adsorption [7]. Among these, sorption, constituting both absorption and adsorption processes, was widely used due to its wide availability, low cost, and ease of operation [7, 8]. It refers to the mechanism dependent on sorbent porosity by which a sorbate is incorporated into the porous structures of a material [9]. Other processes involve splitting the compounds into their basic elements and utilizing pressure or electric energy for oil removal.

With the increased amount of non-edible biomass, organic sorbents have been targeted in oil spill treatments, owing to their low cost, high availability, good biodegradability, and other

eco-friendly properties [9,10,11,12]. Sorption capabilities of rice husk and rice straw have been investigated in various sorbates such as dyes, light crude oil, and crude, spent, and engine oil [13,14,15]. Modifications of sorbents have been employed including alkali treatment, thermal modifications, acetylation, and carbonization [1,5,17,18,19,20]. However, these pre-treatment processes were contradicted as time-consuming and costly [18]. Therefore, researchers utilized the raw states of the sorbents. On the other hand, the sorbent pads obtained for this study meet the standards set by the industry for managing spills.

The properties of the sorbents promote their sorption capabilities. The void spaces in the matrices contribute to their porosity, while the composition such as cellulose, hemicellulose, and lignin account for their hydrophobic-oleophilic properties [10,19]. These properties allow the attachment and entrapment of oil within their structures [21]. However, grinding causes damage to the pores, which hinders oil attachment on its surfaces [15]. Thus, the use of raw unground materials appears to be more desirable in emergency oil spill circumstances.

Bulk density, the mass of a bulk solid occupying a unit volume including interparticle voids, influences oil sorption [1,22]. Specifically, low bulk density favors the formation of capillaries between particles, increasing the available contact area between particles [23]. Although previous studies employed various packing methods such as sphere-shaped mesh bags and tetrahedral oil bags, uniformity of bulk density was not specified which could affect oil sorption [16,24]. Thus, the tetrahedral-shaped mesh from Ismail et al. [16] with



fixed volume was adapted to ensure a rigid structure and uniform volume, thereby maintaining a constant bulk density throughout sorption while still allowing oil to penetrate into the sorbents [25].

Porosity was found to be higher in rice straw than in rice husk [26]. Studies have also shown that porosity influences sorption more than phase composition since sorption capacity increases along with increasing porosities [14,27]. Thus, rice straw is hypothesized to yield a higher diesel percent sorption than rice husk.

This study aimed to determine and compare the percent sorption of raw rice husk (RRH), raw rice straw (RRS), and sorbent pad for diesel oil. It specifically aims to:

- (i) determine the pre-submersion and post-submersion weights (in grams) of the treatment groups (RRH and RRS sorbents) and control group (sorbent pads);
- (ii) evaluate the percent sorption (%) of the three sorbents; and
- (iii) compare the differences in the mean percent sorption of the treatment groups and control group using one-way ANOVA at $p \leq 0.05$.

Methods. - The rice husks and rice straws were washed, oven-dried, cut, sifted, randomized, and then packed inside a tetrahedral frame wrapped in mesh net (TFMN). After which, the samples were weighed and submerged in pure diesel oil. The control samples, or the sorbent pads, were also subjected to the same packing and submersion procedures. All the sorbents were allowed to drip before getting their post-submersion weights. The percent sorption values were then calculated, compared, and analyzed using One-Way Analysis of Variance (ANOVA) at $p \leq 0.05$. A total of 30 samples, 10 for each type of sorbent, were administered.

Procurement of materials. The RRH and RRS were collected from a rice farm in Guimaras Island (10°43'46.88"N latitude and 122°40'59.594"S longitude) and were verified as *Oryza sativa* L., Rc 418 variety by the Office of Municipal Agriculturist in Buenavista, Guimaras. Meanwhile, the commercial-grade sorbent pads were purchased from YMC Philippines based in Metro Manila. The diesel oil was obtained from a gasoline station in Iloilo City. The tetrahedral frames and mesh net were acquired from local stores in Iloilo City.

Preparation. The RRH and RRS were washed with distilled water and oven-dried at 60°C for 24 hours. The RRS was cut into 9mm similar to that of the RRH, while the RRH remained at its original length. Both of these were hand-sieved through fine mesh sieves of 3 mm and 5 mm to attain the desired particle size range of 3 to 5 mm.

Randomization. To minimize the biases in this study, the sorbents were subjected to the coning and quartering method by gradually reducing the aggregate to randomly obtain each sample. The oil sorbates were subjected to the "lottery method" to assign them to their respective sample treatment groups with equal chances of being selected.

Packing of Sorbents. All sorbents were packed inside the TFMN as storage for oil retrieval. This was prepared by wrapping a 15x15cm mesh net around the frame, then filled with 3.00 grams of the specific sorbent, and sealed using a plastic heat sealer. The excess fabric was then cut. There were 10 samples for each type of sorbent: RRH, RRS, and sorbent pads, resulting in a total of 30 samples.

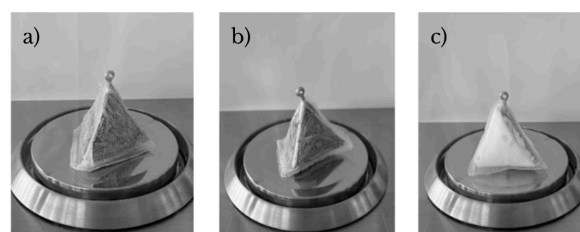


Figure 1. TFMN with a) RRH sample, b) RRS sample, and c) sorbent pad.

Bulk Density. To ensure the uniformity of packing across the sorbents, a constant edge length was set among all TFMN such that the bulk density, when computed, would uniformly equate to 0.28 g/cm³.

Sorption Test. The packed sorbents were simultaneously submerged in 300 mL of pure diesel oil for 15 minutes and were then allowed to drip for another 15 minutes. To minimize the possible effects of any trapped oil in the TFMN, five (5) replicates of empty TFMN were subjected to the same sorption procedures. After which, each packed sorbent was weighed, followed by subtracting the average weight of the empty TFMNs to obtain the final post-submersion weight of the sorbents only.

Data Analysis. The percent sorption values across the sorbents were computed with the formula derived from Razavi et al. (2014):

$$\% \text{ Sorption} = \left(\frac{S_t - S_0}{\text{initial oil}} \right) \times 100$$

Where:

S_t = post-submersion weight (in grams) of the sorbent containing the sorbed oil

S_0 = pre-submersion weight (in grams) of the sorbent
initial oil = weight (in grams) of the diesel oil before sorption

Statistical Analysis. There are three independent means to analyze; therefore, one-way ANOVA, along with its applicable inferential non-parametric, parametric, and post-hoc tests, is an applicable statistical test for this study [28]. The computed percent sorption data of each sorbent was inputted in the Jamovi Software (ver. 2.3.17.0) and was subjected



to the inferential non-parametric Shapiro-Wilk test to determine the normality of the data. To assess the homogeneity of variances across the normally distributed percent sorption of the sorbents, the parametric Levene's test was utilized.

One-way ANOVA was used to determine the presence of a significant statistical difference across the three mean percent sorption values. The significance level was set at 0.05. Lastly, to make pairwise comparisons between the three means, the Tukey post-hoc test was used to further reveal the specific differences.

Safety Procedure. Health and safety protocols were observed during the conduct of the whole experiment, including the wearing of personal protective equipment such as gloves, goggles, masks, and polypropylene laboratory gowns. High-density polyethylene containers were used for the storage and handling of hazardous chemicals or the diesel oil in accordance with the MSDS. For disposal, excess and contaminated diesel oil and used sorbents were handed to the health and safety officer of Philippine Science High School - Western Visayas Campus.

