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Design and Development of Rocket Engine's Static Firing Test Stand of the Weather Rocket: Application of Finite Element Method

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Abstract

The DARE-TO research for weather rocket system for environment, atmospheric and weather observation use static testing to detect faults early, fix them rapidly, foresee errors, and solve bugs before they're coded. The most significant advantage of static testing is that it saves businesses time and money. This study compares two models of a rocket engine's static firing test stand, designed to withstand the average thrust force generated during testing. The models utilize an MS plate as an impact plate and were subjected to simulations using SOLIDWORKS software. The simulations assessed stress concentration, displacement movement, strain, and safety factors. The results indicate that Model A absorbs more stress and exhibits greater movement compared to Model B when subjected to the same load. Model B demonstrates higher stability and a lower risk of failure, as evidenced by a higher factor of safety throughout its structure. However, under the maximum applied force, Model B shows signs of reduced safety threshold and durability. Moreover, Model A approaches the maximum strain limit. Based on these findings, Model B is recommended as the preferred design for the Rocket Engine's Static Firing Test Stand due to its superior performance in stress absorption, movement resistance, strain limit, and safety factor distribution.

Keywords : Rocket motor stand, Rocket motor, Static test, Solid rocket motor, Finite Element Analysis

1. INTRODUCTION

The Philippine space program, which encompasses space research and development, is currently managed by the newly formed Philippine Space Agency (PHILSA) in collaboration with several departments within the Department of Science and Technology (DOST). Rockets are utilized to dispatch satellites and Space Shuttles into space. Their incredible motors allow rockets to be impacted by space at immeasurable velocities, putting them in the right circle. Holy Angel University was awarded a DARE TO (Discovery-Applied Research and Extension for Trans/Inter-disciplinary Opportunities) research grant by the Commission on Higher Education to design a weather rocket, but the rocket structure consists of a rocket engine. The rocket engine, on the other hand, is subjected to tests in facilities known as test remains before they are put into service. Given the importance of this type of testing, several critical questions arise: how well are these tests performed? How does the design survive the rocket thrust load? Are the measured metrics ascertained by these tests, such as temperature versus exposure time? What degree of certainty and confidence can be assigned to these metrics? And how do these metrics play into the decision-making of the Rocket DARE-TO researchers?

Figure 1 shows the typical rocket engine rocket engine's static firing test procedure made by NASA for The Marshall Space Flight Center at NASA tested a miniature solid rocket motor that was supposed to look like the Space Launch System Booster for the SLS solid rocket booster, this is a cost-effective and efficient technique to test a new nozzle insulating materials.
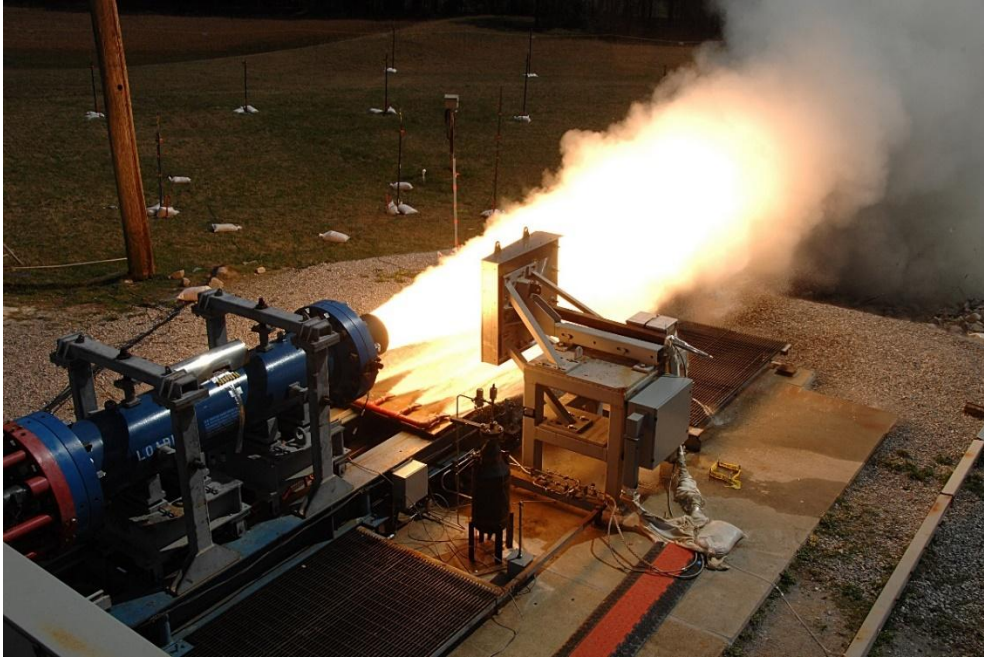
Figure 1 Typical rocket engine's static firing test procedure by NASA

