

***Phyllanthus amarus* (GALE OF THE WIND) LEAFBEXTRACT AS A NATURAL
CORROSION INHIBITOR**

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ABSTRACT

This study investigated the effectiveness of *Phyllanthus amarus* (Gale of the Wind) leaf extract as a natural corrosion inhibitor for mild steel, offering a sustainable alternative to synthetic inhibitors, which pose environmental and health risks. The researchers prepared three extract concentrations (0.36018 g/mL, 0.30015g/mL, and 0.24012 g/mL) using an ethanolic extraction method. Mild steel samples were treated with these extracts, a blank control (water), and a no-application group before being submerged in 1M HCl for 24 hours. Corrosion rates were measured using the weight loss method, and data were analyzed through ANOVA and Tukey's HSD test. The results showed that all extract-treated samples exhibited significantly lower corrosion rates compared to no-application and blank control group, confirming the inhibitory potential of *Phyllanthus amarus*. However, no significant difference was observed among the three extract concentrations, suggesting that even the lowest concentration effectively reduces corrosion. The study concluded that *Phyllanthus amarus* leaf extract is a viable eco-friendly corrosion inhibitor for mild steel. It is recommended that future research explore its effectiveness on different metals, investigate higher extract concentrations, and employ advanced corrosion testing methods such as Electrochemical Impedance Spectroscopy to gain deeper insights into its protection mechanisms.

CHAPTER I

PROBLEM AND ITS SCOPE

This chapter tackles the introduction of the topic. It is further classified into the following parts: I.) Background of the Study, which presents an overview of the research topic, providing context and explaining the rationale behind conducting the study; II.) Statement of the Problem, which outlines the general research question along with specific inquiries that the study aims to address; III.) Null Hypothesis, where the assumptions and expected outcomes of the study are outlined; IV.) Conceptual Framework, where the theoretical structure is visually presented that guides the study, outlining the key concepts and their relationships; V.) Significance of the Study, where the potential benefits and beneficiaries of the study are identified; VI.) Definition of Terms, which clarifies specific terms and concepts used throughout the study; and lastly, VII.) Scope and Delimitations, where the boundaries and limitations of the research are discussed.

Background of the Study

For decades, metals have been essential components in construction and industrialization. They are used in infrastructure projects, building structures, machinery, appliances, and many other applications due to their strength, durability, and versatility. However, despite these properties, metals are not exempt from damage or deterioration. They can corrode when exposed to corrosive factors, which can weaken and damage the affected metal. According to Ibrahim et al. (2021), a material's slow or gradual

deterioration as a result of chemical reactions with its surroundings is called corrosion, and it primarily affects metal.

This can greatly affect the efficiency and functionality of metals, as corrosion weakens the metal structure and may lead to malfunctions in equipment made from metals like steel and aluminum. Corrosion can weaken the structural integrity of industrial equipment like buckets, pump components, tanks, piping, compressors, and valve gates, increasing the risk of failure (Cowlshaw, 2021). In addition, corrosion poses a serious safety hazard, potentially causing accidents, leaks, and explosions, which can escalate into more significant issues. It also results in substantial economic losses due to the high costs of repairs, maintenance, and replacement of corroded materials.

There are various types of metals, with steel being one of the most widely used in the industry. Among the basic types of steel bars is the Mild Steel Bar, which has been utilized for many years in building construction. Unlike other types of bars, mild steel plain bars have a smooth outer surface, as their name suggests, and a relatively lower tensile strength of approximately 40,000 psi (Tag, 2021). Like all metals, mild steel bars are not resistant to the threat of corrosion.

To prevent issues arising from corrosion, several corrosion inhibitors are already commercially available. A corrosion inhibitor is an agent that reduces or stops the corrosion of metal surfaces exposed to the environment. The problem with these commercially available inhibitors is that they are typically synthetic materials, raising concerns about toxicity, pollution, and health effects. This has led to increasing research into more sustainable alternatives.

The use of natural extracts especially those from plants as inhibitors, wherein in this study for corrosion, is an area of increasing interest due to its advantages particularly in the environment as they are biodegradable and eco-friendly. Several plant extracts are said to have properties that could prevent corrosion. Few studies have already shown the effectiveness of plants as corrosion inhibitors but more research study is needed to explore other plant species.

As per Bagalkotkar et al. (2006), *Phyllanthus amarus* is a small annual herb from the Euphorbiaceae family. They also noted that it is commonly referred to as a 'stone breaker' or 'chanca piedra' because of its traditional use in treating kidney stones. *Phyllanthus amarus* is known to have antioxidant properties that may act as potential corrosion inhibitors. According to Herbanext Laboratories, Inc. (n.d.), *Phyllanthus amarus* contains active phytochemicals, such as flavonoids, polyphenols, and tannins. These compounds have the potential to inhibit corrosion, which is the reason why the researchers chose this herbal plant, particularly for this study; however, their application as a corrosion inhibitor has not been thoroughly studied and thus requires further investigation.

Therefore, this research study was conducted with the aim of evaluating the effectiveness of *Phyllanthus amarus* (Gale of the Wind) leaf extract as an eco-friendly alternative corrosion inhibitor for metals.

Statement of the Problem

Generally, this study aimed to evaluate the effectiveness of *Phyllanthus amarus* (Gale of the Wind) leaf extract as a corrosion inhibitor for steel metals.

Specifically, this study aimed to answer the following questions:

1. What is the effect of different concentrations (0.36018g/ml, 0.30015g/ml, and 0.24012g/ml) of *Phyllanthus amarus* leaf extract on the rate of metal corrosion?
2. Which among the concentrations (0.36018g/ml, 0.30015g/ml, and 0.24012g/ml) of *Phyllanthus amarus* leaf extract is the most effective as a corrosion inhibitor in metals in terms of the rate of metal corrosion?
3. Is there a significant difference in corrosion inhibition efficiency between *Phyllanthus amarus* leaf extract and blank control in terms of the rate of metal corrosion?

Hypothesis

There is no significant difference in the rate of metal corrosion between metals treated with *Phyllanthus amarus* (Gale of the Wind) leaf extract and blank control.