Results and Discussion. - RRS yielded a mean percent sorption of 4.71 which is significantly higher than RRH of 2.97. Sorbent pads, on the other hand, exhibited the highest mean percent sorption of 7.31. (Table 1)

Table 1. Mean weights of RRH, RRS, and sorbent pads before and after sorption (in grams), and their corresponding mean percent sorption values (%).

Sorbent Type	Before Sorption (g)	After Sorption (g)	Percent Sorption (%)
RRH	3.00±0.0006	10.33±0.38	2.97±0.15
RRS	3.00±0.0002	14.66±0.82	4.71±0.38
Sorbent Pads	3.00±0.0003	21.01±0.66	7.25±0.42

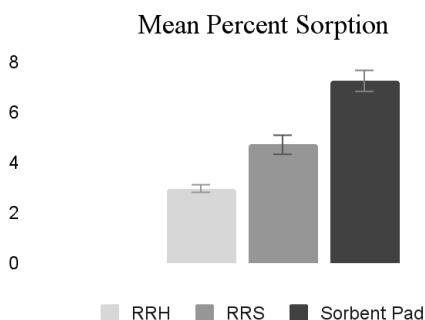


Figure 2. Mean percent sorption of RRH, RRS, and sorbent pad in diesel oil.

The Shapiro-Wilk test revealed a normal distribution among the calculated percent sorption values. The homogeneity of variances in the data was confirmed through the Levene's test. Following the satisfied assumptions, one-way ANOVA indicated a statistically significant difference among the three types of sorbents ($p < 0.00001$). The Tukey post-hoc test further showed that sorbent pad has the highest

mean percent sorption (7.25%) while RRS (4.71%) exhibited significantly higher sorption than RRH (2.97%).

The oil sorption performances of sorbents can be associated with the hydrophobic-oleophilic properties of the material, which were dependent on, porosity, chemical constituents of the sorbent (i.e. lignocellulosic components), and surface roughness [29]. In addition, bulk density is recognized as a critical factor in the oil uptake of sorbents [5].

Relating to previous studies, porosity can be accounted for the higher percent sorption of RRS. A study on the physical properties revealed that rice straw has porosity values ranging from 71.21% to 85.28% while rice husk, on the other hand, has values ranging from 63.64% to 73.23% [26]. Porosity is defined as the measure of the volume space occupied by the pores per volume space occupied by the total sample [30]. It enables the incorporation of oil spillages into their matrix in which as porosities of different sorbents increase, the sorption capacities also increase [27,31].

For the filling of pores to occur, the following must be present: (1) the porous structure and (2) the mechanism that will transport the oil into the porous structure, such as the oil adhesion to its surface, thereby promoting capillary movement [32]. RRH and RRS are made up of cellulose, hemicellulose, and lignin with values of 45.8%, 16.9%, 17.2% for RRH, and 42.2%, 23.7%, 13.1% for RRS, respectively [33]. Cellulose and hemicellulose contain hydroxyl (OH) and acid groups that contribute to the samples' hydrophilicity thus limiting their usage for oil cleanup [29,34]. Lignin, on the other hand, is the hydrophobic component of organic materials. Petroleum components bind to the hydrophobic functional groups of the sorbent for sorption to occur [13]. A previous report has found a higher lignin content of rice husk than rice straw which is in contradiction with the trend observed from the results in this study [33]. Nevertheless, porosity was established to have a stronger influence on sorption performance than phase composition [14]. This may explain the higher sorption of RRS despite having less lignin content than RRH. The high percent sorption of the commercial sorbent pads can be attributed to their high oil recovery ratio once used to their full capacity [20].

A material can be characterized as a sorbent if it allows the sorbate to penetrate into its void through capillary forces or attach to its external surfaces [7]. Focusing on the surface roughness of the samples, this property was suggested to be a part of the adhesion process between the oil and the sorbent's surface [35,36]. A previous report has proven the rough surface of raw rice husk and rice straw [37]. Thus, the oil sorption performance of these sorbents could have also been affected by the factor above. In light of these, RRH and RRS can be considered as sorbents such that diesel oil was able to attach to their structures, thereby acquiring mean percent sorption values of 2.97% and 4.71% respectively.



During the sorption procedures, similar contact times and dripping times that were previously employed in the investigation involving adsorption and absorption procedures were taken into consideration [38,39]. The 15-minute contact time was adopted in line with the observation that 5 grams of RRH and RRS sorbents yielded the highest sorption values when submerged within the given timeframe [38]. This duration is important in allowing sufficient oil-sorbent contact to ensure that saturation has been reached. Similarly, a 15-minute dripping time was also employed in consideration for real-world applications and also to account for more oil uptake by the sorbent [40].

Varying values of bulk density may influence oil sorption performance, i.e. lower bulk density facilitates the formation of capillaries between particles [23]. This increases the contact area between the particles or porosity, increasing the flow of oil inside the material and also resulting in higher sorption of oil molecules [1]. Taking this into consideration, all the sorbent containers were set with a fixed bulk density of 0.28 g/cm³. This value was only set to accommodate the sorbents in the container but is not the most optimal value for bulk density. In this light, a tetrahedral-shaped frame served as the rigid structure of the sorbent container, considering that it has the largest surface area among the convex bodies in n-dimensional space [41]. Meanwhile, in attaining a constant volume for the packed sorbents, a mesh net made of nylon was used to wrap around the tetrahedral frame and contain the sorbents for the standardization of the oil sorption test. In the three-dimensional networks of the nylon, the intertwined fibers allowed oil to penetrate into the sorbents [25].

Limitations. Due to limited access to specialized instruments, the determination and in-depth analysis of the mechanisms that specifically occurred during the sorption procedures (i.e. absorption and adsorption) and the characterization of the sorbents using Langmuir isotherm model, SEM analysis, FTIR analysis, etc. were not conducted. Moreover, considering the varying physical shapes of both RRH and RRS, the particle size ranging from 3 mm to 5 mm did not guarantee an equal width and length between samples. Their particle size was solely based on the particles that passed through the 5 mm sieve and remained on top of the 3 mm. Moreover, due to the lack of sieve shakers, the use of hand-sieving procedures did not guarantee uniformity in terms of the rate of strokes and intensity. With regards to the dripping time, the point where no point of further dripping is observed cannot be determined in this study. Lastly, the raw data in four decimal places recorded from the analytical balance were reduced as the statistical software allows the expression of data only in three decimal places. With this, the percent sorption values only represent the rounded-off values obtained from the experiment.

Conclusion. - In evaluating oil sorption capabilities, RRS was found to be a more effective sorbent than RRH, owing to the significantly higher

percent sorption of the former in diesel oil. However, RRS is not comparable with the commercially available sorbent pad as the latter displayed prominently higher percent sorption owing to its main design which is intended for industrial oil spills. Nevertheless, RRS can still serve as an alternative sorbent in oil spill emergencies with the significant amount of oil it can sorb. By maintaining a uniform bulk density with the use of tetrahedral frames, this study provided an improved method for gathering more reliable data for sorption studies.

Recommendations. - To further provide an in-depth analysis of the sorption mechanism and the properties of the sorbents, it is recommended to conduct further analysis (e.g. SEM, FTIR microscopy, etc.) and utilize mathematical models (e.g. Langmuir isotherm model). To establish uniformity in the particle size, future studies may opt to use machines for uniform cutting and sieving of the materials.

Additionally, to assess the full dripping profile of the sorbent, it is recommended to determine and report the value at the “point of no dripping” since the values will not be overestimated or over-reported [8]. A different statistical software is recommended to ensure consistent decimal places from obtaining raw data until analysis. The use of a water-oil system could also be considered to mimic real-life scenarios. In actual oil spill incidents, dry rice husk and rice straw may be contained in a material similar to the mesh net used in the TFMN for easy retrieval after use. In cases where the samples require drying, sun drying until a constant weight for at least two consecutive days is achieved, may be used as an alternative to oven drying as a means of removing any excess moisture from the samples.

