

# Bioremediating Butuanon: Investigating the Potential of Termite Nest Microbes and Banana Peel Biochar in Improving Water Quality

Debbie G. Villacuatro <sup>1</sup>, Angel Mary V. Florentino <sup>2</sup>, Jhon Reynald B. Ajoc <sup>3</sup>, John Caryl A. Sa-a <sup>4</sup>, Niña Therese Avenido <sup>5</sup>, Adrian M. Abarquez <sup>6</sup>, Rhino Rienz L. Casas <sup>7</sup>, Edilyn C. Balcita <sup>8</sup>  
Maguikay National High School

<sup>1</sup> [villacuatrodebbie@gmail.com](mailto:villacuatrodebbie@gmail.com), <sup>2</sup> [maryvaliente@gmail.com](mailto:maryvaliente@gmail.com), <sup>3</sup> [reynaldajoc@gmail.com](mailto:reynaldajoc@gmail.com),

<sup>4</sup> [johncarylsaa@gmail.com](mailto:johncarylsaa@gmail.com), <sup>5</sup> [avenidoninatheres021@gmail.com](mailto:avenidoninatheres021@gmail.com), <sup>6</sup> [adrian.abarquez@deped.gov.ph](mailto:adrian.abarquez@deped.gov.ph),

<sup>7</sup> [rhinorienz.casas@deped.gov.ph](mailto:rhinorienz.casas@deped.gov.ph), <sup>8</sup> [edilyn.balcita@deped.gov.ph](mailto:edilyn.balcita@deped.gov.ph)

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Corresponding Email:

[adrian.abarquez@deped.gov.ph](mailto:adrian.abarquez@deped.gov.ph)

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## Index Terms:

termite nest microbes, banana peel biochar, water quality, butuanon river

**Abstract.** Termite nest microbes and banana peel biochar are natural, nutrient-rich materials with potential applications in sustainable bioremediation. This study evaluated their effectiveness as low-cost treatment agents for improving the water quality of the critically polluted Butuanon River in Mandaue City, Cebu. Using a posttest-only true experimental design under a quantitative research approach, polluted river water samples were treated with termite nest microbes and banana peel biochar prepared via pyrolysis at 350°C applied individually and in combination at varying concentrations (1g, 2g, and 3g). The effects of the treatments were assessed based on changes in pH level, turbidity, odor, color, and selected heavy metal concentrations across three trials. Water samples were collected from the field and analyzed under controlled laboratory conditions during the academic year 2024–2025. Statistical analysis using one-way ANOVA and Tukey HSD post hoc tests revealed that all treatments significantly altered water parameters ( $p < 0.05$ ). The findings indicate that banana peel biochar demonstrated stronger performance in enhancing clarity, color, and odor due to its high adsorption capacity and porous structure. In contrast, combined treatments produced greater, dose-dependent increases in pH levels, attributed to the synergistic buffering effect of mineral-rich termite material and alkaline biochar. However, higher combined dosages also increased turbidity, likely due to suspended particles from the added materials. While no heavy metals were detected, the presence of non-metal contaminants like sulfite and fluoride was noted. Overall, the results highlight the potential of termite nest microbes and banana peel biochar as effective, low-cost, and environmentally sustainable alternatives for water quality improvement. These findings support the application of locally available natural materials in community-based environmental remediation efforts.

## Introduction

Termites and their mounds are recognized as nutrient-rich ecological hotspots that sustain diverse bacterial communities. Their nests are enriched with essential nutrients, such as nitrogen, phosphorus, and organic carbon, which contribute to soil fertility and provide favorable conditions for microbial growth, including actinobacteria. These bacterial communities are valuable for bioenergy production, soil enhancement, and environmental cleanup—critical pillars of sustainable development. According to Enagbonma and Babalola (2019), termite nests harbor diverse microbial populations capable of degrading organic pollutants and improving soil quality. In addition, Denloye et al. (2016) reported that termites and their nests can accumulate heavy metals, highlighting their role in bioremediation and environmental

monitoring. These microbes and the nutrient-rich termite environment offer promising potential to improve water quality by breaking down harmful substances in rivers and to support sustainable ecological management.

On the other hand, banana peel biochar is a type of charcoal made by heating dried banana peels in a low-oxygen environment, a process called pyrolysis. This biochar is rich in nutrients like potassium, phosphorus, and calcium, making it useful as a natural fertilizer. When mixed with soil, it helps improve water retention, soil structure, and plant growth. It also helps trap carbon in the soil, making it an eco-friendly way to reduce waste and fight climate change. Banana peel biochar, a byproduct of agricultural waste, has been shown to possess adsorptive properties that can bind contaminants and improve soil and water quality. According to Tariku and Meskel (2022), banana peel biochar is a porous, carbon-rich substance produced through the pyrolysis of banana peels—an agricultural waste—under limited oxygen conditions. It functions as an effective, low-cost adsorbent due to its high surface area and functional groups (e.g., hydroxyl, carboxyl, and carbonyl), which enable it to bind pollutants such as heavy metals, dyes, and organic compounds in water and soil remediation applications.

The Butuanon River, which flows through Mandaue City, has long been a concern, as it was officially declared biologically dead as early as 1992 and, despite efforts, remains highly polluted. Recent water tests in 2023 and a 2025 meeting by the Butuanon River Watershed Water Quality Management Area (WQMA) confirmed that the river still contains high levels of coliform bacteria and solid waste (DENR-EMB 7, 2025). According to Chamen and Visco (2024) in their study "*The Role of Watershed Management Board in the Rehabilitation of Butuanon River Watershed in Cebu, Philippines*", the river's poor condition is mainly due to ongoing pollution, improper waste disposal, and weak enforcement of environmental regulations. They argue that despite various rehabilitation efforts, water quality has not improved significantly, and stronger watershed governance and stakeholder cooperation are urgently needed. Additionally, according to Abida (2022), the potential of reclaimed water for agricultural use is emphasized as an environmentally responsible practice that can address both water shortages and ecological degradation. Applying the concept of reclaimed water reuse to the Butuanon River context can help reduce the strain on natural water bodies, promote safer farming practices, and support long-term food security. This study is valuable as it encourages local stakeholders to consider alternative water sources that protect both human health and the environment.