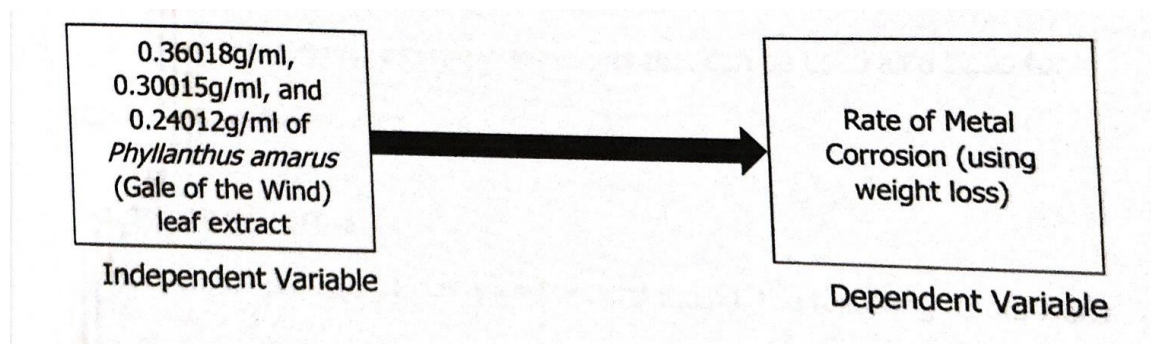


Figure 1.1 Conceptual Framework of the Study

Significance of the Study

The result of the study will result the following:

Botanist. This study will raise awareness of the ability of *Phyllanthus amarus* leaf extract as an alternative corrosion inhibitor for metals.

Construction and Engineers. This study could aid in enhancing the durability of buildings, bridges, and other metals.

Paint and Coating Industries. The research could lead to eco-friendly coatings that incorporate plant extracts, emphasizing sustainability.

Environmentalist. The study can promote greener alternatives to synthetic chemicals, reducing environmental impact.

Future Researcher. This research offers essential insights that can be used as a basis for conducting further studies.

Definition of Terms

For the purpose of clarity and understanding, the following terms were specified with their conceptual and operational definitions.

Corrosion. It is the process of materials, especially metals, deteriorating or deteriorating slowly due to chemical interactions with their environment (Ibrahimi et al., 2021).

In this study, Corrosion refers to the degradation of metal samples using the salt spray test.

Corrosion Inhibitor. It is a material that, when added with a liquid or gas (typically a metal or alloy), lessens or stops the corrosive action of metal surfaces that come into contact with the environment (Otutu, 2024).

In this study, it refers to the substance that reduces the corrosion rate of a steel metal in different corrosion environments.

Leaf extract. It is obtained by extracting bioactive compounds from plant leaves using solvents such as water or ethanol (Hemmami et al., 2024).

In this study, leaf extract refers to the substance taken from the *Phyllanthus Amarus* (Gale of the wind) to be used as the corrosion inhibitor using methanolic extraction.

Metals. These are a class of elements characterized by high electrical and thermal conductivity, malleability, ductility, and a lustrous appearance (Helmenstine, 2019).

In this study, it refers to mild steel metal that will be used to test the leaf extract as a corrosion inhibitor.

Phyllanthus amarus (Gale of the Wind). Commonly known as Gale of the Wind is a small shrub or herbaceous plant that is native to Southeast Asia. It has a woody stem and small, oval-shaped leaves (Wamucii, 2023).

In this study, *Phyllantus Amarus* (Gale of the Wind) refers to the plant that will be used as the source of leaf extract for the corrosion inhibitor.

Scope and Delimitation

This study was conducted to find out the effectiveness of *Phyllanthus amarus* (Gale of the Wind) leaf extract as an eco-friendly corrosion inhibitor for metals. *Phyllanthus amarus* (Gale of the Wind) leaves were gathered at Brgy. Puyas, Cabatuan, and extracted at Cabatuan National Comprehensive High School on February 10 - 24, 2025. The researchers used a mild steel flat bar treated with *Phyllanthus amarus* (Gale of the Wind) leaf extract as a corrosion inhibitor and then evaluated its effectiveness. The steel was obtained from the mild steel bar.

CHAPTER II

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents the Review of Related Literature and Studies consisting of I.) Corrosion and Its Impact on Metals and Related Studies; II.) Corrosion Inhibitor and Related Studies; III.) Green Corrosion Inhibitors: Plant Extracts and Related Studies; IV.) *Phyllanthus amarus* (Gale of the Wind) and Related Studies

Corrosion and Its Impact on Metals

Corrosion can be defined as the unfavorable degradation of a material, typically metals or alloys, due to an electrochemical or chemical reaction with their surroundings that negatively impacts the qualities of the metals or alloys that need to be conserved. Mainly because of the charge transfer reactions at the electrified interfaces between the metallic substance and its surroundings, which cause the metallic substance to become spontaneously unstable (Raut, 2023).

There are six primary forms of corrosion. Uniform corrosion, also known as general attack, is the most common type, characterized by a uniform loss of material over the entire surface. This form is typically predictable and can be managed through proper material selection and protective coatings. Galvanic corrosion occurs when two dissimilar

metals are in electrical contact in a corrosive environment, leading to accelerated corrosion of the more anodic metal. Crevice corrosion is localized and occurs in confined spaces where stagnant solutions can accumulate, such as under gaskets or washers. Pitting corrosion is another localized form, resulting in small, deep pits on the metal surface, often difficult to detect and more dangerous than uniform corrosion due to its concentrated nature. Erosion corrosion combines mechanical wear and chemical attack, typically occurring in fast-flowing fluids, leading to accelerated material loss. Lastly, stress corrosion cracking involves the growth of cracks due to the combined effects of tensile stress and a corrosive environment, which can lead to sudden and catastrophic failures (Ibrahimi et al., 2021).

According to the study of Shree Meenakshi (2021), the corrosion of pipe material and associated systems as a result of interaction with the working environment is known as pipeline corrosion. It impacts both metal and non-metal pipelines and accessories. The corrosion of pipelines and the consequent catastrophic disasters they can cause cost the economy billions of dollars. In 2016, it was predicted that the yearly cost of corrosion in the United States, including direct and indirect costs, exceeded USD \$1.1 trillion. Stated differently, rusting is a serious issue. It mostly affects pipelines used for subterranean, submerged, or buried applications that are composed of metals including copper, aluminum, cast iron, carbon steel, stainless steel, and alloy steel pipes. The oil and gas industry therefore faces a critical challenge in designing and choosing the optimum materials and technologies for pipelines and their corrosion prevention systems.

According to White (2023), the expense of corrosion is enormous worldwide, to put it simply. The report estimates that it comes to a total of \$2.5 trillion (USD), and that

figure does not even account for the effects on the environment or personal safety. Given that \$2.5 trillion is about 3.4% of the world's gross domestic product (GDP), corrosion is undoubtedly a significant and expensive issue. Businesses can save a lot of money by proactively introducing corrosion controls. The analysis from NACE International estimates that if more people employed those solutions, the global savings might range from \$357 to \$875 billion (USD) a year. That represents 15-35% of corrosion's overall cost, which is no small accomplishment.