The typical components for a rocket engine static stand are shown in figure 2. The main components are (1) the steel plate or the impact plate facing the rocket engine, where the thrust force is absorbed or resists the rocket engine thrust, and (2) the load cell. The load cell is an electronic component that sends signals to the DAS (Data Acquisition System) to measure the thrust force produced by the rocket engine. The (3) base plate serves to hold all the components of the design and to support the alignment of the (4) base angle, (5) pivot plate that holds the rocket engine (6), and the (7) support bracket that holds the steel plate. The RCS Motor stand specification is Maximum recommended thrust 2,000 lbs. or about 8.9 KN and Recommended maximum motor length 60".
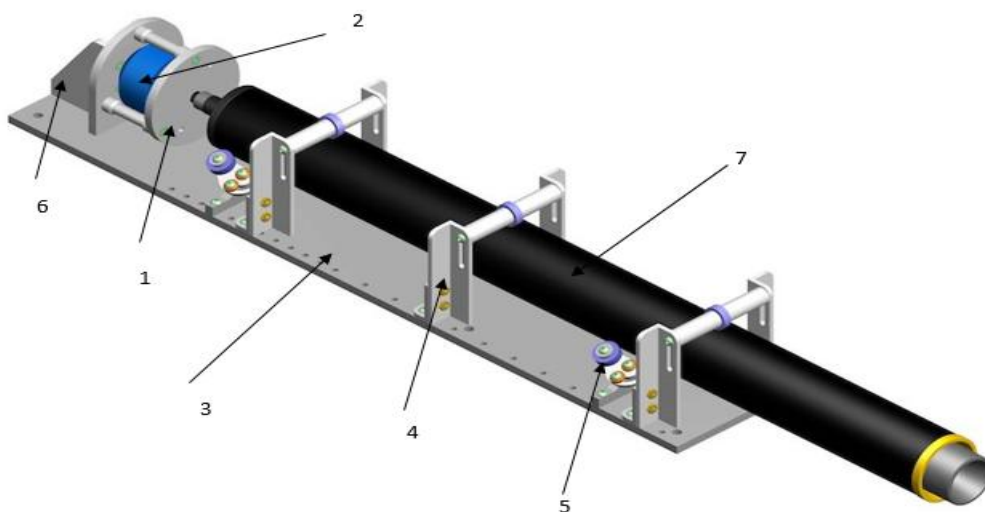
Figure 2 Typical rocket engine's static stand design by RCS Rocket Motor Components

For decades, the US Army's Redstone Test Center (RTC) conducted several static tests. The proposed design for the test stand is based on the "L" type RTC design in figure 3, but the problem is how to fabricate this kind of huge and heavy test stand if the static test is in a different area, and if the study is indoor, safety is based on the safety aspects of an indoor test stand, including the properties of acoustic noise on the test stand (Korting and Reitsma, 2012).
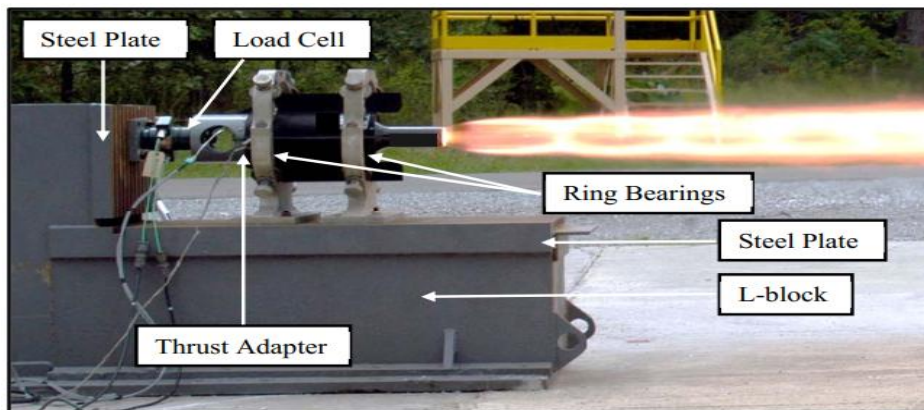
Figure 3 Test stand of Redstone Test Center

Texas A&M University created yet another design for a Lab-Scale Hybrid Rocket Test Stand. Figure 4 depicts the rocket test stand. Significant individual parts are featured, including the oxidizer and inactive gas solenoid valves, oxidizer and chamber pressure diagnostics, injector port, igniter, burning chamber, load cell, straight bearing get together, and remote-control box. The oxidizer stockpiling tank has not yet appeared. (J. Thomas, J. Stahl, G. Morrow & E. Petersen, 2016). The design was established to monitor the Hybrid Rocket motor characteristics and performance in a lab-scale model. A hypothetical half rocket model was created and used to estimate fuel grains, a burning chamber, injector, and spout. The ignition chamber can accommodate fuel grains ranging in length from 5 to 12 cm, with a starting ignition port breadth ranging from 2 to 20 mm.
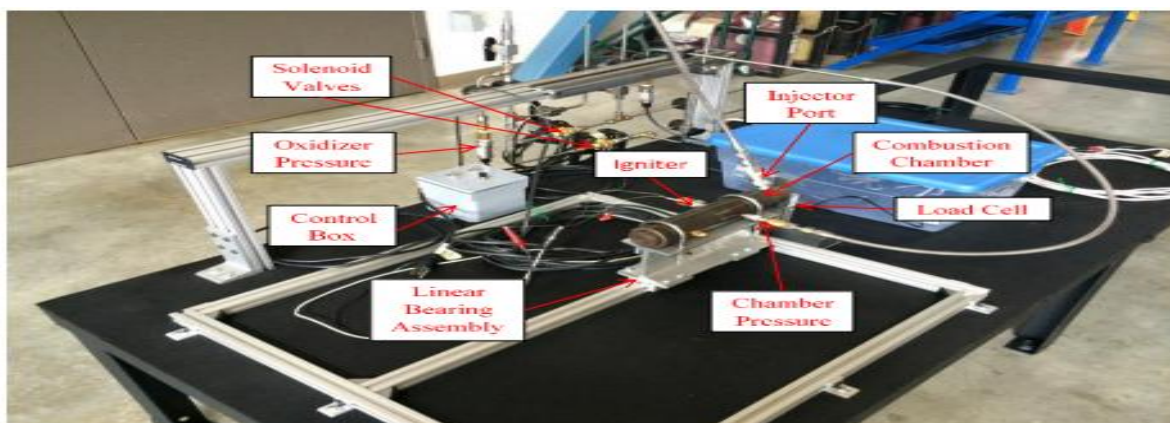
Figure 4 L-Block Static Fire Test Testing Methodology