Internationally, a study by Abdus-Salam and Bello (2015) in Iran, entitled "*Kinetics, thermodynamics and competitive adsorption of lead and zinc ions onto termite mound*," found that termite mound material shows a greater preference for lead adsorption over zinc if both metals are present. This study emphasizes the efficacy and affordability of termite cliffs as natural adsorbents for removing heavy metals from contaminated water. Their natural composition enables effective ionization, especially of lead, even under competitive conditions, demonstrating their potential as low-cost, environmentally friendly solutions for sustainable environmental rehabilitation. Nationally, a study conducted in Manila by Urgel et al. (2024), "*Removal of diesel oil from water using biochar derived from waste banana peels as adsorbent*". Suggests that banana peels have an effective use in the filtering of diesel oil from water. It has demonstrated the effectiveness of banana peel biochar (BPBC), derived from discarded banana peel powder, as an adsorbent for removing diesel oil from water. BPBC, synthesized and thoroughly characterized through slow pyrolysis, has high porosity, thermal stability, and hydrophobicity - key properties of oil and water separation. Overall, BPBC offers a sustainable, cost-effective solution for oil spill cleanup and wastewater treatment, and provides a valuable application for water conservation.

Additionally, a local study conducted at Talamban, Cebu City by Larino and Castañares (2019), titled "*The Effect of Pulang-Bato Spring on the Levels of Copper and Zinc at the Zone of Impact of the Spring and a Section of Butuanon River*," found that the Butuanon River, one of the most important rivers in Cebu's territory, is heavily contaminated by copper and zinc metals. Over the years, various environmental samples have been collected, including water, sediments, umbrella plants, guppy fish, and earthworms, and all have been contaminated with these metals. This suggests that metals are present in the river's water. Without immediate intervention and remediation, the river's condition will likely worsen, potentially rendering it biologically dead and unusable for future generations.

Most existing studies have explored termite nest materials and banana peel biochar separately for water remediation, but few have examined their combined effectiveness. There is limited research applying these materials in real-world polluted rivers like the Butuanon River in Mandaue City. Locally, studies often overlook specific physical and chemical parameters such as clarity, odor, pH, and heavy metal content. Additionally, the effect of varying doses from 1 gram to 3 grams under field conditions remains largely unexplored. This study addresses these gaps by investigating the combined potential of termite nest microbes and banana peel biochar as a low-cost, sustainable solution for improving water quality in urban environments.

Thus, this study investigated the viability of termite nest microbes and banana peel biochar as bioremediation agents for improving the water quality of the Butuanon River in Mandaue City.

*Theoretical Background*

This study is anchored on the Ecological Niche Theory by Hutchinson (1957), which explains how microbes adapt to specific environmental conditions, and is supported by the Brunauer–Emmett–Teller (BET) Theory by Brunauer, Emmett, and Teller (1938), which explains physical adsorption in porous materials like biochar. These theories guide the study's focus on using termite nest microbes and banana peel biochar to improve water quality in the Butuanon River. This framework is also aligned with Sustainable Development Goal 6 (SDG 6), which promotes access to clean water and reducing pollution through sustainable solutions.

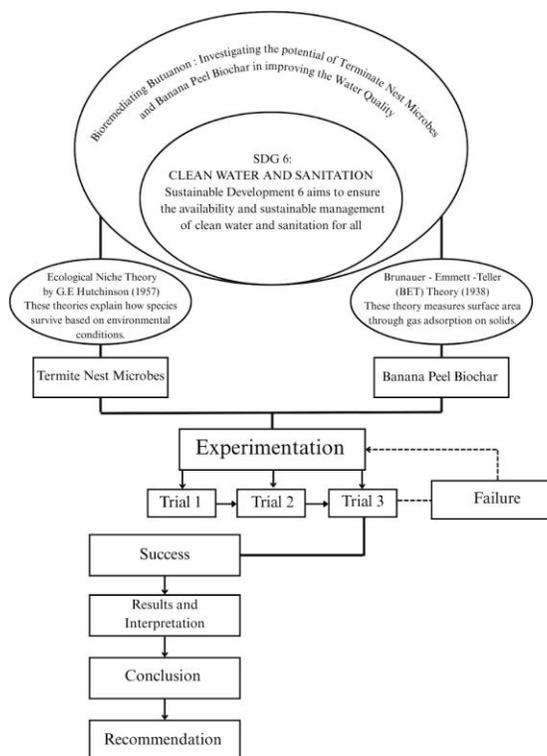


Figure 1. A schematic diagram of bioremediating butuanon: investigating the potential of termite nest microbes and banana peel biochar in improving the water quality.

This study is also guided by the Brunauer–Emmett–Teller (BET) Theory, developed by Brunauer, Emmett, and Teller in 1938. The BET Theory explains how the surface area and porosity of materials determine their ability to adsorb molecules. In water treatment, this theory is widely used to assess the effectiveness of materials like activated carbon and biochar in trapping pollutants. A higher surface area means greater capacity to capture harmful substances, such as heavy metals and organic waste. This makes the BET Theory essential in evaluating materials used in physical filtration systems.

In this study, the BET Theory supports the use of banana peel biochar as a low-cost and natural filtration medium. When banana peels undergo pyrolysis, they become porous and carbon-rich, creating a material ideal for adsorbing pollutants. This physical structure allows banana peel biochar to remove suspended solids, toxic chemicals, and other contaminants from water. A study by Channei et al. (2025), titled "From Waste to Value: Banana-Peel-Derived Adsorbents for Efficient Removal of Polar Compounds from Used Palm Oil", confirmed that banana-peel-derived adsorbents are highly effective at pollutant removal due to their large surface area and porous structure. Their findings directly validate the use of banana peel biochar as a key component of the water purification process in this study.

In addition, this study aligns with Sustainable Development Goal 6 (SDG 6), Target 6.3, established by the United Nations in 2015. This goal focuses on reducing pollution, eliminating dumping, and minimizing hazardous chemical releases into water systems. It promotes the use of sustainable, nature-based technologies to protect water ecosystems. Using termite nest microbes and banana peel biochar, both locally available and biodegradable, directly supports the objectives of SDG 6. These natural resources offer an innovative yet low-cost solution to water pollution in underserved urban communities.

The SDG 6 framework is connected to this study because it encourages environmental solutions that are both accessible and community-driven. By using natural, biological, and physical agents for water purification, the study supports access to clean water while minimizing environmental harm. It demonstrates how scientific knowledge and local resources can be combined to meet global sustainability goals. The integration of ecological theory, material science, and international development goals highlights the interdisciplinary strength of this study. Through this framework, the research contributes to improving water quality in practical, affordable, and sustainable ways.

Thus, the combination of the Ecological Niche Theory, Brunauer–Emmett–Teller (BET) Theory, and the Sustainable Development Goal 6 Framework provides a solid foundation for this study. The Ecological Niche Theory justifies the use of termite microbes as biological agents adapted to polluted water environments. The BET Theory explains how banana peel biochar can physically filter contaminants through adsorption. SDG 6 reinforces the importance of using sustainable, nature-based approaches for water purification. Together, these theories support an effective, affordable, and environmentally aligned bioremediation model.