Corrosion Inhibitors

According to Nanotechnology in the Automotive Industry (2022), a corrosion inhibitor can be defined as a substance that reduces the corrosion rate of a metal surface exposed to the corrosive environment by its chemical activity, thus extending the service life of metallic components. This excludes any chemical that reduces the corrosion rate by substantial pH variation, or oxygen and hydrogen sulfide scavengers, causing removal of aggressive species from the solution (Monticelli, 2018). Inhibitors in small concentrations are added to cooling water, acid, and steam to maintain an inhibiting surface film (Popov, 2015).

Chemical inhibitors are a reactant or process that slows or halts a chemical reaction. This type of inhibitor can stop or slow the rust and corrosion of metals and metal alloys. It has many industrial applications. Chemical inhibitors decrease corrosion rates and can prevent acid or oxidation damage to metals or metal alloys (Carignan, 2023). Natural inhibitors, derived from plants and minerals, are eco-friendly, biodegradable, and low in toxicity. However, they may have limited effectiveness and

may be unsuitable for severe corrosion environments. Despite these limitations, natural inhibitors are gaining popularity as sustainable and eco-friendly alternatives to synthetic inhibitors that can be used in various applications, such as in the oil and gas industry and for preserving historical artifacts. Natural inhibitors are renewable, biodegradable, and safe for human exposure, making them appropriate for industries such as food and pharmaceuticals (Al-Amiery et al., 2023).

Research on green corrosion inhibitors (GCI) increased and favorable results are collected. It is said that the most important factors of the GCI are biodegradability and easy preparation. It has been found that plant extracts contain compounds that have anti-corrosion properties (Sheydaei, 2024). This study concluded that plants are ideal to replace synthetic organic corrosion inhibitors as the researchers found out that the plant extracts contain several phytochemicals that adsorb and inhibit metallic corrosion (Verma et al., 2018). In this study, it has been shown that plant-based green corrosion inhibitors can be a great option for replacing traditional, toxic, harmful, and expensive corrosion inhibitors as they have high corrosion inhibition efficiency in various media. inhibitors as they have high corrosion inhibition efficiency in various media. Moreover, plant extracts are abundant, biocompatible, cheap, biodegradable, and nontoxic (Zakeri et al., 2022). Several plant extracts have been investigated using various factors to assess their effectiveness. The results show that most of them have an excellent capacity for inhibition, usually above 90%. These outstanding outcomes demonstrate their efficiency in comparison with traditional methods and call for further study before large-scale application (Murungi & Sulaimon, 2022).

Traditional corrosion inhibitors, such as chromates, phosphates, and molybdates, have long been the preferred choice due to their demonstrated efficacy in corrosion prevention. However, the use of these inhibitors comes with significant downsides, including toxicity, environmental degradation, and poor health impacts. Notably, chromates, which are known for their remarkable efficacy in corrosion control, have also been identified as carcinogens. In contrast, phosphates contribute to eutrophication, which fosters algae growth and results in water contamination (Al-Amiery et al., 2020). These inhibitors have the potential to disrupt an enzyme system at one location in the body, disrupt a biochemical process, or cause irreversible (permanent) damage to an organ system, such as the liver or kidneys. The toxicity could appear when the compound is being synthesized or when it is being used (Marzorati et al., 2018).

Several studies have shown the effectiveness of natural inhibitors. A study by Raha et al. (2016) found that the olive leaf extract was an effective green inhibitor of copper in 0.5 M NaCl. Potentiodynamic polarization and electrochemical impedance spectroscopy were used to examine the inhibitory effect of olive leaf extract on copper corrosion in 0.5 M NaCl solution. Throughout the 24-hour trials conducted for this study, it was discovered that reached a for the highest inhibition efficiency over time and reached 90% for the highest inhibitor concentration taken into consideration.

Hernández et al. (2021) used *Artemisia vulgaris* as a natural inhibitor. Through a simple Soxhlet extraction process using 15g of *Artemisia vulgaris* and 260 mL of Ether, the inhibitor was produced. Following the production of the inhibitor, the steel was submerged in it to create a coating that prevents corrosion. The efficiency of this method was evaluated through Electrochemical Impedance Spectroscopy (EIS) and polarization

resistance, where Nyquist diagrams and Tafel curves were obtained, for steels with and without treatment. The results showed the corrosion resistance which has increased to 93%, and an 88% decrease in the corrosion rate.

The use of natural gums as environmentally safe corrosion inhibitors for metal and alloys has in recent times received tremendous attention by several researchers. The use of natural gums for corrosion inhibitors for metals and alloys for various applications is attractive because they are economical, renewable materials, easily available, non-hazardous, potentially biodegradable and also biocompatible with the natural environment. This study concludes that the use of gums as an alternative corrosion inhibitor for costly corrosion inhibitors should be pursued and more research should be carried out on other gums and also on other corrosive environments like CO₂, H₂S, and NaCl, which have a great impact on metals in the oil and gas industries. This paradigm shift will create chemicals that are beneficial to the environment and human beings on one hand and also prevent losses due to the effect of corrosion on the other hand (Peter et al., 2015).

Green Corrosion Inhibitors: Plant Extracts

Green inhibitors are extensively used to control the corrosion of different types of steel in acidic environments, especially in the oil and gas industry. Based on their chemical nature, green inhibitors can be classified into two groups namely organic and inorganic. Several types of organic green inhibitors include plants (extracts, oil), ionic liquids, amino acids, drugs, and natural polymers. (Wei et al., 2020) The application of green corrosion inhibitors, which reduce corrosion rates to the appropriate level with low

environmental impact, is one of the emerging key approaches to controlling corrosion in modern society. From the standpoint of environmental compatibility, this research field is undergoing significant developments. Nowadays, due to increasing ecological awareness, corrosion inhibitors are subject to stringent restrictions and regulations enforced by environmental agencies in several nations. According to these requirements, these chemicals must be environmentally acceptable and safe. In light of this, intensive research has been undertaken in recent years aimed at the development of green corrosion inhibitors from plant extracts. Being readily available, inexpensive, biodegradable, and safe makes these substances promising alternatives to hazardous conventional corrosion inhibitors. (Zakeri et al., 2022)

The study of *Saraca ashoka* extract as a corrosion inhibitor by modeling the epicathecin molecule through DFT calculation. Based on global parameters, such as HOMO, LUMO, and AN, the authors suggested that donor-acceptor interactions were established by n electrons of the aromatic ring of vacant d-orbital of surface iron atoms. Unshared electron pairs of heteroatoms and vacant d-orbital on iron were possible as well (Saxena et al., 2020).