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Comparison of diesel oil removal properties of primary and secondary leaf fibers of *Ananas bracteatus*

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Article Info	Abstract
Submitted: June 27, 2023 Approved: Sept. 28, 2023 Published: Dec. 31, 2023 Keywords: oil spill diesel oil sorberent pineapple leaf fibers fiber diameter	The increasing dependence of humans on oil-based energy constitutes the risk of oil spills which pose hazards to the environment. Some existing oil spill cleanup methods apply chemicals that are harmful to marine life. Pineapple leaf fibers (PALFs) have been used as a sorberent and they showed excellent oil sorption, but are yet to be separated into primary and secondary leaf fibers. <i>Bastos</i> are coarse while <i>liniwan</i> are fine fibers which affect their oil sorption capacity since they have varying fiber diameters and surface area. In this study, primary (<i>bastos</i>) and secondary (<i>liniwan</i>) PALFs were used as sorberents and subjected to diesel oil. The mean sorption capacity by <i>bastos</i>, <i>liniwan</i>, and sorberent pad were 13.76 g/g, 14.09 g/g, and 4.43 g/g, respectively. <i>Bastos</i> and <i>liniwan</i> were found to have no significant difference between their mean oil sorption capacity and exhibited a significantly higher mean oil sorption capacity than the sorberent pads. This implies that both the <i>bastos</i> and <i>liniwan</i> can be used as sorberents for potential diesel oil spills. It is suggested to use <i>bastos</i> more as an alternative in diesel oil removal since it is not used in other industries as compared to <i>liniwan</i>.

Introduction. - The Philippines is an archipelagic country, and shipping is the primary mode of inter-island transportation. Marine transport is also the backbone of international trade and the global economy [1]. It is also located at the Coral Triangle, which is an area of importance as it is recognized as the global center of marine biodiversity [2]. The increasing dependence of humans on oil-based energy has raised concerns about the risk of increasing oil spills.

The International Tanker Owners Pollution Federation recorded a total of 15,000 tonnes of spilled oil in 2022 which was caused by tanker incidents globally [3]. The Philippine Coast Guard, as secured by the National Operation Center for Oil Pollution (NOCOP), has recorded 553 oil spills as of 2019, more than half of which are caused by vessel oil spills (55.15%). Vessels usually transport petroleum products including diesel oil, which is also the top-imported petroleum product in the country in 2022 [2,4]. Moreover, MT Princess Empress was carrying 800,000 liters of industrial fuel oil when it sank in February 2023. This resulted in threats to fishing communities and biodiversity in 20 marine protected areas [5].

Oil spills can have catastrophic consequences for both the environment and human health. Oil spills are major water pollutants that kill marine organisms; with some that are suitable for human consumption [6]. These pollutants may spread and reach rivers and other aquatic habitats, posing a hazard to our environment [7]. Ecological changes, primarily the loss of key organisms from a community, may also be observed as a result of oil spills [8].

Dispersion and in-situ burning are some of the current solutions to oil spills. However, dispersion uses chemicals that are harmful to marine life and in-situ burning produces gases that are harmful to our atmosphere and toxic to human bodies, so it is important to find methods to mitigate the effect of oil pollution and also recover the spilled oil simultaneously such as the process of sorption through organic sorberents [9,10]. Organic sorberents have been emerging as possible alternatives for oil spill cleanup due to their availability, eco-friendliness, and low cost [11].

Oil sorption is an alternative method used to recover oils with the help of sorberent materials that act like a sponge [12]. Synthetic sorberents such as polypropylene are commonly used in oil sorption because they have a high sorption potential, but they are non-biodegradable and expensive [13]. This led researchers to study biodegradable and low-cost sorberents such as lignocellulosic materials.

Plant waste fibers, which are characterized as lignocellulosic materials, are resources composed primarily of cellulose, hemicellulose, and lignin. These can be derived from plant substances such as agricultural residues [14]. The Philippines is the world's second-largest producer of pineapple plant residue, wherein the fibers derived from the pineapple leaves are usually dumped for composting, thus making them agricultural wastes which would make them useful for biowaste utilization [15]. Previous studies have utilized pineapple leaf fibers (PALFs) as biosorberents for oil such as the study of Gomes et al. [16] who found that the peat (commercial sorberent) and the curaua PALF showed similar sorption capacity. Moreover, utilized PALFs



blended with polyethylene/polypropylene sheath core composites (ES) from Ekwonu et al. [17] were utilized as sorbents for diesel and automotive gas oil. Cheu et al. [18] also used pineapple leaves but are chemically pretreated to exhibit higher oil sorption capacity.

According to the study of Sena Neto et al. [19], leaves of *Ananas bracteatus*, more commonly known as Red Spanish Pineapple, have been found to have higher cellulose content than other genotypes of pineapple. As higher cellulose content contributes to higher sorption potential [20], *Ananas bracteatus* leaf fibers can provide more alternative sorbent materials to other genotypes of PALFs that had already been utilized as oil sorbents [16,17,18].

PALFs are classified according to their fineness: the coarse fiber with a higher fineness value (primary PALF or *bastos*) and the fine fiber with a lower fineness value (secondary PALF or *liniwan*) [21]. Fineness is related to the fiber thickness or diameter [22]. As fineness decreases, the diameter of individual fiber decreases and therefore increases the surface area available for sorption. *Liniwan*, having a lower fineness makes it a more ideal material in the textile industry compared to *bastos*.

Studies on oil removal using PALF have not separated the *bastos* and *liniwan* [16,17,18]. Due to their difference in fiber fineness, which affects their surface area [22], the individual sorption performance of *bastos* and *liniwan* must be investigated to provide an alternative sorbent material for oil sorption instead of using all fiber parts of the pineapple leaf.

This study aimed to determine and compare the percent diesel oil removal of *bastos*, *liniwan*, and sorbent pads. Specifically, this research sought to:

- (i) determine the mean fiber diameter (μm) of *bastos* and *liniwan* through ImageJ analysis based on scanning electron microscopy (SEM);
- (ii) determine the mean difference between the mean fiber diameters (μm) of *bastos* and *liniwan* using independent samples t-test;
- (iii) determine the mean oil sorption capacity (g/g) and mean percent oil removal of the control (sorbent pads) and treatment groups (*bastos* and *liniwan*);
- (iv) determine the mean difference of the oil sorption capacity (g/g) and percent oil removal (%) of the control and treatment groups using one-way ANOVA.

Methods. - The fibers were sent for SEM imaging and the fiber diameter of *bastos* and *liniwan* was measured using an image processing software (ImageJ). Ten replicates of sorbent from the treatment and control groups were allowed to sorb oil at a constant contact time. The mass of sorbent before and after sorption was measured to get the sorption capacity and percent oil removal.

Materials. *Bastos* and *liniwan* were procured from

a pineapple fiber-weaving business in Balete, Aklan as thread-like fibers which are readily available for utilization while sorbent pads were obtained from Philippine Environmental & Technical Systems and Services, Inc. Diesel oil was procured from SEOIL - Tagbac in Jaro, Iloilo.

Preparation. *Bastos*, *liniwan*, and sorbent pads were cut into 1 to 2 cm [23], and 0.5 grams of each sample was placed in a 50-cm³ metal mesh bag [9,10,24,25]. Diesel oil with a volume of 200 mL was poured into each 250 mL beaker (Pyrex, Germany) [26]. Three samples of empty metal mesh baskets were immersed in the oil under the same experimental conditions. The mass of oil removed was then taken and averaged. It was then subtracted from the mass of the sorbents after sorption. The average mass of oil removed by the mesh basket was subtracted from the mass of oil removed by the sorbents encapsulated in the metal basket with sorbed oil.