### *Statement of the Problem*

This scientific endeavor investigated the potential of termite nest microbes and banana peel biochar as bioremediation agents to improve the water quality of the Butuanon River located in Mandaue City, Cebu, in the S.Y. 2025-2026. The results of this study served as the basis for recommendations toward sustainable and low-cost water treatment solutions for polluted urban rivers.

Specifically, this study answered the following questions:

1. What are the effects of treatments on the chemical characteristics of the water in terms of:
  - 1.1. pH level after treatment termite nest microbes alone;
  - 1.2. pH level after treatment banana peel biochar alone;
  - 1.3. pH level after treatment 1 g termite nest + 1 g banana peel biochar;
  - 1.4. pH level after treatment 2 g termite nest + 2 g banana peel biochar;
  - 1.5. pH level after treatment 3 g termite nest + 3 g banana peel biochar; and
  - 1.6. concentration of selected heavy metals (Lead, Mercury, and Chromium)?
2. Is there a significant difference in the pH levels of Butuanon River water among the different treatments?
3. What are the effects of the treatments on the physical characteristics of the water in terms of
  - 3.1. clarity;
  - 3.2. color; and
  - 3.3. odor?
4. Is there a significant difference in the turbidity (clarity) levels of Butuanon River water among the different treatments?
5. Based on the results, what recommendations may be proposed?

### *Statement of Hypotheses*

At 0.05 significance level.

H<sub>01</sub>: There is a significant difference in the pH levels of Butuanon River water among the different treatments.

H<sub>02</sub>: There is a significant difference in the turbidity (clarity) levels of Butuanon River water among the different treatments.

## **Methodology**

### *Research Design*

This study used a posttest-only design, a true experimental design, within the quantitative research approach. This design was characterized by the deliberate manipulation of variables, the control of external factors, and the objective measurement of outcomes. A posttest-only true experimental design is a quantitative research design in which subjects are randomly assigned to treatments, no pretest is conducted, and only post-intervention results are measured. It was used to determine cause-and-effect relationships without the influence of pretesting effects (Singh & Masuku, 2014).

The researchers implemented various treatments involving termite nest microbes and banana peel biochar, both individually and in combination, applied to samples of polluted river water. Changes in turbidity, pH, odor, and heavy metal

concentration were measured to evaluate the effects of these treatments. This experimental framework was designed to objectively evaluate the potential of natural, low-cost bioremediation methods to enhance water quality.

#### *Research Environment*

This study was conducted in two environments: the field and the laboratory. Water samples were collected from the Butuanon River in Mandaue City, Cebu, which the Department of Environment and Natural Resources – Environmental Management Bureau Region VII (2023) identified as critically polluted due to untreated domestic wastewater, industrial effluents, and solid waste accumulation. This river was selected as the testing ground to examine the potential of natural treatment methods using termite nest microbes and banana peel biochar. The sampling site provided a real-world context for evaluating bioremediation and filtration under highly contaminated conditions.

After field sampling, all experiments were conducted in the Science Laboratory of Maguikay National High School, also located in Mandaue City. This school-based laboratory was equipped with basic testing equipment. The controlled laboratory setting ensured standardized procedures, safe handling of materials, and consistent documentation of results. Experimenting with a local educational institution also made the research accessible, community-integrated, and aligned with resource availability. The study took place during the academic year 2024–2025.

#### *Research Material and Equipment*

The following are the materials and equipment that were used for the study:

The materials utilized in this study included 1.2 kilograms of banana peels as the primary raw material for the production of 21 grams of banana peel biochar through a pyrolysis process under limited oxygen conditions. The banana peels were cut into smaller portions using a kitchen knife and subjected to controlled heating using wood as the heat source. Aluminum foil food containers were used to contain the peels during pyrolysis, while aluminum foil served as a cover to restrict oxygen exposure. Temperature during the process was monitored using a Type K thermocouple. Heat-resistant gloves were worn to ensure safety when handling heated materials. The resulting biochar was ground using a mortar and pestle and sieved to obtain a uniform particle size. In addition, 21 grams of termite nest powder were prepared from a collected termite nest, which served as the source material. The termite nest was placed in a small stock box container, and a long tweezer was used to remove any remaining termites. A sterile scoop was utilized to prevent contamination during sample collection. The termite nest material was ground using a mortar and pestle and sieved to achieve a consistent powder form. Both the biochar and termite nest powders were stored in zip-lock bags under different conditions prior to application.

For the experimental procedure, 1,500 milliliters of river water collected from Butuanon were distributed into 14 small containers. Each container was covered with breathable cloth secured with rubber bands to prevent debris contamination while allowing air circulation. A beaker and glass stirring rod were used for accurate measurement and proper mixing of samples, while a 1-gram measuring plastic spoon ensured precise dosage of treatment materials. Water quality assessment involved the use of a DFRobot analog turbidity sensor module (Gravity Series) connected to an Arduino through jumper wires and an Arduino UNO USB cable for data acquisition and recording. A Greenfield rechargeable portable LED torch and a ruler were used to maintain consistent lighting and distance during turbidity measurements. Additional analyses were conducted using a 14-in-1 water quality test strip to detect heavy metals and other parameters, and a digital LCD pen pH meter tester to determine the pH level of the water samples.

Safety and documentation materials included 15 pairs of surgical hand gloves, 15 pairs of masks, and 100 milliliters of isopropyl alcohol for disinfection of tools and surfaces. Tissue paper was used to dry materials and equipment as needed. A laptop was utilized for data storage and analysis, while a notebook, ballpoint pens, and scientific calculators were used to record observations and perform necessary computations throughout the study.

#### *Research Procedures*

##### *Safety Preparation*

The researchers observed proper personal protective equipment to avoid unnecessary incidents during the experimentation. All researchers wore appropriate safety gear, such as surgical face masks and disposable gloves. The handling of termite nest samples, banana peel biochar, and river water was conducted in a safe laboratory environment to prevent exposure to harmful microorganisms or contaminants. Disinfection procedures were applied to all work surfaces before and after testing to ensure cleanliness and prevent cross-contamination.

Preparation of Materials

The researchers purchased the materials needed for the experimentation from reputable online marketplaces and physical stores. Banana peels were sourced from local fruit vendors and processed into biochar through pyrolysis. Termite nests were obtained from the surroundings in the area of Mandaue City. pH meter and heavy-metal test strips were ordered online, while the turbidity module was purchased at a physical store.