The aqueous extract of *Tinospora crispa* as corrosion inhibition on mild steel in IM HCI was evaluated. Weight loss, EIS, and PP methods are used for deepening the investigation into the corrosion inhibitor properties of the extract. The maximum inhibition, of about 70-80%, was obtained with an 800ppm concentration. Another extract, obtained with acetone-water as an extraction solvent, has been studied as well. In this case, the maximum inhibition efficiency was obtained with a 1000 ppm concentration. The Langmuir absorption isotherm was used to obtain Gibbs absorption

energy ΔG°_{ads} of about -21.87 kJ/mol with the aqueous extract and -20.25 kJ/mol with acetone-water extract. The spontaneous physisorption process was determined by this calculation. SEM imaging confirmed the protection provided by the extracts on the mild steel surface (Apriandanu & Yulizar, 2017).

Jujube leaf extracts have been shown to act as effective corrosion inhibitors for mild steel in acidic solutions. The inhibition efficiency is attributed to the presence of tannins, flavonoids, and saponins, which adsorb onto the metal surface, providing up to 85% efficiency (Kumar & Rani, 2020).

Khadom et al. studied the inhibition effect of *Xanthium strumarium* leaf extract on carbon steel corrosion in the hydrochloric acid solution. Results revealed a 94.8% inhibition efficiency at 1000 ppm inhibitor concentration (Dehghanie et al., 2019).

A study conducted by Arthur and Abechi (2019) investigated the corrosion inhibition of mild steel in an acid medium using *Acalypha chamaedrifolia* leaf extract as a potential inhibitor. This study utilized 20% NaOH and 100g/L of zinc dust to stop the corrosive activity in metals after 24 hours of submerging it. The gravimetric (weight loss) technique was used, which was also employed in our study. This study has been one of our bases in the experiment process.

***Phyllanthus amarus* (Gale of the Wind)**

Herbal plants have always played an important role in medicine and human health, one of which is *Phyllanthus amarus*, also known as the Gale of the Wind. According to Verma et al., (2014), this herb has been used in traditional medicine for nearly three

millennia. Additionally, the plant has been the subject of several studies investigating its pharmacological uses and phytochemical components. However, its application in industries, such as its potential use as an inhibitor, has not yet been extensively studied.

A study by Oshomoh and Uzama-Avenbuan (2020) concluded that the quantitative phytochemical analysis of the ethanol extract of *Phyllanthus amarus* revealed the presence of phenols, flavonoids, saponins, tannins, and alkaloids. Furthermore, *Phyllanthus* species are known for their rich diversity of phytochemicals, including tannins, terpenes, alkaloids, glycosidic compounds, saponins, and flavones (Nisar et al., 2018). Over the past few decades, numerous studies have been undertaken on this powerful herb, covering a range of topics, such as ethnobotany, phytochemistry, bioactivity, and pharmacological studies. Numerous pharmacological activities, including hepatoprotective, antioxidant, antiviral, antibacterial, antidiabetic, anti-inflammatory, anticancer, antimalarial, nephroprotective, and diuretic effects, have been demonstrated by *Phyllanthus amarus* extracts (Ghosh et al., 2022).

Some of the most common phytochemicals with corrosion-inhibiting effects include flavonoids, glycosides, alkaloids, saponins, phytosterols, tannins, anthraquinones, phenolic compounds, triterpenes, and phlobatannins (Zakeri et al., 2022). Many of these phytochemicals are found in *Phyllanthus amarus*, making it a potential corrosion inhibitor. Natural antioxidants, with multiple polar atoms and electron-rich bonds, are potential mixed-type corrosion inhibitors and 'green' alternatives to commercial inorganic inhibitors (Pradipta et al., 2019). Antioxidants delay and prevent oxidation, its presence on the *Phyllanthus amarus* leaves further enhance their potential as corrosion inhibitors.

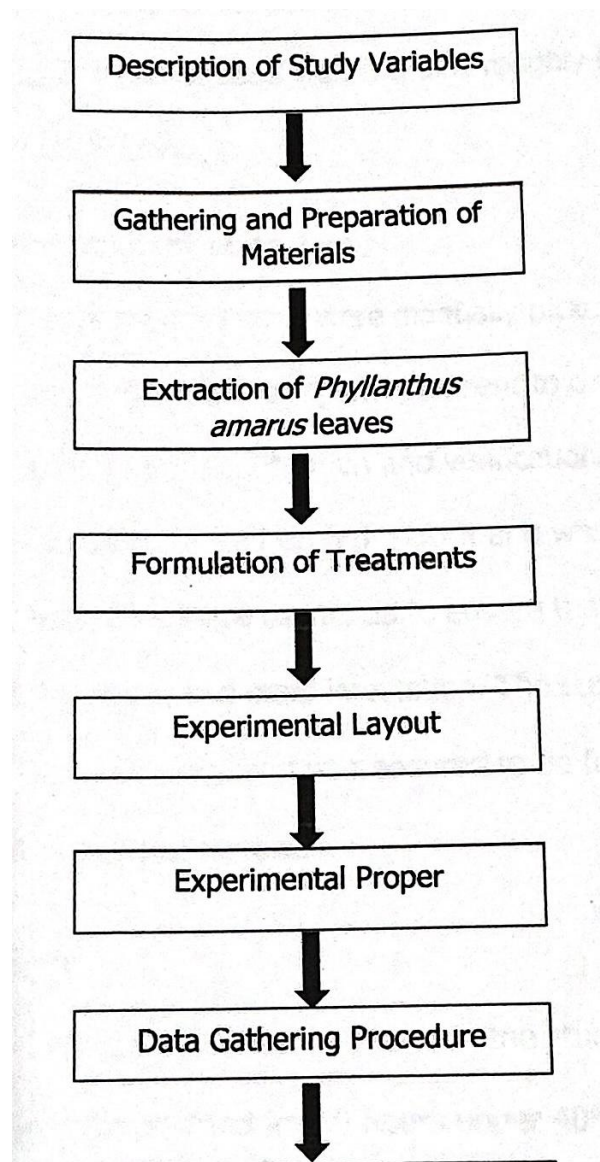
Several studies have demonstrated the potential of *Phyllanthus amarus* as an effective green corrosion inhibitor. Logaraja et al. (2018) investigated the inhibitive action of *Phyllanthus amarus* and *Acalypha indica* extracts on steel coated with epoxy resin, using various methods such as weight loss and acid attack tests, finding that both extracts significantly improved corrosion resistance. Similarly, Olutayo et al. (2021) concluded that *Phyllanthus amarus* leaf extract is an eco-friendly, affordable, biodegradable, renewable, and nontoxic alternative to conventional chemical inhibitors, particularly for aluminum. Pasupathy (2014) also showed that the leaf extract of *Phyllanthus amarus* exhibited high inhibition efficiency against zinc corrosion in 0.5N H₂SO₄, using weight loss, gasometric, and thermometric methods. Together, these studies highlight the effectiveness and sustainability of *Phyllanthus amarus* as a corrosion inhibitor.