Fiber diameter. Dry fiber samples of *bastos* and *liniwan* were sent to the University of the Philippines Visayas Regional Research Center laboratory in Miagao, Iloilo for scanning electron microscopy (SEM, Hitachi SU3500) imaging. The mean diameter of each fiber type was calculated by measuring it three times at different sections of the SEM image using ImageJ software (Version 1.54f).

Preliminary Test. Three samples for each sorbent type were prepared to determine the dripping time of the samples and the amount of oil removed by the metal mesh baskets. Beakers with 200 mL of oil were prepared for each sample. Sorbents were hung on a metal stand for 60 minutes [16]. Then, sorbents were hung above the beakers and the dripping time was recorded until no further dripping [27]. The sorbents were then weighed and recorded.

Sorption test. The *bastos* sorbent was soaked in 200 mL of diesel oil for 60 minutes and was allowed to drip until the point when no further dripping was observed (50 minutes). Finally, the resulting sorbent was weighed using a calibrated analytical balance (KERN ABJ 320-4NM). Similar procedures were followed for the *liniwan* and sorbent pads. Ten samples were tested for each sorbent.

Data Analysis. The oil sorption capacity and percent oil removal [24] for each sorbent were calculated using the following formula:

$$\text{Sorption capacity (g/g)} = \frac{S_T - S_o}{S_o}$$

$$\text{Percent removal (\%)} = \frac{S_T - S_o}{O_i} \times 100$$

Where:

S_T = the mass (in grams) of the sorbent after sorption

S_o = the mass (in grams) of the sorbent before sorption

O_i = the mass (in grams) of the sorbate before sorption



Statistical Analysis. ImageJ and Microsoft Excel 2016 were used to calculate the mean fiber diameter, mean sorption capacity, and mean oil percent removal of the sorbents, respectively. An Independent t-test was conducted to compare the mean difference between the mean fiber diameters in Jamovi 2.3.18. One-way ANOVA and Games-Howell post hoc test were conducted to compare the three mean sorption capacities and oil percent removal using Jamovi 2.3.18.

Safety Procedure. Excess diesel oil and used sorbents were stored in a closed container and handed over to the Chemistry Science Research Assistant for proper disposal.

Results and Discussion. - The surface morphology of both fibers was found to be closely similar to each other in reference to their microfibrillar structure, exhibiting rectangular, rough surfaces as can be seen in Figures 1 and 2. *Bastos* and *liniwan* revealed defined block-like structures which contribute to a rougher surface [25]. According to Ekwonu et al. [17], this unique block-shaped structure contributed to the excellent oil retention property of the PALF. This block-like structure is the leaf epidermal tissue fragments which are characterized by a reticular aspect pattern [28].

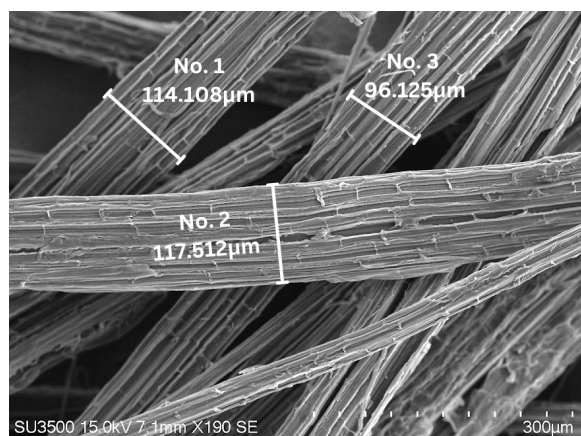


Figure 1. SEM image of primary PALF (*bastos*) at 190x magnification.

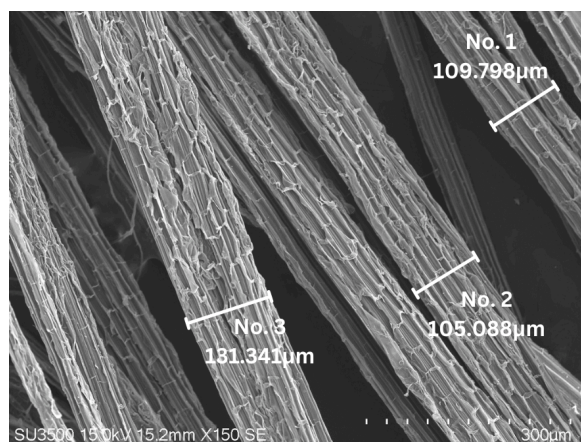


Figure 2. SEM image of secondary PALF (*liniwan*) at 150x magnification.

Based on the results of the ImageJ analysis, the mean fiber diameters of *bastos* and *liniwan* were $109.25 \pm 11.49 \mu\text{m}$ and $115.41 \pm 14.00 \mu\text{m}$, respectively. No statistically significant difference was found between the fiber diameters of both fibers based on their t-test results ($p = 0.587$). *Bastos* and *liniwan* were found to have similar fiber fineness as described by their similar mean fiber diameters. Fiber fineness is a factor in the sorption mechanism as finer fibers constitute more surface area for higher oil uptake [22]. According to Carvalho et al. [21], the secondary PALF or *liniwan* is used in textile production because of its low fiber fineness while the primary PALF or *bastos* are not being used in textile production; however, the ImageJ results contradict this as *bastos* and *liniwan* showed similar fiber diameters. In their optical microscopic images, *bastos* and *liniwan* were found to have similar fiber diameters, which have some correlation to fiber fineness [22]. Finer fibers contribute to smaller fiber diameters, allowing them to have higher surface area and more available sorption sites for sorption [29].

The sorption capacity and percent removal values of *bastos* and *liniwan* have been found to be significantly higher than those of the sorbent pads, while it was also found that there is no significant difference between *bastos* and *liniwan*. *Bastos* yielded a mean sorption capacity of $13.76 \pm 1.53 \text{ g/g}$. The *liniwan* sorbent, on the other hand, had a mean sorption capacity of $14.09 \pm 0.84 \text{ g/g}$. Furthermore, the sorbent pad yielded a mean oil sorption capacity of $4.43 \pm 0.34 \text{ g/g}$.

Bastos yielded a mean percent oil removal of $4.15 \pm 0.46\%$. *Liniwan*, on the other hand, had a mean percent oil removal of $4.25 \pm 0.25\%$. Finally, for the sorbent pad, the mean percent oil removal was $1.34 \pm 0.10\%$. Figure 3 shows the respective mean percent oil removal (%) of the three samples for diesel oil.

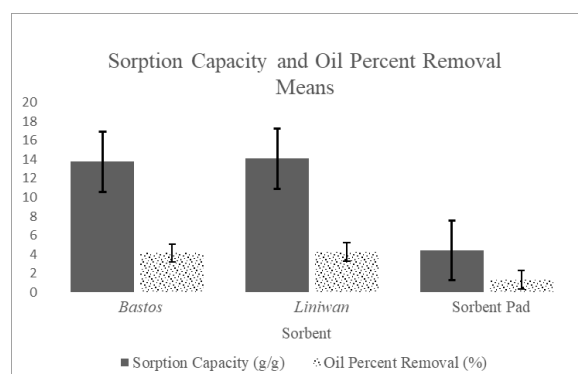


Figure 3. Mean sorption capacity (g/g) and mean percent oil removal (%) of *bastos*, *liniwan*, and sorbent pads for diesel oil.