Experimental Procedure

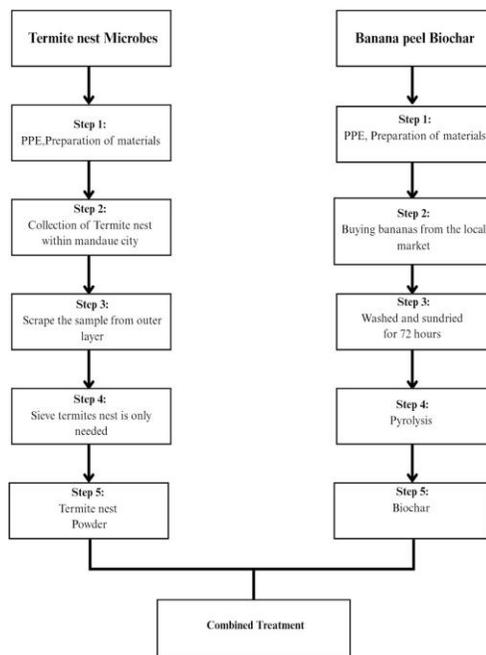


Figure 2. Flowchart of procedures for collecting termite nest microbes and banana peel biochar.

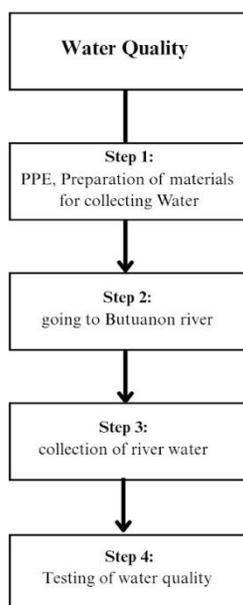


Figure 3. Flowchart of procedures for collecting water quality.

#### *Step 1: Safety Precautions*

Throughout the entire experimentation process, strict laboratory safety measures were observed. Researchers wore complete personal protective equipment (PPE), including gloves, surgical masks, and laboratory coats, while handling contaminated river water, termite nest samples, and banana peel biochar. Work areas, tools, and containers were sanitized before and after use to prevent contamination. Proper disposal of treated water and residual materials was followed in accordance with waste management protocols to minimize health and environmental risks.

#### *Step 2: Preparation for Collecting Termite Nest Microbes*

To ensure safe, sterile, and effective collection of termite nest microbes, careful preparation with the appropriate materials was performed. Researchers wore gloves and masks to maintain hygiene and minimize the risk of contamination. All tools, such as sterile steel, containers, and the area, were disinfected with isopropyl alcohol spray. Before going to the collection site, containers and zip-lock bags were labeled with their respective treatments, trials, and pyrolysis conditions for banana peel biochar.

#### *Step 3: Collection of Termite Nest Microbes*

Active termite nest samples were collected from a natural arboreal (tree-dwelling) termite nest located within Mandaue City. A portion of the mound was removed, making sure not to cause major damage to the colony structure, and long tweezers were used afterward to remove the remaining termites. The collected nest material was placed into a clean and sterile container. Personal protective equipment, such as gloves and masks, was worn throughout the process, and tools were sterilized with alcohol spray before and after sampling. Only the necessary amount of nest material was taken to minimize disturbance and ensure the sustainability of the termite mound.

#### *Step 4: Collection and Preparation of Banana Peels*

Banana peels were sourced from local markets to ensure a readily available and cost-effective supply of raw material. The peels were first washed thoroughly five times with clean tap water to remove dirt and residues that could interfere with the biochar's adsorption properties, then cut into small pieces. After washing, the peels were spread evenly in a container and sun-dried for approximately 72 hours, or until fully dehydrated and brittle.

#### *Step 5: Pyrolysis Process of Banana Peels*

The dried banana peels underwent controlled pyrolysis in a closed aluminum container, which served as a low-cost yet efficient carbonization chamber. The container was placed on a stable open-fire setup, and temperature was carefully monitored using a Type K thermocouple. A single pyrolysis condition was applied across all trials, with heating at 350 °C for 2 hours in Trials 1, 2, and 3 to ensure process consistency and comparable results. Heat-resistant gloves and appropriate personal protective equipment were used throughout the procedure. Following pyrolysis, the resulting black, porous biochar was allowed to cool naturally inside the aluminum container. Once cooled, the biochar was transferred to a container, ground into a fine powder using a clean mortar and pestle, and sieved to obtain a uniform particle size. The processed biochar was then stored in an airtight, properly labeled zip-lock bag until further experimental use.

#### *Step 6: Preparation for Collecting River Water Samples*

Before going to the river, all the needed materials were cleaned and prepared. Plastic containers and beakers were washed with soap, rinsed with clean water, and sprayed with alcohol to ensure they were free from dirt and germs. Safety items like gloves and masks were used to protect the collectors.

#### *Step 7: Collection of River Water Samples*

River water was collected from the Butuanon River at a designated sampling point in Maguikay, Mandaue City, Cebu. Each container was rinsed three times with river water before being filled with the actual sample. Around 100 ml was collected per container, making sure to dip the container just below the surface. After filling, the containers were tightly closed and brought to the laboratory. Once there, the samples were stored properly to maintain their natural condition and accurately reflect the river's pollution levels.

*Step 8: Preparation of the Treatments (Treatment A to E)*

Five treatment variations were prepared, each using a container with 100 ml of contaminated river water. Treatment A contained termite nest powder only, while Treatment B contained banana peel biochar only. Treatment C had 1 g of termite nest and 1 g of banana peel biochar, Treatment D had 2 g of termite nest and 2 g of banana peel biochar, and Treatment E had 3 g of termite nest and 3 g of banana peel biochar. These treatments allowed comparison between the individual and combined effects of the materials at different concentrations.

*Step 9: Measurement of the Materials*

All termite nest powder and banana peel biochar for treatments were accurately measured using a measuring plastic spoon (1 gram). Each amount corresponded to the designated ratios for Treatments A through E. Care was taken to avoid spillage or loss of material during measurement. The precise measuring process ensured the reliability and consistency of results across all treatments.

*Step 10: Application*

The measured termite nest powder and banana peel biochar were added to containers, each containing 100 ml of contaminated river water. The mixture was stirred evenly for two minutes to ensure proper dispersion. All containers were left to settle for 24 hours in a controlled laboratory environment. Containers were covered with breathable cloth to prevent contamination from debris while allowing air circulation.

*Step 11: Water Quality Testing*

After the 24-hour contact period, treated water samples were tested for water quality. Parameters such as pH were measured using a pH meter. Heavy metal concentrations of Lead, Mercury, and Chromium were analyzed using heavy metal testing strips, and sensory characteristics such as odor and color were evaluated through visual and olfactory comparisons.