Related studies and literature highlighting the problem of corrosion and the use of corrosion inhibitors emphasize the importance of this research. It has also been discussed that certain plant extracts have been found to inhibit corrosion effectively. Moreover, the advantages and efficiency of using plant-based extracts over synthetic inhibitors have been well-documented. The researchers observed that the related studies on corrosion inhibitors used less concentrated treatments. Therefore, they aimed to investigate the effect of plant extract as a corrosion inhibitor in more concentrated treatments. In line with this, several studies have identified the phytochemicals present in *Phyllanthus amarus*, which show significant potential in inhibiting corrosion, aligning with the objectives of this study. The related literature and studies mentioned will serve as a valuable foundation throughout the research process.

CHAPTER III

METHODOLOGY

This chapter presents and describes the materials that were used and the procedures that were employed in this study. For an overview, refer to Figure 3.1 Schematic Diagram of Research Methodology.



Description of Study Variables

***Phyllanthus amarus* leaves.** Commonly known as Gale of the Wind is a small shrub or herbaceous plant that is native to Southeast Asia. It has a woody stem and small, oval-shaped leaves. Both young and matured leaves will be used in this study.

Steel Metals. A mild steel bar also known as low carbon steel was used in this study. It is a type of carbon steel that contains roughly between 0.05% and 0.25% of carbon by weight.

Gathering and Preparation of Materials

91g of *Phyllanthus amarus* leaves were manually picked at Brgy. Puyas, Cabatuan, Iloilo before sunrise. Plant samples were sent to the Department of Agriculture, Cabatuan, Iloilo, for identification and verification. The *Phyllanthus amarus* leaves were manually plucked from the plant and washed with clean water by the researchers. They were examined to ensure that they were free from insect bites, discoloration, and mold infestation. The steel metal was bought at Balcarse General Merchant Corp. and was ensured to be free from rust, discoloration, and other signs of corrosion.

Extraction Procedure

The Ethanolic Extraction method was used in the study. Fresh leaves of *Phyllanthus amarus* were oven-dried for 60 hours under 40°C temperature and were reduced to size using an electric blender. The blended *Phyllanthus amarus* leaves were soaked in 600mL of 95% ethanol in a 1L plastic bottle for 48 hours. The bottle was sealed and covered with carbon paper. During the first 24 hours, the mixture was shaken for 30 seconds every hour and was preserved in a refrigerator for 6 hours. It was then filtered twice using Whatman #1 filter paper into another Erlenmeyer flask. Solid residues were pressed for additional extracts, and the mixture was combined with the earlier filtered extract. The filtrate was set up for rotary evaporation at 47°C with 41 rpm. The extracts were stored in a clean bottle and sealed with cling wrap. It was covered with carbon paper to prevent light from passing through.

Formulation of Treatments

The *Phyllanthus amarus* leaf extract was concentrated via rotary evaporation, removing excess ethanol and yielding 94 ml. This served as the stock solution for treatment formulations following Arthur and Abechi (2019). Three concentrations—0.36018 g/mL, 0.30015 g/mL, and 0.24012 g/mL—were prepared using $C_1V_1 = C_2V_2$, where C_1 (0.6003 g/mL) is the stock concentration, C_2 is the target concentration, V_1 is the stock volume needed, and V_2 (20 mL) is the final volume.

This study has five treatments: 0.36018g/ml, 0.30015g/ml, and 0.24012g/ml concentration of *Phyllanthus amarus* leaf extract, blank control, and no application. The extract was formulated with water as the solvent. In formulating 0.36018g/ml of *Phyllanthus amarus* leaf extract, 12.0 mL of *Phyllanthus amarus* leaf extract was added

with 8.0 mL solvent, and this was labelled as T1. In formulating 0.30015g/ml of *Phyllanthus amarus* leaf extract, 10.0 mL of extract was mixed with 10.0 mL of water, and this was labeled as T2. In formulating 0.24012g/ml of *Phyllanthus amarus* leaf extract, 8.0 mL of extract was mixed with 12 mL of water, and this was labeled as T3. Water was used as the blank control, and no application was used as the negative control.

Experimental Layout

This study has five treatments, and each treatment setup was replicated three times. A Completely Randomized Design (CRD) was used as the experimental design.

T3R2	T2R3	T4R2	T5R1	T1R1
T4R1	T5R2	T2R1	T3R3	T1R2
T1R3	T3R1	T5R3	T2R2	T4R3

The assignment of treatments per plate was done using the lottery method.

Table 3.1 Experimental Layout of the Study

Legend:

T1 - 0.36018g/ml of *Phyllanthus amarus* leaf extract

T2 - 0.30015g/ml of *Phyllanthus amarus* leaf extract

T3 - 0.24012g/ml of *Phyllanthus amarus* leaf extract

T4 - Blank Control

T5 - No application

R1 - First Replication

R2 - Second Replication

R3 - Third Replication

Experimental Proper

The weight loss technique employed by Arthur and Abechi (2019) in their study was the basis of the experimental proper with some modifications to determine *Phyllanthus amarus* leaf extract as a natural corrosion inhibitor for mild steel flat bars.

The mild steel bar coupons were cut into approximately 2.5-centimeter. Each coupon was abraded and polished using emery paper, washed thoroughly with distilled water, degreased with acetone, and dried. The coupons were then weighed and recorded using an electronic weighing balance. The length, width, and height of each coupon were then measured to solve for the surface area. A thread was tied to each of the mild steel pieces for easy suspension in the media. The coupons were soaked in various concentrations (0.36018g/ml, 0.30015g/ml, and 0.24012g/ml of *Phyllanthus amarus* leaf extract, blank control, and no application for 2 hours in a 100-milliliter beaker. After that, the samples were dried, and each mild steel bar was treated with different treatments, and the no-application (negative control) coupons were submerged in 20 milliliters of 1M HCl for 24 hours. The experimental setup was kept in the laboratory, away from direct sunlight. Each coupon was removed from the corrosive substance. The corroded coupons were washed in 20% NaOH and 100 g/L zinc dust to stop the corrosion reaction. The

coupons were washed and dried using acetone. The coupons were then reweighed and recorded.

Data Gathering Procedure

The corrosion rate was determined using data gathered from weight loss, surface area of the metal samples, and time of exposure of the metal samples. The weight loss after being exposed to the treatments was calculated by subtracting the weight of the steel after exposure from its weight before exposure, in grams. The corrosion rate was then calculated by dividing the weight loss (in mg) by the product of the surface area of the sample (in cm²), and the time of exposure of the metal samples, expressed in hours (Arthur & Abechi, 2019). The corrosion rate is expressed as an increase in corrosion depth per unit time in unit mg/cm² • h.

$$\text{Weight loss} = W_0 - W_f$$

$$W = \text{Weight loss}$$

$$W_0 = \text{Initial Weight}$$

$$A = \text{Surface Area of the Sample (in cm}^2\text{)}$$

$$W_f = \text{Final Weight}$$

$$T = \text{Time of Exposure of Sample (in hours)}$$

$$\text{Corrosion Rate} = \frac{(W)}{(A)(T)}$$

Data Analysis

The data gathered was analyzed and summarized using the following statistical analyses with the use of Statistical Package for the Social Sciences (SPSS).