There was a statistically significant difference between groups as determined by One-way ANOVA ($F(2,27) = 668.5725$, $p = 0.0001$). Games-Howell post hoc test revealed that *bastos* and *liniwan* have no significant difference in their sorption capacity and percent oil removal ($p = 0.8277$). *Bastos* exhibited a significantly higher sorption capacity and mean percent oil removal than the sorbent pad ($p < 0.001$). In addition, *liniwan* ($p < 0.001$) exhibited a



significantly higher sorption capacity and mean percent removal than the sorbent pad ($p < 0.001$). *Ananas bracteatus* PALFs have significantly higher mean sorption capacity and percent oil sorption than commercial sorbent pads, thus, they can be used as a sorbent for potential diesel oil spills. Additionally, the results imply that both the *bastos* and *liniwan* have similar levels of effectiveness in terms of oil sorption.

Both *bastos* and *liniwan* are capable of sorption for diesel oil. The mechanism of oil sorption by *bastos* and *liniwan* can be either by absorption, adsorption, capillary action, or a combination of the aforementioned. The fiber diameter has some correlation with the fiber cross-sectional areas which affects the sorption mechanism of PALFs. Finer fibers contribute to a smaller diameter [22], which leads to more available sorption sites leading to a higher sorption capacity [29]. The sorption process in natural fibers can be a product of physical factors, transport of oil molecules to the surfaces of the sorbent, and chemical factors, which involve the Van der Waals interaction between the oil and the sorbents [18,30]. As *bastos* and *liniwan* are both natural fibers collected from *Ananas bracteatus* leaves, the mechanism involved in the sorption process can be explained by the said factors. Sample granulometry is a significant factor in the percent oil removal of PALFs for diesel oil as it affects the surface area of the samples [16].

This study was able to determine the sorption capacity and percent oil removal of *bastos* and *liniwan* collected from *Ananas bracteatus* comparing it to sorbent pads. The sorption capacity and percent oil removal of *liniwan* do not have a significant difference from that of *bastos*. In addition, there is a significant difference between the sorption capacity and percent oil removal of the treatment (PALFs) and the control group (sorbent pads). The fiber diameters from the SEM imaging correlate with the sorption capacity and percent oil removal of the fibers since the sorption capacity and percent oil removal of *bastos* and *liniwan* have no statistical mean difference and their mean fiber diameters also have no statistical mean difference. The results showed that both *bastos* and *liniwan* may be used as alternative materials for the removal of diesel oil. Although *bastos* and *liniwan* were found to have no significant mean difference, *bastos* may be used as an alternative sorbent to oil spills rather than *liniwan* since the latter is used as raw materials for textile production.

Limitations. Even though the fiber diameter of raw *bastos* and *liniwan* was determined, only partial areas of the fiber samples were assessed for SEM analysis. Moreover, this study only utilized 1-2 cm lengths of cut PALFs, the optimal granulometric sizes for the maximum sorption capacity of PALFs were not determined due to the absence of sorption tests of varying granulometric sizes.

Conclusion. - As *bastos* and *liniwan* have the same performance in the removal of oil, *bastos* may be utilized as an alternative sorbent material for oil spills as *liniwan* already have their use in the textile industry.

Recommendations. - Future studies may utilize more areas of the PALFs to be subjected to SEM imaging to minimize error in randomization and to have a more accurate presentation of the surface morphology of PALFs. Moreover, sorption tests may include quantifying for fiber fineness and varying sample granulometry to determine which granulometric category constitutes the optimal sorption capacity of PALFs. In addition, other statistical tools which include more decimal places for calculations such as SPSS and RStudio may be used for the data analysis since Jamovi 2.3.18 can only cater to up to three decimal places. Furthermore, future studies can also test the sorption capacity of the samples in an oil-water mixture and test more oil types such as bunker fuel, jet fuel, and others.

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Water quality assessment of post-chlorinated wells in San Juan, Molo, Iloilo City following acute gastroenteritis (AGE) outbreak

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Article Info	Abstract
Submitted: Jul 11, 2023 Approved: Jan 24, 2024 Published: Feb 25, 2024 Keywords: water wells physicochemical microbiological PNSDW	Groundwater wells in areas like San Juan, Molo, Iloilo City are important water sources for domestic use. However, these wells are susceptible to contamination, leading to waterborne illnesses. Following an outbreak of acute gastroenteritis (AGE) in Iloilo City in August 2022, water sources in affected communities were examined and treated with chlorine. Despite these efforts, the number of AGE cases continues to rise in San Juan, Molo, one of the most affected areas in the city. This study aimed to evaluate the water quality of post-chlorinated wells in San Juan, Molo, Iloilo City, focusing on physicochemical and microbiological properties. The assessment revealed that the analyzed wells exceeded the maximum allowable level (MAL) set by the Philippine National Standards for Drinking Water (PNSDW) of 2017 in terms of turbidity, color, residual chlorine content, and total coliform count. Consequently, the water from these post-chlorinated wells is unsuitable for domestic use. These findings suggest that disinfection strategies for wells in San Juan, Molo, Iloilo City are ineffective in eliminating pathogens and maintaining water quality.

Introduction. - The addition of a substance to water that adversely affects and changes its properties is called water pollution [1]. Water pollution has been a present and imminent threat to the health and livelihoods of many people all over the globe with over 780 million people having no safe and secure water sources and 2.5 billion having no proper water sanitation [2]. Pollutants are categorized as: chemical, physical, physiological, and biological. [1]. Physical pollutants include any effect on color, turbidity, temperature, suspended solids, foam, and radioactivity, while physiological pollutants include any change in taste and odor. Chemical pollutants include inorganic and organic materials that affect the Biological Oxygen Demand (BOD), pH, and toxicity of a particular body of water. Biological pollutants include the presence of bacteria, viruses, protozoa, and helminths.

Pollutants that lead to adverse effects to water supply are considered as contaminants. All contaminants are considered to be pollutants; however, not all pollutants can be considered contaminants. Contamination is the presence of a pollutant, where it should not be, or at abnormal concentrations, making it a contaminant [3]. The proliferation of waterborne biological contaminants such as microorganisms that include bacteria, viruses, protozoa, is seen as the primary root of waterborne diseases. Instances of waterborne contamination are prevalent and waterborne disease epidemics can still occur even when drinking water is piped but not disinfected [4]. Moreover, within a five-year span, exposure to waterborne biological contaminants was the cause of approximately one third of illnesses in the Philippines, such as acute gastroenteritis (AGE) [5].

Acute gastroenteritis (AGE) is a common and potentially serious infectious illness characterized by diarrhea, vomiting, and abdominal cramps. It is most often caused by a variety of pathogens, including bacteria, viruses, and parasites. AGE is transmitted through the fecal-oral route, meaning that the pathogen is ingested from contaminated food, water, or surfaces, or through direct contact with an infected individual. Symptoms typically develop within 1-3 days of exposure and can range from mild to severe. Severe cases can lead to dehydration, electrolyte imbalances, seizures, coma, and even death [6].

Waterborne outbreaks of enteric disease occur either when public drinking water supplies are not adequately treated after contamination with surface water, or when surface waters that are contaminated with enteric pathogens, have been used for recreational and/or domestic purposes.

Water quality analysis is an important step to identify water contamination of biological contaminants. Studies that focused on analyzing the quality of drinking water in the Philippines have been conducted in different regions of the country, such as the analyzing of the physicochemical and biological properties of water samples from selected barangays in Laoang, Northern Samar, Philippines [7], as there were existing cases of waterborne diseases from the specific barangays they collected water samples from. Another study also examined the drinking water quality of different schools in Tarlac City, Philippines, through its physicochemical and biological properties [8].