*Trial Procedures*

Three independent trials were conducted to evaluate the effectiveness of each treatment. All trials were carried out on the same day and within the same time frame using Butuanon River water, prepared termite nest powder, and banana peel biochar produced under the same pyrolysis conditions.

*Trial 1:*

The first trial followed the standard procedure, with the banana peel biochar produced through pyrolysis at 350 °C for 2 hours before application. Each treatment setup was prepared in a separate container containing 100 mL of river water. The designated bioremediation agents were added according to their respective ratios, and the mixture was stirred for 2 minutes. The containers were covered with breathable cloth and allowed to settle for 24 hours in a shaded area. After the settling period, pH was measured, followed by odor assessment, turbidity testing, and heavy metal analysis for Lead, Chromium, and Mercury.

*Trial 2:*

The second trial followed the same procedure as Trial 1, using freshly collected river water and newly prepared materials. The banana peel biochar used in this trial was also produced through pyrolysis at 350 °C for 2 hours. The same contact time, settling conditions, and testing sequence were maintained to ensure consistency.

*Trial 3:*

The third trial was conducted under identical conditions, using prepared batches of materials and river water. The banana peel biochar was likewise produced at 350 °C for 2 hours. Data from all three trials were compared to determine reproducibility and assess statistical consistency. For all trials, each treatment was tested under the same conditions. Testing was conducted at the same time of day, with only one parameter measured at a time. All results were immediately encoded into a digital spreadsheet.

Data Gathering Procedure

Positive Control

The researchers investigated the potential of termite nest microbes, banana peel biochar, and their combined treatment as eco-friendly agents for improving water quality. Equal volumes of river water were treated with activated carbon at 100 mL, following the same mixing, 24-hour contact, and stirring as in the experimental groups. Activated carbon served as a benchmark to compare the effectiveness of termite nest microbes and banana peel biochar.

Formulation of the Experimental Setup

The study was conducted at the Science Laboratory of Maguikay National High School and at Sudlon, Maguikay, GK Village Mandaue City, Cebu, during the School Year 2025–2026. Contaminated water samples were collected from a designated sampling point in the Butuanon River. Termite nest samples were gathered from a natural arboreal (tree-dwelling) termite nest located within Mandaue City. At the same time, banana peels were sourced from local markets and processed into biochar through controlled pyrolysis

Experimental Setups

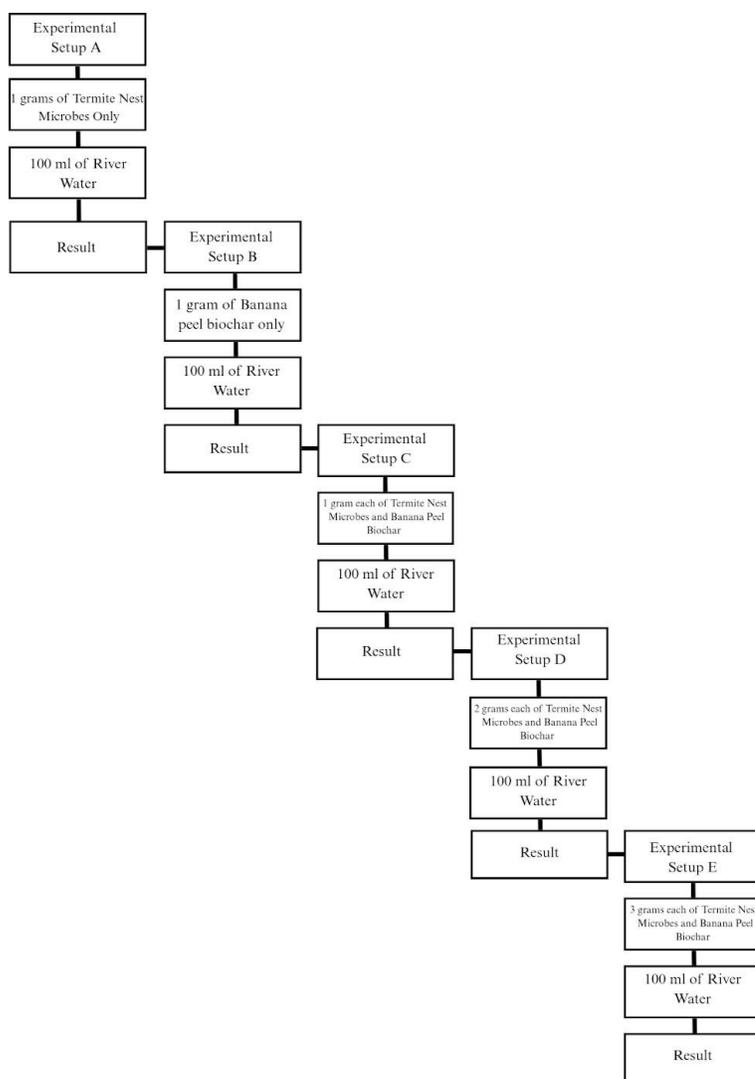


Figure 4. Flowchart of Experimental setups

### *Experimental Setup A*

#### *Termite Nest Only*

Termite nest (Isoptera) material containing naturally occurring microbes was used as a bioremediation treatment for Butuanon River water. This setup functioned as one of the experimental groups to compare its efficiency against other treatments. A measured amount of termite nest material was added to the collected river water samples to assess its capacity to improve water quality parameters, including pH, turbidity, odor, color, and heavy metal content. The aim was to determine the viability of termite nest microbes as a natural treatment agent.

### *Experimental Setup B*

#### *Banana Peel Biochar Only*

Banana peels (*Musa paradisiaca*) were purchased from the local market and processed into biochar through pyrolysis. The resulting biochar served as an additional experimental group in the water quality improvement test. Equal quantities of biochar were applied to separate river water samples, matching the treatment volume used in the termite nest setup. The performance of banana peel biochar was assessed by analyzing the same physical and chemical water quality indicators, allowing direct comparison with the termite nest treatment.

### *Experimental Setup C*

#### *Termite Nest Microbes + Banana Peel Biochar*

A combination of termite nest material and banana peel biochar was prepared in varying quantities (1:1 g, 2:2 g, and 3:3 g) to test potential synergistic effects on water purification. This multi-treatment approach aimed to determine whether the combined action of microbial biodegradation and biochar's adsorptive properties would yield greater improvements in water quality than either treatment alone.