Mean. This was used to summarize the weight loss and corrosion rate per treatment after the experiment.

Standard Deviation. This was used to indicate the homogeneity of the treatment's results.

One-way analysis of variance (ANOVA). This was used to determine the significant difference between the corrosion rate measured in different treatments.

Post Hoc Tukey HS Test. This was used to identify which treatment will significantly differ from other treatments.

All inferential analysis will be computed at $\alpha = 0.05$ level.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents the results obtained from the experiment conducted. It consists of the following parts: 1) Weight loss of mild steel bars and 2) the corrosion rate of each metal sample with their respective discussions and interpretations of the results.

Weight Loss

The researchers obtained the weight loss of each sample by subtracting the final weight from the initial weight after 24 hours of submerging the samples in a corrosive substance. The treatments include three *Phyllanthus amarus* leaf extract concentrations, a blank control (water), and a no-application. The mean and standard deviation for each treatment were calculated to analyze the consistency and variability of results.

The Blank Control (Water) exhibited the highest mean weight loss at 0.2067g, with a standard deviation of 0.0351g, indicating significant material degradation and variability in corrosion effects. The No Application condition had a lower weight loss compared to blank control, of 0.1600g (SD = 0.0100g). It suggests that water exposure accelerated corrosion compared to untreated samples.

Treatment 3(0.24012 g/mL) recorded the highest weight loss among the treated samples followed by Treatment 1(0.36018 g/mL) with slightly lower weight loss with a small standard deviation, indicating consistent results. Treatment 2(0.30015 g/mL) exhibited the lowest weight loss among the treated samples but had a higher standard deviation, suggesting more variability in the results.

These findings confirm that untreated samples corrode more rapidly compared to the treated ones based on their mean weight loss.

Table 4.1 Mean weight loss (in grams) of each sample 24 hours after being subjected to corrosive substance

Treatments	Replications			Treatment Total	Treatment Mean	Standard Deviation
	I	II	III			
0.36018 g/mL of <i>Phyllanthus amarus</i> leaf extract	0.05g	0.04g	0.04g	0.13g	0.0433g	0.0058g
0.30015 g/mL concentration of <i>Phyllanthus amarus</i> leaf extract	0.03g	0.05g	0.03g	0.11g	0.0367g	0.011g
0.24012 g/mL concentration of <i>Phyllanthus amarus</i> leaf extract	0.04g	0.06g	0.06g	0.16g	0.0533g	0.011g
Blank Control (Water)	0.21g	0.17g	0.24g	0.62g	0.2067g	0.0351g
No Application	0.16g	0.17g	0.15g	0.48g	0.16g	0.01g
Grand Total				1.80g		
Grand Mean					0.12g	

Corrosion Rate

The corrosion rate of each metal sample was obtained using its surface area, immersion time, and the recorded weight loss. The unit for the corrosion rate is in ($\text{mg}/\text{cm}^2 \cdot \text{h}$). Table 4.2 presents the corrosion rate of metal samples treated with different concentrations of *Phyllanthus amarus* leaf extract, alongside a blank control (water) and no application. The results indicate that the corrosion rate varies with the concentration of the extract, suggesting its potential as a corrosion inhibitor.

Among the treatments using *Phyllanthus amarus* leaf extract, Treatment 1 exhibited the lowest corrosion rate, followed closely by Treatment 2. Treatment 3 showed a slightly higher corrosion rate, indicating a gradual increase among the experimental treatments. In comparison, the No Application treatment resulted in a significantly higher corrosion rate, while the Blank Control (Water) recorded the highest mean corrosion rate. These findings demonstrate that metal samples corrode more rapidly in the absence of the *Phyllanthus amarus* extract, reinforcing its effectiveness as a potential corrosion inhibitor.

The Grand Mean ($0.3838 \text{ mg}/\text{cm}^2\text{oh}$) represents the average corrosion rate across all treatments. The high standard deviation observed in the Blank Control (0.1532) suggests greater variability in corrosion rates when no treatment is applied. On the other hand, treatments with *Phyllanthus amarus* had lower standard deviations, indicating more consistent corrosion inhibition.

Table 4.2 The corrosion rate of each metal sample in (mg/cm² • h)

Treatments	Replications			Treatment Total	Treatment Mean	Standard Deviation
	I	II	III			
0.36018 g/mL of <i>Phyllanthus amarus</i> leaf extract	0.189	0.158	0.140	0.487	0.1623	0.0248
0.30015 g/mL concentration of <i>Phyllanthus amarus</i> leaf extract	0.118	0.189	0.181	0.488	0.1627	0.0389
0.24012 g/mL <i>Phyllanthus amarus</i> leaf extract	0.151	0.237	0.227	0.615	0.2050	0.0457
Blank control (Water)	0.762	0.643	0.947	2.352	0.7840	0.1532
No Application	0.631	0.617	0.567	1.815	0.6050	0.0333
Grand Total				5.757		
Grand Mean					0.3838	

After making sure that the data gathered is in normal distribution, the corrosion rates were analyzed using one-way ANOVA as shown in table 4.3. The ANOVA results indicated a significant difference in corrosion rates among the different treatments, as

evidenced by the high F-value (43.931) and the extremely low significance value (Sig. = 0.000). The sum of squares between groups (1.017) is much higher than that of within groups (0.058), suggesting that the variations in corrosion rate are largely due to differences in treatments rather than random chance. The mean square for between groups (0.254) is significantly higher compared to within groups (0.006), reinforcing the strong impact of treatment on corrosion rate. Since the significance value is less than 0.05, we reject the null hypothesis, confirming that at least one treatment significantly differs from the others in its effect on corrosion.

Table 4.3 Statistical analysis of the corrosion rates using the one-way ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.017	4	.254	43.931	.000
Within Groups	.058	10	.006		
Total	1.075	14			

Tukey HSD post hoc test was undertaken since it was found in one-way ANOVA (Table 4.3) that there is a significant difference in the mean corrosion rates.