Last August 30, 2022, a sudden surge of cholera cases was reported in Iloilo City, causing an outbreak [8] that resulted in over 777 cases of Acute Gastroenteritis (AGE) as of October 4, 2022 [10]. The district in Iloilo City with the highest number of cases was Molo, Iloilo City with 165 cases; and Barangay San Juan, Molo having the most with 30 cases as of October 4, 2022 [10]. The City Health Office had already begun examining and treating different water sources around the city's localities where Acute Gastroenteritis cases were starting to rise in numbers [11]. However, according to the CHO acting officer, the chlorination efforts in Iloilo City remain ineffectual since the cases of AGE keep on rising, which is probably due to recontamination, the proximity of water well systems to canals and septic tanks, ineffectiveness of chlorination protocols, and the water table itself being contaminated [12]. As of October 4, 2022, the district of Molo has reached 30 cases of AGE, the highest in the whole city of Iloilo. More specifically, Barangay San Juan, Molo had the highest number of AGE cases [10] in the district which placed a huge risk towards the health and well-being of citizens residing in the community.

Domestic water is termed as water coming from domestic water supplies that provides water for households for their daily use such as cooking, bathing, washing the dishes and utensils, cleaning the house, and doing laundry [13]. According to the Department of Environment and Natural Resources (DENR) Administrative Order (DENR-AO or DAO) No. 08, series of 2016, different water bodies are classified depending on where it is sourced, how it is used, and on what standards should the water source be compared to [14]. In the Administrative Order, domestic water is classified as Class A and listed as Public Water Supply Class II which is intended as sources of water supply requiring conventional treatment that includes processes such as coagulation, sedimentation, filtration, and disinfection which are all processes that are conducted in wells supplying water in Barangay San Juan, Molo, Iloilo City. Furthermore, Class A water sources are compared with the Philippine National Standards for Drinking Water (PNSDW) of 2017 [15] to determine if they are viable for public use. In this study, the modified PNSDW mandatory parameters are used to assess if the wells comply with the given standard.

The knowledge obtained from this research would assist in providing a comprehensive water quality assessment of post-chlorinated wells using an evidence-based analysis that outlines the physicochemical and microbiological properties [16] which is especially useful to localities that fall short in observing well water monitoring, and will serve as a basis for future well disinfection and recovery protocols that can properly inactivate water pathogens [17]. This study sought to record water quality parameters such as the physical properties consisting of color (apparent) and turbidity; the chemical properties consisting of nitrate, pH, total dissolved solids (TDS) and residual chlorine; and the microbiological properties specifically total coliform count. These parameters are modified from the

Philippine National Standards for Drinking Water (PNSDW) of 2017 [15], with the exclusion of the heavy metals consisting of lead, cadmium and arsenic. Heavy metal contamination usually occurs due to human activities such as mining, industrial discharge from steel plants, battery factories and thermal power plants, sites for traffic, municipal and hazardous wastes and lastly, agricultural runoff from the overuse of fertilizers containing heavy metals [18, 19, 20]. San Juan, Molo, Iloilo City is a residential area that lacks any present factory, farmland nor mining areas which makes heavy metal contamination uncommon; hence it was excluded from the study in favor of studying parameters that are more relevant given the conditions and the environment.

The data and results would be most significant to the citizens of Barangay San Juan, Molo, Iloilo City, the Iloilo City Epidemiological Surveillance Unit, the Iloilo City Health Office, and Department of Health Region 6 since it would provide them with the information on the water quality of selected post-chlorinated wells in terms of the physicochemical and microbiological properties. Lastly, it would provide baseline information that would be significant in providing clean water and sanitation to developing communities, which is in accordance with Sustainable Development Goal number 6.

Methods. - This study is categorized as descriptive as it sought to assess the water quality of post-chlorinated wells in San Juan, Molo, Iloilo City (10.6856°, 122.5449°) on January 11, 2023 following the Acute Gastroenteritis outbreak in August 2022. The data gathering procedure of the research consisted of: sampling site selection, water sample collection, transportation of water samples, onsite physicochemical analysis, laboratory microbial analysis, the data analysis and safety precautions and disposal methods. The timespan of the data gathering procedures was two weeks to ensure that an adequate sample of data was collected.

Site Selection. The selected sampling site was Zone 3 barangay San Juan, Molo, Iloilo City due to its high incidence of acute gastroenteritis (AGE) cases. Three well samples were selected, with three replicates varying in depth as water quality can vary with depth, due to factors such as temperature, salinity, and the presence of different organisms and chemicals. (top, middle and bottom) were followed, with the well samples being the well attributed to the highest number of AGE cases (10.68844° 122.54146°), the well that has no cases of AGE (10.68882° 122.54298°), and a well that has a moderate number of AGE cases (10.68786° 122.54126°); serving as the median, and distilled water as the control sample.

Materials. The materials used were derived from the guide by the Department of Science and Technology Regional Standard and Testing Laboratory (DOST RSTL) Region VI specifically for collecting water samples from wells. The physicochemical analysis utilized the bucket found in the selected wells for the collection of water. Other materials included a clean, disinfected plastic bucket where collected water was poured in for



physicochemical analysis. The following equipment was used for the physicochemical analysis: YSI ProDSS multiparameter water meter, and TDS meter. The microbiological analysis also followed the aforementioned guide in which an autoclaved 400mL glass bottle with a metal cap was used. Other materials included a 20-meter rope for sample collection, a cooler box for transport, masking tape and a pen for labelling. The total amount of water collected for the physicochemical analysis was not strictly measured as long as the YSI ProDSS's probes were able to be fully submerged. The microbiological analysis used 400mL of water as prescribed by the DOST RSTL Region VI.

Water Sample Collection. An autoclaved and sterilized bottle was prepared for water sample collection by tying a rope around the neck of the bottle and attaching a weight underneath the bottle for it to descend faster. The bottle was then slowly lowered into the well, whilst avoiding hitting the sides, to fill and collect the water sample. After the bottle is almost full, it is pulled back up, making sure to leave an air gap within the bottle before sealing. The bottle was then labeled with the sample number, time collected, and researcher name before being stored in an ice box to preserve its contents.

Physicochemical Analysis. Physicochemical analysis did not follow strict guidelines in the volume of water used as the YSI ProDSS multiparameter water meter only required its probes to be fully submerged. The Physicochemical analysis was done onsite using a YSI ProDSS multiparameter water meter and a TDS meter to measure the physicochemical parameters: pH, turbidity, TDS, residual chlorine content and nitrate content. Each probe for the corresponding parameters was calibrated using distilled water. Color was personally evaluated [14] for any discernible discoloration that affects the opinion of the consumer.

Microbiological Analysis Microbiological analysis utilized 400mL of water per replicate. The research followed a triplicate approach in which 1,200 mL of water was collected from each well. The microbiological analysis involved the Multiple Tube Fermentation Test (MPN) to confirm and specify the microbial presence within the water samples. A presumptive test involving the culture of water sample bacteria in Lactose Broth was done and followed by a confirmatory test involving the same culture in Brilliant Green Lactose Bile (BGLB) broth. The total coliform count of the water samples is determined using the table below.

Table 1. Most Probable Number (MPN) Index in a Five 10-mL Water sample (Standard Method for the Examination of Water and Wastewater, APHA, AQA, 2012 22nd Ed.)

No. of Tubes with Positive results in 5 tubes with 10 mL Each	MPN Index/100 mL
0	<1.1
1	1.1
2	2.6
3	4.6
4	8.0
5	>8.0

Data Analysis. The means of the parameters (pH, turbidity, TDS, residual chlorine content, nitrate content and total coliform count) were equated and compared with the PNSDW [13]. Color was instead evaluated wherein any noticeable discoloration will affect a consumer's opinion, rendering it unable to comply with the standards for drinking water. The results are then tabulated and are highlighted where the wells comply or do not comply with the established standard.