The Data Acquisition System, which includes the load cell Rocket Motor used concentrically with the Strain Gauge Loadcell to measure thrust data, is an important aspect of the test stand. Knauber illustrated the effects that thrust misalignment, e.g., canted nozzle, has on a static test stand. Thrust, as defined by Webster, is "a forward-

directed force developed in a jet or rocket engine as a reaction to the rearward ejection of fuel gases at high velocities". A load cell is a type of transducer that converts a given thrust to an electrical signal that can be acquired, stored, and analyzed. The magnitude of the electrical signal generated by a load cell is directly proportional to the amount of thrust applied to its measurement element. The load cell measurement element. The work displayed right now is engaged in precisely estimating the conveyed push of a strong rocket engine as a component of time to distinguish changes in execution. These estimates are obtained through a static test that is still using load cells. The estimation vulnerability and dynamic reaction of the framework are the primary components of concern. Testing with different rocket motors varies with different thrusts so that the test stand can resist the thrust deployed by the force of the rocket.

In the Philippine rocket study, the current rocket motor stand does not provide wide knowledge, particularly in the presence of overall design optimization and without a foundation for material and simulation selection such as stress-strain analysis made by finite elements. Test stands are arranged in deciding the working parameters and reachable exhibitions of Propellants. A rocket motor static test area is where motors might be tried on the ground, under controlled conditions. A ground test program is commonly required before the motor is ensured for flight. Ground testing is modest in contrast with the expense of taking a chance with a whole strategic the lives of a flight team.

The problem is that locally available mild steel can be used in this design and what are the design parameters to resist the thrust force of the rocket motor to have significant data for the Holy Angel University Weather Rocket study? Additionally, there are a predetermined number of tests that can be tried, and both financing and test run time include some hidden costs. Rocket study is very expensive in terms of testing, so the design is to be tested through further studies, as the selection of materials and the subject for simulation. This work will intend to analyze the rocket engine test stand that represents the impact of a test for rocket engine prototypes, ROCKSIM simulation was used to verify up to 2,000 pounds of thrust force, which was compared to BURNSIM simulation and validated by NASA (Glenn Research Center Isentropic Flow and Mass Flow Calculator). To observe the ability of the structure to meet the demand safely.

The proposed two model designs are simplified models to optimize the selection of the material, reduce the material cost, and simulate the rocket engine's static firing test stand. This configuration can utilize both linear and static simulations. Unlike other rocket engine firing test stands that outsource design and purchase from other countries, the suggested design will only employ locally accessible materials that will be self-sustaining, can be used for a variety of motor sizes on a single platform, and can be deployed in a variety of test areas and for chemical composition verification. About the Philippine space program, the plan is to incorporate (HAU) Holy Angel University's school of Engineering and Architecture to support the Philippine Space Science Education Program (PESSAP) here in the province of Pampanga. To be specific, the DARE TO HAU ROCKET team will develop a weather rocket to observe the weather that aims to reach at least 7km in altitude with the use of two rockets of the same size as the main vehicle. Use both solid propellants of potassium nitrate and sugar.

The selection of material is a primary concern in this study, particularly the thrust plate, Material choice is a stage during the time spent planning any physical article. With regards to the item plans, the fundamental objective of material determination is to limit cost while meeting the item's execution objectives. Computation for material testing is based on the tensile strength of the materials. Tensile strength is defined as the maximum

load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material. The mechanical properties of metals are those that have to do with the material's ability to resist mechanical forces and burdens. Quality, solidity, flexibility, pliancy, pliability, fragility, pliability, strength, versatility, creep, and hardness is all mechanical properties of metal.

The choice of legitimate material for fabrication is one of the most troublesome issues for engineers. The best material is one that serves the ideal target at a reasonable cost. The accompanying elements ought to be considered while choosing the material: Availability of the materials, suitability of the materials for the working conditions in service, and the cost of the materials. Carbon steel is a type of mild steel that is commonly used in the Philippines. It is general-purpose carbon steel that is easily machined and welded and can be solidified through carburizing and other surface-solidifying techniques. This grade of steel may be welded by all normal methods: low-carbon electrodes are recommended. Mild steel is an iron and carbon-based ferrous metal. It's a low-cost material with qualities that make it suited for a wide range of technical tasks. Explicit assembling controls are utilized for surface planning, compound arrangement, rolling, and warming procedures. Each of these procedures results in an unrivaled quality item suitable for manufacturing procedures such as welding, producing, penetrating, machining, cold drawing, and warmth treating. According to research by Case et al. (1999), most engineering components fail due to stress. Stress analysis is an important part of engineering science also, Stress is a response to a force acting on a material's or object's unit area. When the force applied exceeds the object's capacity, an internal reaction will result in deformation or failure (Stress: Definition, Importance, Types, Examples, and Benefits, n.d.). The component under stress can range from the legs of an integrated circuit to the legs of an offshore drilling rig, or from the pressure hull of a submarine to the fuselage of a jumbo jet aircraft. To determine the stress absorbed in the structure, there are many techniques to assess the model. The basic principle behind this is stress analysis. Stress is calculated by dividing the force by the area of its generation, and because this area ("A") can be either sectional or axial, the basic stress formula is " $\sigma = F/A$ ". The combination of stress analysis, fatigue analysis, and accelerated durability testing yields an indicator of device structural reliability. Finite element analysis (FEA) on a high-performance computer system is commonly used for stress analysis and to find vulnerabilities in their design prototypes. FEA uses the finite element method (FEM) is a numerical approach for calculating the device's maximum stress and strain under specified boundary and loading conditions. The FEM includes verification and validation to establish the accuracy and credibility of the stress analysis results. The ASME standards committee's general guideline for FEM verification and validation is a valuable resource to consider when creating a device FEM verification and validation plan.