Table 4.4 revealed significant differences in corrosion rates among the treatments. Notably, treatments 4 (Blank Control) and 5 (No Application) show a statistically significant difference from treatments 1, 2, and 3 with p-values < 0.05, suggesting it has a unique impact compared to these treatments. However, no significant differences are observed among Treatments 1, 2, and 3 (p-values > 0.05), meaning their effects on corrosion rates are relatively similar. The 95% confidence intervals (CI) further support

these findings, as intervals for significant comparisons do not include zero, confirming meaningful differences. Overall, the results highlight treatments 5 and 4 as significantly different compared to the other three, having relatively higher corrosion rates, while the remaining treatments exhibit comparable results.

Table 4.4 Tukey HSD Post Hoc Test

(I) Treatments	(J) Treatments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.000333	.062116	1.000	-.20476	.20409
	3	-.042667	.062116	.955	-.24709	.16176
	4	-.621667*	.062116	.000	-.82609	-.41724
	5	-.442667*	.062116	.000	-.64709	-.23824
2	1	.000333	.062116	1.000	-.20409	.20476
	3	-.042333	.062116	.956	-.24676	.16209
	4	-.621333*	.062116	.000	-.82576	-.41691
	5	-.442333*	.062116	.000	-.64676	-.23791
3	1	.042667	.062116	.955	-.16176	.24709
	2	.042333	.062116	.956	-.16209	.24676
	4	-.579000*	.062116	.000	-.78343	-.37457
	5	-.400000*	.062116	.001	-.60443	-.19557

4	1	.621667*	.062116	.000	.41724	.82609
	2	.621333*	.062116	.000	.41691	.82576
	3	.579000*	.062116	.000	.37457	.78343
	5	.179000	.062116	.094	-.02543	.38343
5	1	.442667*	.062116	.000	.23824	.64709
	2	.442333*	.062116	.000	.23791	.64676
	3	.400000*	.062116	.001	.19557	.60443
	4	-.179000	.062116	.094	-.38343	.02543

CHAPTER V

SUMMARY, CONCLUSION, AND RECOMMENDATION

This chapter presents the summary of the whole study, the conclusions and recommendations based on the results gathered.

Summary

This study was conducted to find out the effectiveness of *Phyllanthus amarus* (Gale of the Wind) leaf extract as a natural corrosion inhibitor for metals in terms of corrosion rate. This study was conducted on February 10 - March 3 at Cabatuan National Comprehensive High School.

The *Phyllanthus amarus* leaves were manually picked at Brgy. Puyas, Cabatuan, Iloilo. Plant samples were sent to the Department of Agriculture, Cabatuan, Iloilo, for identification and verification. The *Phyllanthus amarus* leaves were manually plucked from the plant and then washed with clean water. They were ensured to be free from insect bites, discoloration, and mold infestation. The steel metal was bought at Balcarse

General Merchant Corp. and was ensured to be free from rust, discoloration, and other signs of corrosion.

The *Phyllanthus amarus* leaves underwent an ethanolic extraction method. There were five treatments in the study, and each was replicated thrice using a Completely Randomized Design (CRD). The treatments are as follows: 0.36018g/ml, 0.30015g/ml, and 0.24012g/ml concentration of *Phyllanthus amarus* leaf extract, blank control (water) and no application. The weight loss technique was used to determine the corrosion rate. The data was analyzed using the mean, standard deviation, one-way ANOVA, and Post Hoc Tukey HSD Test.

Results suggested that *Phyllanthus amarus* experimental treatments were significantly different compared to blank control and negative control; however, there is no significant difference between the *Phyllanthus amarus* experimental treatments (0.36018g/ml, 0.30015g/ml, and 0.24012g/ml concentrations), indicating that their corrosion rates are comparable.

Conclusion

Based on the results, *Phyllanthus amarus* leaf extract proved to be an effective natural corrosion inhibitor for metals. The varying concentrations of the extract successfully reduced corrosion rates. The one-way ANOVA analysis confirmed a significant difference in corrosion rates among the five treatments. The three experimental treatments exhibited comparable corrosion rates as they did not significantly differ from one another. However, their corrosion rates were significantly lower than those of the Blank Control and Negative Control, indicating the inhibitory effect of *Phyllanthus amarus* leaf extract on metal corrosion.

Recommendation

Based on the results of this study, the researchers recommend *Phyllanthus amarus* leaf extract as a natural corrosion inhibitor. To further investigate its effectiveness, they suggest testing the extract on different types of metals with varying compositions and using higher concentrations of the experimental treatments. Additionally, the researchers recommend employing Electrochemical Impedance Spectroscopy (EIS) and Potentiodynamic Polarization to obtain more precise measurements of the extract's inhibitory effects on metal corrosion.

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APPENDICES



Cabatuan National Comprehensive High School
SENIOR HIGH SCHOOL DEPARTMENT
Cabatuan, Iloilo

MONTH OF OCTOBER 2024						
SUN	MON	TUES	WED	THURS	FRI	SAT
		1	2 Working on Chapter 2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26



Cabatuan National Comprehensive High School
SENIOR HIGH SCHOOL DEPARTMENT
Cabatuan, Iloilo

MONTH OF DECEMBER 2024						
SUN	MON	TUES	WED	THURS	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28



Cabatuan National Comprehensive High School
SENIOR HIGH SCHOOL DEPARTMENT
 Cabatuan, Iloilo

MONTH OF FEBRUARY 2025						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2	3 Collecting, Washing, and Plucking of <i>Phyllanthus</i> <i>amarus</i>	4 Oven Drying of the <i>Phyllanthus</i> <i>amarus</i> leaves	5 Oven Drying of the <i>Phyllanthus</i> <i>amarus</i> leaves	6 Oven Drying of the <i>Phyllanthus</i> <i>amarus</i> leaves	7	8
9 Powderizing the dried <i>Phyllanthus</i> <i>amarus</i> leaves	10	11	12	13 Writing Formal Letter to the University of San Agustin for Rotary Evaporation	14	15
16 Ethanollic Exraction	17 Ethanollic Exraction	18 Ethanollic Exraction	19	20	21	22
23	24	25	26	27	28 Rotary Evaporation	



SENIOR HIGH SCHOOL DEPARTMENT
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MONTH OF NOVEMBER 2024						
SUN	MON	TUES	WED	THURS	FRI	SAT
					1	2
3	4	5	6	7 Working on Chapter 3	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30



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APPENDIX A

CALENDAR OF ACTIVITIES

MONTH OF AUGUST 2024						
SUN	MON	TUES	WED	THURS	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29 Formulating 5 Research Titles	30	31



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MONTH OF JANUARY 2025						
SUN	MON	TUES	WED	THURS	FRI	SAT
			1	2	3 Finalization of Research Proposal	4
5	6	7	8	9	10 D.A. Verification of <i>Phyllanthus amarus</i>	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28 Buying of the needed materials and chemicals like Ethanol and Acetone	29	30	31	