Safety Procedure. To ensure safety, personal protective equipment (PPE) such as gloves, face masks and laboratory coats were worn at all times, especially when handling possibly contaminated water and hot objects. The contaminated water and the culture tubes were autoclaved to get rid of possible recontamination before the water and broth is poured into the drain.

Results and Discussion. - The study focused on the physicochemical and microbiological properties of the selected wells. The results were then compared with the Philippine National Standards for Drinking Water (2017) [15].

Physicochemical Analysis. The physicochemical properties taken from the sampling sites were: pH, color, turbidity, TDS, residual chlorine content and nitrate content. Table 2 below presents the pH, color, turbidity, TDS, residual chlorine content and nitrate content of the selected wells. There is noticeable discoloration of water (yellowish) in all the selected wells.

pH. As observed from Table 2, the pH of the three selected wells are slightly basic, nearing the pH of 8. The allowable limits set by the PNSDW 2017 [15] for pH is 6.5 - 8.5. This makes the three wells compliant with the standards set for pH. The mean pH of the selected wells is under 8.0, which resembles seawater (pH 8.1). This alkaline pH can irritate the skin and eyes, and may also affect the absorption of nutrients. In addition, some microorganisms, such as bacteria and parasites, can thrive in alkaline environments, which could increase the risk of waterborne diseases. [21] The normal range for pH in surface water systems is 6.5-8.5 and 6.0-8.5 for groundwater systems. When pH becomes too high, water becomes caustic and can clog or damage water systems by creating coatings, films and precipitates [22]. Although the results are within the standards for drinking water, the WHO recommends a pH of water to be less than 8.0, stating that basic water inhibits effective chlorination [23].

Turbidity. The mean turbidity of the wells ranges from 7-10 Formazin Nephelometric Units (FNU) which makes them non-compliant with the limit of 5 FNU by the PNSDW 2017 [15]. The turbidity of the wells is observed to increase with depth, attributable to the free-floating particles near the middle and bottom of the well, including the composition of the well bottom which is mostly silt, clay and sand particles. The particles scatter light which contributes to the rise of turbidity. Turbidity influences the clarity/murkiness of well water, indicating contamination from a septic system, presence of algae, or other suspended particles. Turbidity and



chlorine-demanding solutes also inhibit the disinfection of free chlorine [24]. High turbidity levels, such as the ones recorded in the selected wells, protect microorganisms during decontamination and stimulate their growth, significantly increasing the chlorine demand [24].

Total Dissolved Solids (TDS). Two of the three wells are compliant with the standards set for the total TDS of drinkable water which is 600 ppm [14]. The TDS of the selected wells also increase with depth and are most often contributed to the application of chlorine. However, as observed from Table 2, the mean TDS of the samples are not in correlation with the residual chlorine content. Total dissolved solids (TDS) indicate the presence of inorganic salts (commonly being calcium, magnesium, potassium, sodium, carbonates, nitrates, bicarbonates, chlorides & sulfates) and a small amount of organic material in well water [23]. Humans contribute to the increase of TDS through agricultural (fertilizers) and urban runoffs (industrial wastewater); the latter being the most probable factor in the high amount of TDS recorded from the selected wells [23]. High amounts of TDS are not necessarily a health hazard when ingested, but it can produce hard water, potentially accompanying a health risk [25].

Color. The results indicate that all of the sampled wells show signs of yellowish discoloration which is not compliant with the PNSDW standards for apparent color. Despite the slight discoloration of water found in the selected wells, it is not enough to dissuade some consumers. Consumer perceptions and aesthetic properties of water should always be considered alongside the health-related guidelines whenever developing and administering regulations and standards. The wells were sampled during the rainy season, with flooding in some areas of the research locale, which may have drastically altered the water properties prior to observation and testing. These alterations most notably affect the physical properties including color. [24]

Residual Chlorine Content. The residual chlorine content of the samples notably exceeds the PNSDW limits which is 0.3-1.5 ppm [15]. This can be attributed to the chlorine application process of the well owners as well as the frequency and the date of chlorination wherein the last chlorination occurred on the same day that the well samples were tested. Residual chlorine partially provides a safeguard to low-level bacterial contamination and growth but has limitations against protozoans and viruses [26]. Chlorine can be monitored and controlled with ease as a disinfectant, and frequent monitoring is recommended whenever chlorination is practiced. The lack of monitoring after chlorination, which is observed in the selected wells, increases the risk of waterborne illnesses stemming from very high concentrations of harmful compounds to the presence of water pathogens. Residual chlorine is not only affected by dose but is also heavily dependent on the frequency and date of the last chlorination. The selected wells significantly surpassed the MAL of the PNSDW 2017 which is most probably due to them being chlorinated a week prior to testing. In addition, factors such as high turbidity and alkalinity (pH) influence the effectiveness of chlorination; but as the pH of the selected wells were within the allowable limits, the residual chlorine content and its effects may not have been affected by the water alkalinity [24].

The nitrates content was undetectable and yielded 0.00 ppm for every single well sample. This is understandable as nitrate content in well water is mostly attributed to industrial or agricultural runoff, which is highly unlikely to occur in San Juan, Molo, a residential area. Nitrates are inorganic salts [23] which, as previously mentioned, contribute to an increase of TDS in water. However, the results yielded little to no nitrate content, rendering these effects negligible.

Table 2. Physicochemical Data of selected wells.

Sampling Site	Mean pH	Color (apparent)	Turbidity (FNU)	TDS (ppm)	Residual Chlorine Content (ppm)	Nitrate Content (ppm)
Well A (Well with no attributed AGE cases)	7.99	Light straw	10.12	542.00	207.11	0.00
Well B (Well with most attributed AGE cases)	7.99	Light yellow	7.28	146.30	852.08	0.00
Well C (Well with moderate attributed AGE cases)	7.89	Light yellow	9.33	677.67	291.79	0.00

Microbiological Analysis. Table 3 exhibits the microbiological data of the sampled wells. When compared with the PNSDW 2017 [15] maximum allowable level for total coliform count of 1.1 MPN/100 mL, the data presented on Table 3 shows that the three selected wells are beyond the standard. The number of coliforms in the water samples makes the wells unfit for domestic use. The microbiological analysis used distilled water as its control to indicate water free from coliform bacteria.

Table 3. Microbiological Data Table (Multiple Tube Fermentation Technique)

Sampling Site	Presumptive Test	Confirmatory Test	Total Coliform Count (MPN/100 mL)
Well A	5	5	>8.0
Well B	5	5	>8.0
Well C	5	5	>8.0
Control	0	0	<1.1



Table 4. Overall analysis of the Selected wells in comparison to the PNSDW

Sampling Site	Parameters						
	Mean pH	Turbidity (FNU)	Color (apparent)	TDS (ppm)	Residual Chlorine Content (ppm)	Nitrate Content (ppm)	Total Coliform Count (MPN/100 mL)
Well A	7.99	10.12	Light straw	542.00	207.11	0.00	>8.00
Well B	7.99	7.28	Light yellow	146.30	852.08	0.00	>8.00
Well C	7.89	9.33	Light yellow	677.67	291.79	0.00	>8.00
PNSDW 2017 Maximum Allowable Level (MAL)	6.50-8.00	5.00	No noticeable discoloration	600	0.30-1.50	50.0	<1.1

Overall Analysis. Table IV presents a comprehensive comparison of the selected wells against the Maximum Allowable Limits (MAL) set by the Philippine National Standards for Drinking Water (PNSDW), considering both physicochemical and microbiological properties.