By breaking complex issues down into smaller, simpler pieces, Finite Element Analysis (FEA), a numerical technique, can solve difficult problems in engineering and physics. It is a computational technique that reduces physical systems or structures to their constituent finite parts in order to approximate their behavior. Each component is governed by mathematical equations based on the laws of physics and mechanics and represents a discrete fraction of the bigger system.

Structural analysis, heat transfer, fluid dynamics, electromagnetics, and other disciplines employ FEA extensively. When examining systems with complex geometries, material properties, and boundary conditions, it is especially helpful. Stress, strain, displacement, temperature distribution, and other characteristics can be calculated using

FEA by discretizing the system into smaller parts and simulating the behavior within each element.

To determine structural modes of a rocket engine's static firing test stand while varying equipment orientations Finite element analysis (FEA) is the strategy for utilizing virtual reproduction innovation to test how an item configuration responds to physical impacts, including twisting, heat, vibration, liquid streams, and different effects. With FEm reenactment devices, you can assess structures from the get-go in the planning cycle, figure out what will cause untimely disappointments, rapidly investigate configuration changes to lessen cost and weight, and decide the item's factor of security (Favato & Magalhãe, 2015). Finite element analysis is a powerful tool for engineers, particularly mechanical engineers, who use it to simulate physical models ranging from simple to complicated. In the engineering industry, there are many different forms of finite element analysis software, but a qualified mechanical engineer or FEM simulator should be familiar with at least one of these programs to produce accurate simulations of real-world engineering systems. In addition, the software that is chosen should be tailored to the researcher's profession. One of the software products certified by the Aerospace Standards Committee (NL) is Solidworks Simulation (Get the Facts about Simulation Accuracy, 2019). Holy Angel University's Mechanical Engineering department adopted Solidworks software in 2016, which includes 3D modeling and analysis, which was used to implement this study. SOLIDWORKS Simulation is an arrangement of investigation devices that utilizes FEM to foresee an item's true physical conduct by testing CAD models. The portfolio conveys straight, non-direct static and dynamic investigation arrangements isolated into three items: Simulation Standard, Simulation Professional, and Simulation Premium, every one of which adds simple to-utilize capacities to take care of perpetual testing issues. Some material testing incorporates a few methods, such as damaging testing to locate the attribute of a specific material characteristic. Testing on materials can be categorized as destructive or non-destructive. In destructive testing, a material sample is subjected to force until it fails or breaks. Non-destructive testing exerts force on the material sample but releases it before the substance is irreparably harmed (tec-science, 2018). The Universal Testing Machine can test different materials in a small example and not an entire machine plan, by measuring and analyzing the performance of raw materials and component parts under various compressive or tensile stresses, universal testing machines are used to assess the physical and mechanical qualities of raw materials and components. Simulation has a feature that can manipulate the entire machine design and predict the machine's weak spot so that it can be in numbers. Because mild steel is subject to testing for the thrust plate of the Test Stand, mild steel material is known for its adaptability; therefore, a stress examination must be conducted, and others must be included in the examination. In an experiment done by Alhassan et al., 2020, the mechanical characteristics of mild steel, galvanized iron, and stainless steel under tensile and flexural loading were examined.

2. Objectives

Since static testing is a significant job in rocket study, testing of rocket engines on a test stand centered on sway or the push sent by the rocket engine with the nearness of numerous structures to be thought about, for example, design support and choice of materials to be tried, the accompanying goals were made for the design of the test stand:

1. To design and simulate the rocket engine's static firing test stand using structural steel materials such as MS Steel Plate particular in the impact plate.
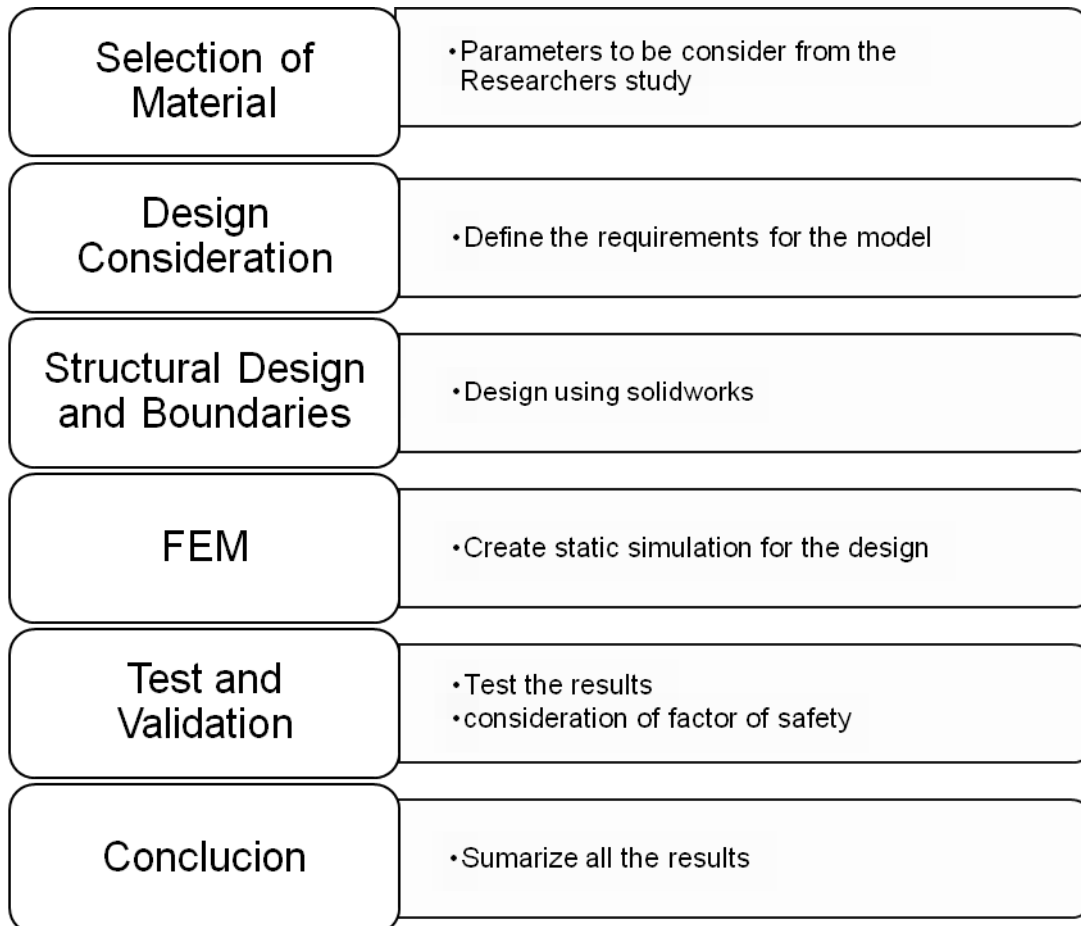
2. To test the structural behavior of the designed firing stand using finite element method against the pressing loads, displacement, and strain developed while the rocket engine was under static firing test and the temperature to which all components were exposed regarding the time of exposure.

3. To compare two model rocket test stand models' durability with the same condition and determine the model that best fits the requirement for the rocket engine's static firing test stand based on a factor of safety threshold.

3. Materials and methods

This section should provide enough detail to allow full replication of the study by suitably skilled investigators. Protocols for new methods should be included, but well-established protocols may simply be referenced. Simulation of the static test using the Finite Element Method was conducted for this study using Solid works: a.) design the rocket motor test stand to consider the rocket motor size and other parameters and b.) Finite Element Analysis is used to determine the stress plot and the natural frequencies of the rocket motor test stand to evaluate the impact force given by the rocket motor.

| Selection of Material | • Parameters to be consider from the Researchers study |
Design Consideration	• Define the requirements for the model
Structural Design and Boundaries	• Design using solidworks
FEM	• Create static simulation for the design
Test and Validation	• Test the results • consideration of factor of safety
Conclucion	• Sumarize all the results

Figure 5 a method for structural design and Analysis

The structural design and analysis of the Rocket Motor Test Stand have comprised of six (6) procedures, which are as follows:

A. **Hypothetical Approach for the Selection of Materials** The solutions presented in this research were obtained through considerations and hypotheses. The considerations were made due to the load's orientation applied to the structure and the boundary conditions. The hypothesis will be presented with a variation in the impact plate mounts' model and thickness. In materials science, the quality of a material is its capacity to resist an applied load without failure or deformation. The stress made by the thrust force can be calculated using the true stress applied to the load divided by the actual cross-sectional area (the changing area concerning time) of the specimen at that load. The load was applied to a load cell area.

Model A and Model B initial parameters are subject to calculation with free determined locally available mild steel materials. The stress and ultimate strength or maximum force of the material can resist without fracture. The formula is based on the strength of the material. The formula derived from the normal stress replaces the yield stress with the normal stress to calculate the maximum force applied to the plate, which is proportional to the product of yield stress and cross-sectional area. Maximum Force and Thickness of the Plate: to calculate the maximum Load, $P =$ yield stress $*$ Area $= \sigma * A$ and the Shearing Stress, $V =$ Thickness $*$ Area $= t * A$, where: σ, Stress in MPa, P, Thrust Force in N, shearing stress is caused by forces parallel to the area resisting the force. V, and A, Area of the impact plate in mm2. The rationale for the parameters in modeling SOLIDWORKS is that the cumulative load is compared to the thrust power of the rocket motor, and the measured maximum force must be greater than the estimated one, considering the Safety Factor as well.