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MONTH OF SEPTEMBER 2024						
SUN	MON	TUES	WED	THURS	FRI	SAT
1	2	3	4	5	6 Finalizing chosen research topic	7
8	9	10	11	12	13	14
15	16	17 Working on chapter 1	18	19	20	21
22	23	24	25	26	27	28
29	30	31				



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MONTH OF MARCH 2025						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1 Experiment Process
2 Gathering of Data	3 Data Analysis	4	5	6	7	8 Working on Chapters 4 and 5
9	10	11 Final Research Defense	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					



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Cabatuan, Iloilo

APPENDIX B

EXPENDITURES

Materials	Quantity	Unit	Unit Price	Total Cost
Mild steel flat bar	1		₱150.00	₱150.00
Sodium Hydroxide	200	g	₱350.00	₱350.00
Acetone	400	mL	₱400.00	₱1,600.00
95% Ethanol	1	L	₱550.00	₱550.00
Carbon paper	2	pcs	₱10.00	₱20.00
Emery paper	2	pcs	₱35.00	₱70.00
29% Muriatic acid	1	L	₱104.00	₱104.00
Zinc dust	100	g	₱200.00	₱200.00
Filter paper	4	pcs	₱25.00	₱100.00
Distilled water	3	L	₱35.00	₱105.00
				₱3,249.00

Services	No. of hours	Unit Price	Total Cost
Facilities and Administration	2	₱1560.00	₱1560.00
Rotary evaporator	2	₱210.00	₱420.00



Cabatuan National Comprehensive High School
SENIOR HIGH SCHOOL DEPARTMENT
Cabatuan, Iloilo

APPENDIX D

COMPUTATIONS

A. Surface area of each metal sample

$$A = 2(lw * lh * wh)$$

Where: l – Length; w-width; h-height

Metal Samples	Length (cm)	Width (cm)	Height (cm)	Surface Area (cm ²)
T1R1	2.3	2.2	0.1	11.02
T1R2	2.2	2.2	0.1	10.56
T1R3	2.5	2.2	0.1	11.94
T2R1	2.2	2.2	0.1	10.56
T2R2	2.3	2.2	0.1	11.02
T2R3	2.4	2.2	0.1	11.48
T3R1	2.3	2.2	0.1	11.02
T3R2	2.2	2.2	0.1	10.56
T3R3	2.3	2.2	0.1	11.02
T4R1	2.4	2.2	0.1	11.48
T4R2	2.3	2.2	0.1	11.02
T4R3	2.2	2.2	0.1	10.56
T5R1	2.2	2.2	0.1	10.56
T5R2	2.4	2.2	0.1	11.48
T5R3	2.3	2.2	0.1	11.02

APPENDIX E
PICTORIALS



Plate 1. Gathering of *Phyllanthus amarus*

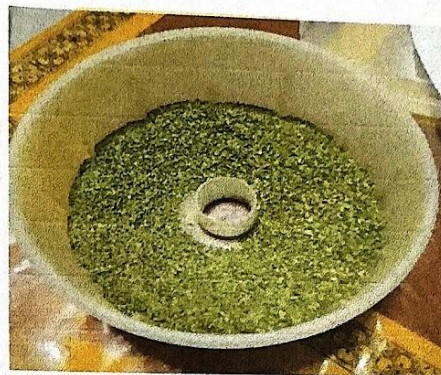


Plate 2. Powderized leaves of *Phyllanthus amarus*



Plate 3. Soaking of *Phyllanthus amarus* in 95% Ethanol



Plate 4. Filtration Process of the Mixture



Plate 5. Rotary Evaporation of the *Phyllanthus amarus* and Ethanol mixture



Plate 6. Preparation of the Mild Steel Flat Bars



Plate 7. Weighing of the Extract for the Formulation of Treatments



Plate 8. Degreasing the Mild Steel Flat Bar using Acetone

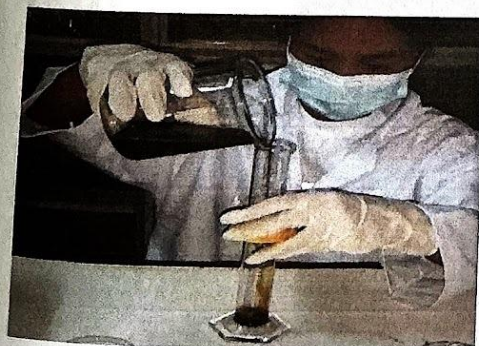


Plate 9. Formulation of Various Treatments



Plate 10. Weighing of each metal sample and measuring their Length, Width, and Height



Plate 11. Soaking of the Metal Samples to their Respective Treatments for 2 hours



Plate 12. Exposing the Metal Samples to 1M HCl for 24 hours



Plate 13. Formulation of the 20% NaOH solution

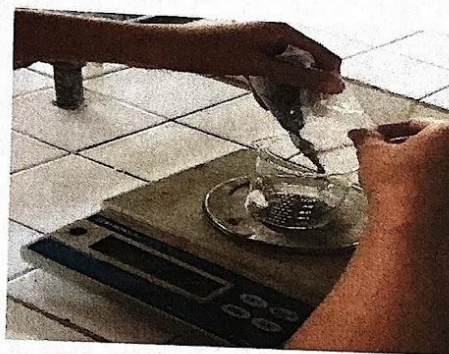


Plate 14. Preparation of the 100g Zinc Dust



Plate 15. Mixing the 20% NaOH solution and 100g of Zinc Dust



Plate 16. Washing the corroded Metal Samples using 100g of Zinc Dust in a 20% NaOH solution



Plate 11. Soaking of the Metal Samples to their Respective Treatments for 2 hours



Plate 12. Exposing the Metal Samples to 1M HCl for 24 hours



Plate 13. Formulation of the 20% NaOH solution

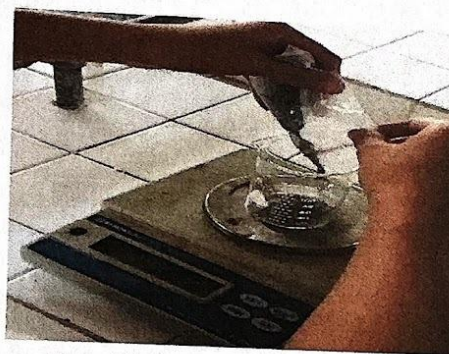


Plate 14. Preparation of the 100g Zinc Dust



Plate 15. Mixing the 20% NaOH solution and 100g of Zinc Dust



Plate 16. Washing the corroded Metal Samples using 100g of Zinc Dust in a 20% NaOH solution



Plate 17. Cleaning and Drying of each Metal Sample using Acetone



Plate 18. Reweighing each Metal Sample for the Final Weight