### *Experimentation Testing*

Materials were applied at the Science Laboratory of Maguikay National High School. The experiment used termite nest material containing natural microbes, banana peel biochar (prepared through pyrolysis), mixing containers, a pH meter, turbidity, odor, and heavy metal testing kits (Lead, Chromium, and Mercury). Specifically, five setups were used: termite nest only, banana peel biochar only, 1 g termite nest + 1 g biochar, 2 g termite nest + 2 g biochar, and 3 g termite nest + 3 g biochar. The termite nest material served as the microbial treatment source, while the banana peel biochar provided the adsorptive medium for removing impurities from the river water. The pH meter, turbidity Arduino, and heavy metal testing kits were used to evaluate changes in water quality after treatment. Results from each setup were analyzed to determine the effectiveness of the treatments in improving water quality.

### *Water Quality Testing*

The materials were tested in three consecutive trials at Maguikay National High School Science Laboratory. For each trial, treated and untreated samples of Butuanon River water were monitored for changes in pH, odor, color, and heavy metal concentration after the application of termite nest microbes and banana peel biochar. Cellular phone timers were used to ensure precise monitoring intervals. Five researchers participated in the testing: one managed the timing, one recorded the measurements, another handled documentation while observing, and the remaining three researchers prepared the treatments and conducted the water quality tests.

### *Statistical Treatment of Data*

To analyze the gathered data, the researchers used a one-way analysis of variance (ANOVA). This test was applied to compare the means across multiple groups. All data collected in the study were quantified and tested using this parametric test.

## Results and Discussion

### *The pH level of the water after the treatment*

Table 3 presents the pH levels of the different treatment setups across three experimental trials, showing variations among Setups A, B, C, D, and E in assessing treatment effectiveness. The results demonstrate that all treatments increased the water pH, though to varying extents depending on the material and dosage applied. The termite nest material alone produced a moderate rise in pH, supporting findings that termite mound soils contain alkaline minerals and possess buffering capacity that neutralizes acidity (Apori et al., 2020; Abdus-Salam & Bello, 2015). Banana peel biochar alone resulted in a greater increase in pH, consistent with literature describing biochar as inherently alkaline due to its ash content and surface functional groups formed during pyrolysis (Oladipo et al., 2019; Kataya et al., 2023). Moreover, the combined application of termite nest material and banana peel biochar showed a progressive, dose-dependent increase in pH, with higher dosages producing higher pH values, aligning with previous studies indicating that mineral-rich soils and carbon-based biochars exhibit synergistic buffering effects when combined, thereby enhancing pH stabilization and improving water quality (Enagbonma & Babalola, 2019; Ge et al., 2022; Bai et al., 2024). Overall, these findings are consistent with existing literature and confirm the effectiveness of both individual and combined treatments in improving water pH.

	Setup A	Setup B	Setup C	Setup D	Setup E
Trial 1	7.65	8.75	8.63	8.83	9.05
Trial 2	7.64	8.78	8.65	8.82	9.07
Trial 3	7.64	8.78	8.68	8.85	9.11
Average	7.643	8.77	8.653	8.833	9.077

*Table 3. The pH level of the water after the adding the treatments (A, B, C, D, and E)*

### *The significant difference in the pH level of water after adding the treatments*

Table 4 shows a statistically significant difference in the pH levels of Butuanon River water across treatments, as determined by Analysis of Variance (ANOVA), with  $p < 0.05$  and a high F-value indicating that termite nest material, banana peel biochar, and their combined applications significantly influenced the acid–base balance of the water. The rejection of the null hypothesis confirms that at least one treatment produced a measurable effect on pH. The increase in pH can be attributed to adsorption and buffering mechanisms, as banana peel biochar contains alkaline functional groups and porous carbon structures consistent with Brunauer–Emmett–Teller (BET) Theory (Brunauer et al., 1938), while termite nest soils possess mineral and microbial components capable of stabilizing environmental chemistry (Adebajo et al., 2021; Opafola et al., 2022). Empirical evidence further supports the adsorption capacity of banana peel materials (Akpomie & Conradie, 2020; Al-Sareji et al., 2024). These findings are also consistent with Ecological Niche Theory (Hutchinson, 1957), which emphasizes the importance of maintaining optimal pH conditions for aquatic ecosystem stability.

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	4	3.6855	0.9214	2159.4778	0.00000
Error (within groups)	10	0.004267	0.0004267		
Total	14	3.6898	0.2636		

\*significant at p-value  $< 0.05$

*Table 4. The significant difference in the pH level of water after adding the treatments (A, B, C, D, and E)*

### *Post hoc analysis using Tukey HSD to determine which group is/are different*

Table 5 presents the results of the Tukey Honestly Significant Difference (HSD) post hoc test conducted after the significant ANOVA result to determine which treatment means differed while controlling the family-wise error rate (Tukey, 1949;

Montgomery, 2017). All pairwise comparisons among the five treatments were statistically significant ( $p < 0.05$ ), with large studentized range (Q) statistics ranging from 5.31 to 120.19 and extremely small p-values, confirming distinct pH outcomes. Setup A (pH 7.64) was significantly lower than all other treatments, whereas Setup E (3g+3g) obtained the highest mean pH of 9.077, forming its own statistical group. The combined treatments (Setups C, D, and E) demonstrated a clear dose-response relationship, with increasing dosage resulting in progressively higher pH values. The use of confidence intervals and Q statistics strengthens the reliability of these findings (Zar, 2010; Altman, 1991).

0	Difference	SE	Q	Lower CI	Upper CI	Critical Mean	p-value
x1-x2	1.1267	0.01193	94.4739	1.0712	1.1822	0.05551	0.00000
x1-x3	1.01	0.01193	84.6911	0.9545	1.0655	0.05551	0.00000
x1-x4	1.19	0.01193	99.7845	1.1345	1.2455	0.05551	0.00000
x1-x5	1.4333	0.01193	120.1887	1.3778	1.4888	0.05551	0.00000
x2-x3	0.1167	0.01193	9.7828	0.06116	0.1722	0.05551	0.0003069
x2-x4	0.06333	0.01193	5.3106	0.007827	0.1188	0.05551	0.02434
x2-x5	0.3067	0.01193	25.7148	0.2512	0.3622	0.05551	0.00000
x3-x4	0.18	0.01193	15.0935	0.1245	0.2355	0.05551	0.000006765
x3-x5	0.4233	0.01193	35.4976	0.3678	0.4788	0.05551	0.00000
x4-x5	0.2433	0.01193	20.4042	0.1878	0.2988	0.05551	0.00000

*Table 5. The post hoc analysis using Tukey HSD to determine which group is/are different*

*The heavy metal concentration after treatment for each trial*

Table 6 shows that heavy metals in the Butuanon River water samples were not detected before or after treatment, indicating concentrations were below the instrument's Below Detection Limit (BDL). This suggests that the sampling site was not contaminated with measurable levels of heavy metals during the testing period. Similar findings were reported by Choudhury et al. (2021), where certain metals such as arsenic and mercury were below detection limits in water but present in sediments. Meng et al. (2022) further explained that seasonal dilution and environmental factors can significantly reduce detectable heavy metal concentrations in surface water. Therefore, the absence of detectable heavy metals in this study may reflect environmental conditions and sediment binding behavior rather than complete absence of contamination sources.