B. Design Consideration The clamp of the rocket motor for the two models is based on the circumference of the normal diameter of the rocket motor of the Weather Rocket shown in figure 4 with a dimension of 127.5 millimeters. Another dimension is the 1000-millimeter length of the motor. The important thing to consider is the center-to-center position of the rocket motor in the load cell and how easy to install the said transducer. The thrust force estimated for the Aluminum 6061 rocket motor and mild steel rocket motor with solid propellant of potassium nitrate and sugar is based on the ROCKSIM software simulation, which was compared to the BURNSIM software simulation and certified by NASA (Glenn Research Center Isentropic Flow and Mass Flow Calculator). And Richard Nakka's parameter threshold for combustion temperature of 1260 °R to 1800 °R.
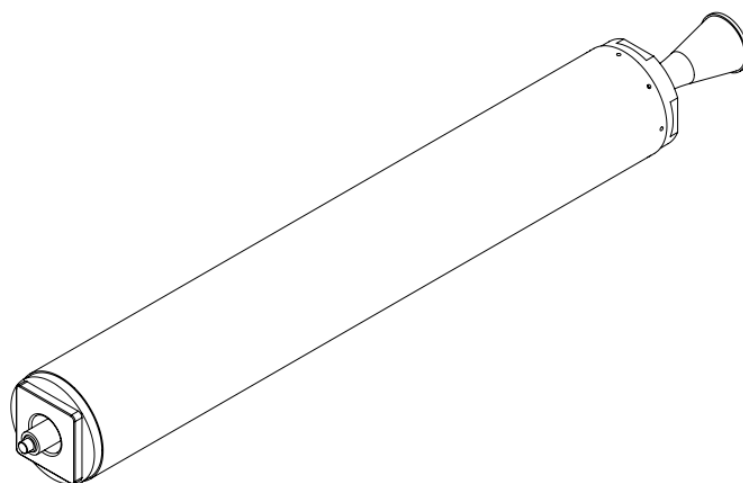
Figure 6 Typical Design for Rocket Engine

Before the main simulation for the rocket engine's static firing test, there was a simulation based on computed design parameters of the rocket that are in close agreement with the parameters and safety threshold. stated by a group of researchers, the HAU rocket team, using the same potassium nitrate and sucrose as a propellant. The characteristics of the manufacturers of such propellants have set the parameters and safety thresholds that are used as the basis for the computation of our parameters.
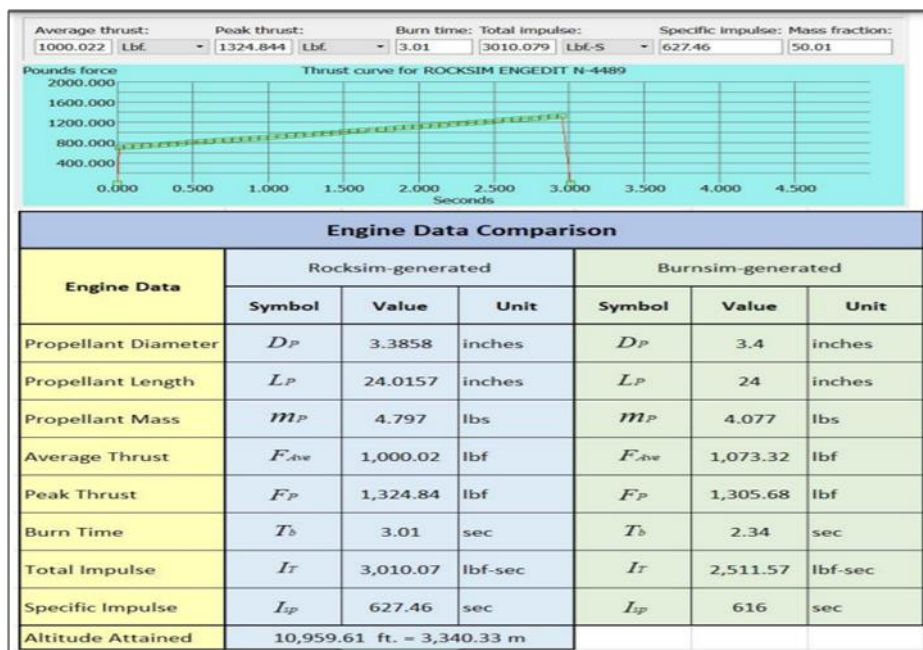

Figure 7 simulation parameters for weather Rocket.

In figure 7, the data from given potassium nitrate and sucrose as a propellant was verified using the ROCKSIM software simulation, which was compared to the BURNSIM software simulation and certified by NASA (Glenn Research Center Isentropic Flow and Mass Flow Calculator) was used to validate the results of the parameter computation. Mass Flow Rate, Weight Flow Rate, Pressure, Temperature, and Density Ratios, Expansion Ratio, and Mach Number are all in near agreement, if not identical. The threshold demand for the Weather rocket is Up to 2,000 lbs of thrust. The total impulse is 3,010.07 lbf-sec and 2,511.57 lbf-sec and the burn time are 3.01 sec and 2.34 sec. The actual simulated average thrust value from ROCKSIM and BURNSIM software are 1,000.02 and 1,305.68 lbs.

C. Structural Design and Boundaries

Figure 8 represents the Model A, which is made up of four (4) parts:(a) the impact plate is 18 mm thick for the thrust force, and where the load cell is installed, the impact plate is made of mild steel, specifically AISI 1020, and is welded to the test stand's base frame with an E6013 welding electrode. (b) The test stand's base is made of a beam with dimensions of 200 x 102 x 9 millimeters. The anchor nails connect the whole test stand to the ground and transfer different types of loads, i.e., tension forces and shear forces I beam is made from mild steel A36 ASTM. The welding process specification is full weld all around end connection using E6013, (c) the clamp for the rocket motor is made of mild steel, and the adjuster is perpendicular to the base to make the clamp center to center to the