Limitations. Water collection sampling and onsite physicochemical testing were done in the rainy season of January, which may directly or indirectly affect the content and properties of the well through rainwater intrusion, possibly introducing foreign objects, sediments and bacteria to the well. There was also a lack of consistency on the well depth as the top, middle and bottom portions of the wells were only estimated instead of using a standard depth. The study is restricted to three wells, making it unable to provide a general well profile of the area.

Conclusion. From the comparison between the data obtained from the selected wells and the PNSDW 2017, it can be concluded that the water from the wells are not fit to be used domestically by the residents. The majority of the wells are highly turbid, with noticeable yellowish tint and an extremely high residual chlorine and coliform presence.

Recommendations. It is recommended for the well owners to follow a robust and technical procedure in the application of chlorine in order to avoid over chlorination of wells. Post-chlorination monitoring should also be implemented in order to confirm the presence or absence of coliforms and other harmful bacteria in the well water before being used for drinking or domestic purposes. Proper shock chlorination methods should be adequately followed such as properly measuring the volume of the well water together with measuring the diameter of well casings. Relying only on the amount of well casings and the well casings filled with water is insufficient in providing an effective amount of chlorine for chlorination. In addition to proper stewardship and by following proper methods in shock chlorination, the physicochemical and

microbiological properties of wells can be preserved, promoting the well-being of citizens.

Additionally, future well water assessment studies perform the on-site physicochemical and microbiological testing multiple times over a long period of time to observe the effects of chlorination with respect to time and to determine if weather circumstances or seasons affect well properties. Increasing the sample size is also recommended to create a more general well profile of San Juan, Molo, Iloilo City. Other non-mandatory parameters should also be included such as salinity, BO, Dissolved Oxygen (DO), phosphorus, and total hardness of water.

Acknowledgment. - We appreciate the assistance of the Iloilo City Epidemiological Surveillance Unit (ICESU) in providing official documents on the status of AGE in Iloilo City. Our deepest thanks to the Barangay San Juan LGU for their hospitality in allowing and supporting the conduct of the study within the premises of the barangay, as well as the Barangay Health Emergency Response Team officials for providing supporting information that was vital in understanding the locale of the site. Our acknowledgement also goes out to the well owners for their consent and accommodation all throughout the conduct of our methodology.

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RESEARCH EVENTS



The Research Events circuit is the series of research-related activities prepared by the Research Unit and/or the scholars with the aim of bringing their studies to the community. The logo to the left is the overarching symbol of the events circuit. The multicolored flame represents the multitude of activities the scholars undertake as embodied in each of the event logos. The interwoven circles represent the infinite possibilities in research. The logo itself is reminiscent of the PSHS logo, representing the values of truth, excellence, and service.

PAGBANTALA Hiligaynon "to inform"



PAGBANTALA 2022 is an oral presentation wherein Batch 2023 was able to impart their knowledge in their respective research studies. The event showed a glimpse of how researchers should present their studies effectively to a panel of experts. This event enabled students to hone their critical thinking and communication skills by defending their papers and providing feedback to the panelists.

PAGBALANDRA Hiligaynon "to show"



PAGBALANDRA 2022 is a poster presentation event that allowed Batch 2023 to showcase their research to the PSHSWVC community. Through this presentation, the audience was introduced to various areas of research. The event also allowed the batch to seek advice from the WVC's alumni to improve their research.

PAGHINUN-ANON Hiligaynon "to inquire"

PAGHINUN-ANON 2022 is the culminating event for Grade 11 Scholars. Work units composed of three members present their research proposal, with the panel of faculty members guiding the scholars in their proposed study as the students prepare to take the next step in their research journey.

PAHISAYOD Hiligaynon "to announce"



PAHISAYOD 2023 is a seminar-workshop where the batch showcased various skills and methods to fellow students. The seminar allowed the researchers to share their studies, and the workshop was where they taught the methods used. Through this, students were given the chance to learn important research skills that they may use in the future.

PAGWARAGWAG Hiligaynon "to broadcast"



PAGWARAGWAG 2023 is a community based science research congress that invited students from schools all across Iloilo. The event consisted of face-to-face oral presentations of the scholars' research projects, and seminar workshops that demonstrated methods used in the researchers' studies. The event aimed to serve as an avenue to spread scientific knowledge to the local community in a manner that the general public may understand.

PAINDIS-INDIS Hiligaynon "to compete"



PAINDIS-INDIS 2023 is a competition wherein each work unit from Batch 2023 submitted a cover page entry of their respective studies. This competition followed a rigid voting and selection process involving audiences from both inside and outside the PSHSWVC community. The winning entry would then be used as the next cover page for Publiscience Volume 6.

ILOILO STEM FAIR 2023

ILOILO STEM FAIR 2023 is a public event, partnering with "Innovate Iloilo" for our scholars to present their research to the mass audience in SM City Iloilo. The event resembled Pagbalandra and Pagwaragwag as researchers explained their posters and showed off their research through gimmicks and games for the audience to play and learn at the same time.

PAGSUGIDADON Hiligaynon "to report"

PAGSUGIDADON 2021 is the culminating event for Grade 10 scholars. Work units composed of five to six students presented their first research proposal to a panel of judges. This marks the students' first major research event and their initiation into the research process.

RESEARCH CONFERENCES

The authors of this volume wish to acknowledge the valuable opportunity provided by the following conferences and conventions, where select studies in this publication were presented. These platforms enabled constructive feedback, scholarly exchange, scientific communication for the masses, and a wider dissemination of the research findings.

Title of Conference	Date	Studies Participated
Philippine Science High School System (PSHSS) Science Research Convention 2022	November 23-26, 2022	1,2
2nd ISSAT International Conference on Data Science in Business, Finance and Industry	January 8-10, 2023	3
Philippine Science High School System (PSHSS) Science Research Summit 2023	April 24-28, 2023	1,2
Sihay National Biology Olympiad: Junior Life Science Research Olympiad	April 29 - May 1, 2023	4

Studies Participated

1. Post-harvest quality assessment of *Carica papaya* L. 'Red Lady' papaya coated with rice bran wax (RBW) (*Sendico et al.*)
2. Diesel oil sorption potential of sugarcane bagasse incorporated with human hair (*Repospolo et al.*)
3. Trend analysis of drought indicators in terms of rice yield for drought identification in a Type III Climate Area in Central Philippines (*Cerna et al.*)
4. Determining Forest Cover Change In National Greening Program Sites In A High Conservation Priority Area By Utilizing Remote Sensing Techniques (*Tolentino et al.*)

RESEARCH LIMITATIONS

The studies compiled in this journal share common methodological constraints that directly impacted the subsequent analysis and interpretation of results. A primary limitation was the frequent lack of specialized equipment and facilities, which forced compromises in experimental protocols. This was compounded by logistical hurdles, including those imposed by the COVID-19 pandemic, which restricted in-person data collection and access to laboratories. Furthermore, the unavailability of specific datasets and libraries limited the scope of statistical analysis and the consideration of additional variables. Consequently, the analytical depth of many studies was compromised by the inability to employ supplemental techniques that could have enhanced the mechanistic understanding of the phenomena.

These limitations, however, are not terminal but rather delineate a clear trajectory for future work. The recommendations put forward by the authors contribute to addressing the identified gaps. By building upon this foundational research with enhanced methodological rigor, future studies can achieve a more comprehensive and robust analysis.

KEYWORD INDEX

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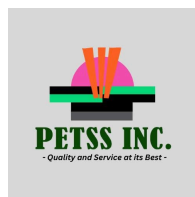
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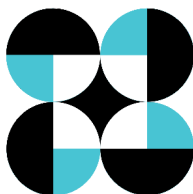
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