	Setup A	Setup B	Setup C	Setup D	Setup E
Trial 1	0	0	0	0	0
Trial 2	0	0	0	0	0
Trial 3	0	0	0	0	0
Average	0	0	0	0	0

*Table 6. The heavy metal concentration after treatment for each trial (A, B, C, D, and E)*

*The non-metal contaminants that are present in the water*

Table 7 indicates that although heavy metals were not detected, non-metal contaminants such as sulfite and fluoride were present before treatment and exhibited measurable changes after application of termite nest microbes and banana peel biochar. The reduction in sulfite concentration aligns with studies showing that termite nest materials contain porous mineral structures and active microbial communities capable of adsorption and ion exchange (Chen et al., 2019; Enagbonma & Babalola, 2019). Likewise, the response of fluoride is consistent with literature emphasizing the high surface area and functional groups of banana peel-derived biochar (Oladipo et al., 2019; Kataya et al., 2023). The combined treatment likely enhanced contaminant removal through synergistic adsorption mechanisms. These results support the applicability of biochar and mineral-rich materials in improving water chemistry.

<b>Sulfite</b>	<b>Setup A</b>	<b>Setup B</b>	<b>Setup C</b>	<b>Setup D</b>	<b>Setup E</b>
Trial 1	10	10	10	10	10
Trial 2	10	10	10	10	10
Trial 3	0	0	0	0	0
Average	6.67	6.67	6.67	6.67	6.67

<b>Fluoride</b>	<b>Setup A</b>	<b>Setup B</b>	<b>Setup C</b>	<b>Setup D</b>	<b>Setup E</b>
Trial 1	4	4	4	4	4
Trial 2	10	10	10	10	10
Trial 3	25	25	25	25	25
Average	13	13	13	13	13

*Table 7. The non-metal contaminants that are present in the water after adding the treatments (A, B, C, D, and E)*

*The turbidity of the water after adding the treatments*

Table 8 presents the observed turbidity values measured in Nephelometric Turbidity Units (NTU) across trials, demonstrating that all treatments reduced turbidity to varying degrees. Termite-derived microbes alone produced moderate turbidity reduction, while banana peel biochar showed greater effectiveness due to its porous structure and adsorption capacity. According to the World Health Organization (WHO, 2017), lower NTU values indicate clearer water, while the Environmental Protection Agency (EPA, 2018) states that turbidity below 1 NTU is generally safe after treatment, and the American Public Health Association (APHA, 2017) classifies turbidity above 50 NTU as poor quality. Measurement consistency was maintained by placing the light source 5 inches from the sample, following nephelometric principles described by Sadar (2014). Overall, the results confirm that adsorption mechanisms contributed to improved water clarity.

	<b>Setup A</b>	<b>Setup B</b>	<b>Setup C</b>	<b>Setup D</b>	<b>Setup E</b>
Trial 1	261.9	200.6	530.7	754.6	876.8
Trial 2	251.8	200.6	564.3	747.6	876.8
Trial 3	241.7	190.3	530.7	747.6	870.9
Average	251.8	197.167	541.9	749.933	874.833

*Table 8. The Nephelometric Turbidity Units (NTU) of the water after adding the treatments (A, B, C, D, and E)*

*The significant difference of turbidity of the water after adding the treatments*

Table 9 shows a statistically significant difference in turbidity levels among treatments based on ANOVA ( $p < 0.05$ ), with a high F-statistic indicating a strong treatment effect on suspended solids removal. The reduction in turbidity can be explained through adsorption and coagulation mechanisms, as biochar's porous surface promotes particle adherence (Apandi et al., 2023; Lee et al., 2018). Termite mound clay also enhances particle aggregation due to its fine structure and surface reactivity (Opafola et al., 2022). These mechanisms align with Brunauer–Emmett–Teller (BET) Theory (Brunauer et al., 1938), which associates greater surface area with higher adsorption capacity. Ecologically, reducing turbidity improves light penetration and supports aquatic productivity, consistent with Ecological Niche Theory (Hutchinson, 1957).

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	4	1066078.088	266519.5219	2460.3467	0.00000
Error (within groups)	10	1083.26	108.326		
Total	14	1067161.348	76225.8105		

*Table 9. The significant difference of turbidity of the water after adding the treatments (A, B, C, D, and E)*

*Post hoc analysis using Tukey HSD to determine which group is/are different*

Table 10 presents the Tukey Honestly Significant Difference (HSD) post hoc results for turbidity following significant ANOVA findings. All pairwise comparisons were statistically significant ( $p < 0.05$ ), with Q statistics ranging from 9.09 to 112.77 and mean differences exceeding the critical value of 27.97 NTU. Setup B ( $\approx 197.2$  NTU) demonstrated the greatest turbidity reduction, whereas increasing combined dosages (Setups C, D, and E:  $\approx 541.9, 749.9,$  and  $874.8$  NTU) resulted in progressively higher turbidity. These findings indicate that excessive combined material quantities increased suspended particles rather than improving clarification. The application of Tukey HSD follows the statistical framework established by Tukey (1949) and recommended by Montgomery (2017) for identifying specific treatment differences while controlling Type I error.

Pair	Difference	SE	Q	Lower CI	Upper CI	Critical Mean	p-value
x1-x2	54.6333	6.009	9.0918	26.6655	82.6012	27.9679	0.0005586
x1-x3	290.1	6.009	48.2772	262.1321	318.0679	27.9679	0.00000
x1-x4	498.1333	6.009	82.8972	470.1655	526.1012	27.9679	0.00000
x1-x5	623.0333	6.009	103.6825	595.0655	651.0012	27.9679	0.00000
x2-x3	344.7333	6.009	57.369	316.7655	372.7012	27.9679	0.00000
x2-x4	552.7667	6.009	91.989	524.7988	580.7345	27.9679	0.00000
x2-x5	677.6667	6.009	112.7744	649.6988	705.6345	27.9679	0.00000
x3-x4	208.0333	6.009	34.62	180.0655	236.0012	27.9679	0.00000
x3-x5	332.9333	6.009	55.4053	304.9655	360.9012	27.9679	0.00000
x4-x5	124.9	6.009	20.7853	96.9321	152.8679	27.9679	0.00000

*Table 10. Post hoc analysis using Tukey HSD to determine which group is/are different*

*The color of the different treatment setups*

Table 11 shows that Setup B consistently obtained a color intensity rating of 1 (clear water) across all three trials, while other setups recorded values ranging from 2 to 5, indicating faint to dark coloration. The uniform results across replicates demonstrate reliability and consistency of treatment effects. The superior color reduction in Setup B aligns with findings by Lee et al. (2018), who reported that biochar effectively adsorbs dissolved organic matter responsible for water discoloration. Similarly, Kusumadewi et al. (2025) emphasized that waste-derived organic adsorbents reduce chromophoric compounds in aquatic systems. Therefore, the results confirm the effectiveness of banana peel biochar in improving river water color quality.