load cell (d) the braces to support the whole model, braces made from 50.8 x 50.80 x 2 in millimeter angle bar is material, an angled shape with corners inside the radius, suitable for all structural applications.
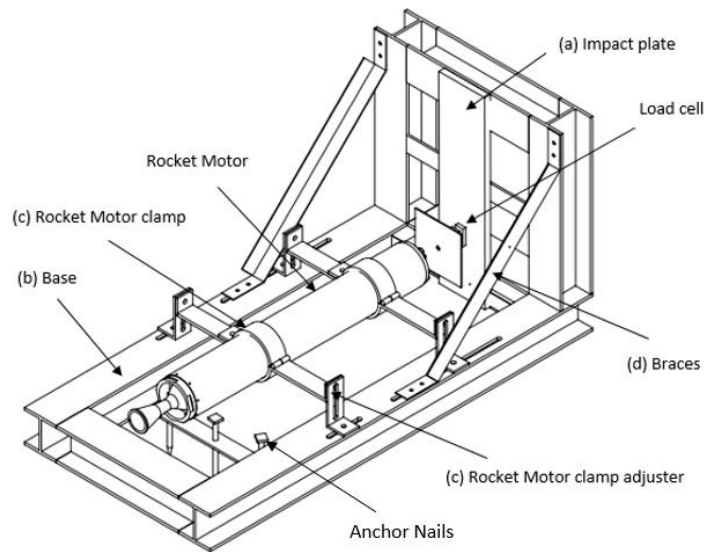
Figure 8 Design for Rocket Motor Static Firing Test Stand Model A
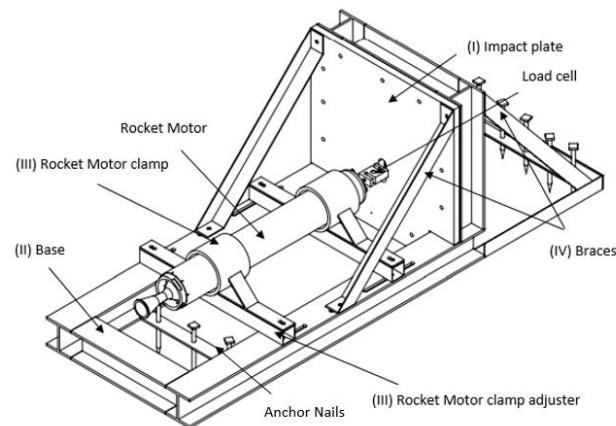
Figure 9 Design for Rocket Static Firing Test Stand Model B

The Model B Shown in figure 9 has the same frame and materials as Model A. The main difference is the impact plate thickness increased by 25 millimeters and bolted to the frame with 10 pieces of M12 x 1.50 x 75 mm. The clamp is made from A36 Seamless pipe (III) with 150 mm nominal diameter schedule 40 and 50mm x 50mm x 3mm square tube to center the motor in the load cell, an additional brace (IV) welded at the back of the impact plate to support the thrust force made of the rocket motor.

D. Finite Element Method

The computational methodology used was based on FEM, so it is segmented into determining the type of element, developing the mathematical model, executing the model discretization, and analyzing the results, to interpret the result precisely through the FEM solver. Figure 10 depicts the steps to be taken for the finite element analysis, with the CAD model created in SOLIDWORKS 3D model. Create a mesh, The finite element mesh is used to segment the CAD model into smaller domains known as components, over which a series of equations is solved. These equations represent approximately the leading equation of interest through a set of polynomial functions described for each element.

Figure 10 Finite Element Method Procedure

The discretization of the model was accomplished by 1D elements. The precision that can be achieved in any FEM model is directly related to the mesh used for finite elements. The mesh of finite elements is used to subdivide the CAD model into smaller domains called components, over which a series of equations is solved. Such equations represent the governing equation of interest roughly through a set of given polynomial functions over each variable. Apply boundary conditions; A Neumann boundary condition, also known as a second-type boundary condition, is one that determines the value of the function's normal derivative. For example, if a heater is attached to one end of an iron bar, energy is added at a steady rate, but the exact temperature is unknown. For this study, the heat produced by the engine is located at the end of the nozzle.

The factor to be included in the simulation is the maximum thrust load on the computation that generates the stress and temperature to the structure. The fixing screws and the engine mount were represented by one-dimensional elements. The plate type element should be used when one dimension, commonly known as thickness, is significantly smaller than the other dimensions. The mathematical model of the structure was discretized utilizing plate-type elements by this. A quadrilateral element, on the other hand, is a fuller and more refined element than a triangle element. Thus, the main element used to discretize the model will be the impact plate. However, at an almost negligible magnitude, it also used frame elements due to geometrical difficulties. The curvature mesh will be utilized to produce the finite element mesh and depicts the final mesh used for the analysis shown in this study. The maximum size of the element will be decided. Before arriving at this mesh, tests were run and meshes were constructed by changing the element sizes.

The researcher should also be aware of all the physics related to the problem, the properties of the materials, the loads, the constraints, and any elements that may affect the interesting results. For example, the properties of the material and the load may not always be understood precisely. During the modeling process, it is important to keep this in mind, as there is no benefit in trying to solve a model with greater accuracy than the input data allows it to be solved. The FEM solution is based on Von Mises. Von Mises's stress is a factor used to assess the yield or fracture of a given element. It is mostly used in ductile materials, for example, metals. Visualization and interpretation of results. The theory states that when the von Mises stress is equal to the stress limit, a ductile material begins to yield

at a spot. In most cases, the yield strength is used as the stress maximum. In addition to the considerations, the location of the loads and contains define the service environment of the model A and B, for each restriction or load defined on one or more entities, create a fixture or external loads such as the weight of the rocket engine and the temperature of the environment where the test is performed. The fixed elements that will be considered in the simulation study are represented by the anchor nails.