	Setup A	Setup B	Setup C	Setup D	Setup E
Trial 1	2	1	3	4	5
Trial 2	2	1	3	4	5
Trial 3	2	1	3	4	5
Average	2	1	3	4	5

\*color intensity: 5 – very dark or muddy, 4 – dark or muddy, 3 – noticeable coloration but still translucent, 2 – very faint tint, and 1 – clear water

*Table 11. The color of the different treatment setups after adding the treatments (A, B, C, D, and E)*

*The odor of the different treatment setup*

Table 12 presents consistent odor intensity ratings across three trials, with Setup B recording the lowest average odor intensity of 1.0 and Setup E the highest at 3.0, while Setups A, C, and D each averaged 2.0. The identical scores across replicates demonstrate reliability of sensory evaluation. According to Sado-Inamura and Fukushi (2018), odor can be systematically assessed alongside physicochemical indicators such as Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD). Butko et al. (2021) further explained that unpleasant river odors are associated with measurable environmental factors such as Chemical Oxygen Demand (COD) and biological activity. These findings support the validity of integrating quantified olfactory assessment with standard water quality parameters for comprehensive environmental evaluation.

	Setup A	Setup B	Setup C	Setup D	Setup E
Trial 1	2	1	2	2	3
Trial 2	2	1	2	2	3
Trial 3	2	1	2	2	3
Average	2	1	2	2	3

\*odor intensity: 5 – strong, 4 – moderate, 3 – slight, 2 – very slight, and 1 – no odor

*Table 12. The odor of the different treatment setup adding the treatments (A, B, C, D, and E)*

## Conclusion and Implications

The use of termite nest microbes and banana peel biochar as alternative bioremediation agents to improve selected water quality parameters of Butuanon River water is strongly supported by the Ecological Niche Theory (Hutchinson, 1957) and the Brunauer–Emmett–Teller (BET) Theory (1938). The Ecological Niche Theory explains how microbial communities from termite nest material, being naturally adapted to chemically complex and nutrient-rich environments, are able to survive and function effectively in polluted water conditions, facilitating organic matter breakdown and contaminant transformation. This principle clarifies the observed improvements in odor and overall water quality indicators following treatment with termite nest material. In parallel, the BET Theory explains how banana peel biochar, due to its highly porous carbon structure with large surface area and pore volume, exhibits enhanced adsorption capacity and pH adjustment. This accounts for the significant improvements in turbidity, color, and odor following biochar treatment, as contaminants are effectively bound to the material's surface through adsorption and ion exchange processes.

The significant differences in treatment performance are attributed to the distinct physical and chemical properties of the two materials. Banana peel biochar demonstrated stronger turbidity, color, and odor improvement due to its high surface area and adsorption efficiency, as predicted by BET adsorption principles. In contrast, the termite nest material contributed both mineral content and active microbial populations adapted to polluted environments, enabling biological contaminant transformation. Combined treatments produced greater increases in pH due to the synergistic buffering effect of the mineral-rich termite material and the alkaline biochar, though higher combined dosages also increased turbidity due to additional suspended particles introduced by the treatment materials themselves. Overall, the results validate both the Ecological Niche Theory and BET Theory by demonstrating that niche-adapted microbial communities and high-porosity adsorbent materials can serve as effective, low-cost, natural bioremediation agents. This study aligns with Sustainable Development Goal 6 (SDG 6) by promoting accessible, nature-based, and sustainable approaches to improving water quality, showing that locally available biological and carbon-based materials are promising options for practical, sustainable water quality improvement.

### Recommendation

This study, which investigates the potential of termite nest microbes and banana peel biochar in improving the water quality of the Butuanon River, is designed to offer meaningful contributions to the following: (1) Educators this study serves as a practical teaching tool that bridges the gap between theory and application. It demonstrates how theoretical concepts such as ecological niches and adsorption are applied to real-world problem-solving. Teachers can use it to encourage student interest in research, innovation, and environmental stewardship. (2) Students this study contributes valuable insights into sustainable practices and scientific research methodology. It inspires critical thinking about solving

environmental issues using local resources and indigenous knowledge. The project also promotes awareness of ecological responsibility and innovation among youth. In addition, it is recommended that proper laboratory testing be included in the study budget, such as the accredited services of the University of San Carlos Water Laboratory, to ensure more accurate, reliable, and scientifically validated results. Allocating funds for professional laboratory analysis strengthens data credibility and improves the overall quality of the research findings. (3) Future Researchers this study serves as a reference point for developing similar investigations involving other bio-waste materials or microbial agents. It provides both conceptual and practical guidance on designing eco-friendly water purification studies. The research contributes to a growing body of work focused on sustainable development and environmental innovation. (4) Environmental Scientists the findings provide empirical data that support the application of microbial remediation and adsorption theory in local river ecosystems. The study enriches ongoing scientific discussions on eco-friendly biotechnologies for environmental restoration. It also serves as a case example of theory-driven, nature-based solutions applied in real-world contexts. (5) Environmental Advocates this research offers a tangible model for community-level environmental action using sustainable materials. It reinforces advocacy for nature-based solutions by demonstrating their practical impact on water systems. The study strengthens efforts to promote eco-conscious behavior and support green initiatives within cities. (6) Local Government Units (LGUs) the study's outcomes can help inform local environmental programs targeting river rehabilitation and solid waste management. By showcasing the effectiveness of biochar and microbial treatments, it offers a science-based, affordable, and scalable strategy. LGUs may adopt these findings to design cleaner and more sustainable urban ecosystems. (7) Urban Communities this study contributes to the development of an accessible, low-cost water purification method using biodegradable materials readily available in local communities. It promotes environmental health by addressing pollution in a critical urban waterway through natural means. Communities may benefit from cleaner water sources without the need for expensive chemical treatments. (8) Public Health Practitioners this study contributes to improving public health by reducing contaminants in river water that may pose risks to nearby populations. It highlights how natural filtration and microbial treatment can support community hygiene and disease prevention.

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## Competing Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

## Data Availability Statement

Data sharing is only available upon submitting a formal request to the authors of the study.

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## Appendices

No appendices are attached in this study