E. Test and Validation

For the hypothesis of loading in respect to the probable inclination of the thrust generated by the motor movement for Model A and Model B, a static linear structural simulation was used to compare the two models. Another possibility investigated was obtaining a curve variation of the highest Von-Mises stress for a load variation in the structure's worst loading condition in the Impact Plate and the rocket motor clamp. This hypothesis will be evaluated by exploring the behavior of the structure in a possible fracture. In the hypothesis for Model A & B, it was established that during the test there would be no problems with misalignment with the rocket motor test stand and the rocket motor mount assembly. Accordingly, the entire load was applied to the area of the load cell, and the distribution of the heat by the rocket engine also affected the whole design about time exposure. The setup is shown in Figure 11 for Models A and B.
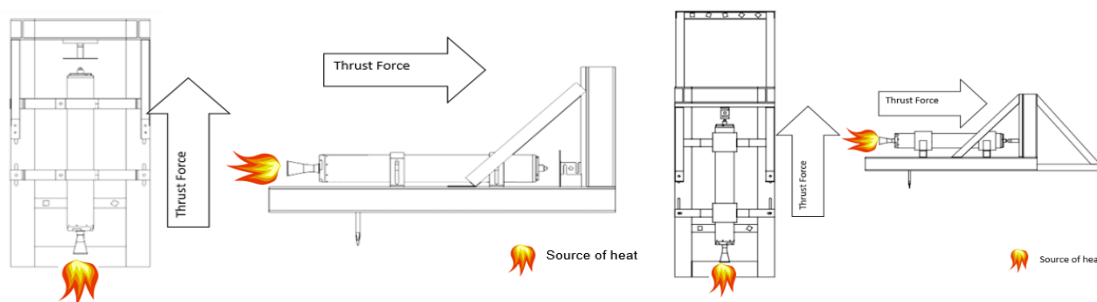
Figure 11: loading condition and heat generated for Model A & B

The modal analysis was carried out with boundary conditions in mind, looking at the degrees of freedom that were appropriate for the structural constraints. When it comes to the problem of failure, the strain is thought to be the most important. The force required to achieve strain increases as the modes of movement increase. As a result, if the strain is equal to or close to the material strain, and there is insufficient energy, the deformation will not occur. Based on the stress-strain diagram performed of the mild steel the fracture strain is 0.2.

For Model A, the impact plate of 18mm is welded to the base frame of the test stand using E6013 welding electrodes under condition loading variation up to 2,000 lb loads. For Model B, an additional brace is welded under condition loading variation of 2,000 lbf loads with an impact plate of 25 mm thick and bolted to the frame with 10 pieces of M12 Consider that the factor of safety is based on rule no. 10 of the Code of Mechanical Engineering Ethics in the Philippines, and an adaptation of the Philippine Society of Mechanical Engineers (PSME) code. The factor of safety for bolted and welded joints must be not less than 5 and a joint efficiency of 0.85 for both models. However, a factor of safety of less than one indicates a high probability of failure. The amount of stress that is within the allowable limit is represented by a factor of safety greater than one.

F. Conclusion

This is where the inference is drawn from the analyzed results, this is also the description of the research's key points. It also reveals the importance of the data examined and raises recommendations.

4. Results

The simulation applied to each model was based on the simulation of the propellant average trust. The actual simulated average thrust values from ROCKSIM and BURNSIM software were 1,000.02 and 1,305.68 lbs and the target thrust force of 2,000 lbs. The following figures are the actual simulated values for stress, displacement, and the factor of safety. Also, the maximum impact due to the maximum impulse was simulated.
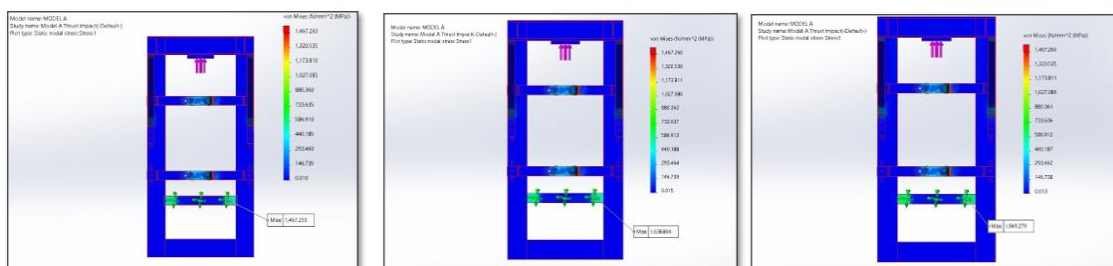
Figure 12 Stress simulated from Model A

The data from the simulated stress impacts of 1,000.02, 1,305.68, and 2,000 lb. force directly to the impact plate of an 18mm MS plate is colored violet arrow, and the boundary conditions assumed fixed are in color green arrow in Figure 12, and the maximum stress in Mpa was (a) 1,467.255, (b) 1,638.804, and (c) 1,949.279, respectively, and was primarily located at the anchor nail support. The heat generated at a combustion temperature of 1800 °R according to Richard Nakka's parameter threshold was simulated, and the heat was distributed centrally in the motor handle. temperature are all important elements in determining the mechanical characteristics of the metal. These characteristics work together to influence how the metal reacts to the stresses it encounters in operations.

The data from the simulated movement due to 1,000.02, 1,305.68, and 2,000 lb. force directly to the impact plate of an 18mm MS plate, colored violet arrow in Figure 13, the displacements are (a) 51.58, (b) 56.68, and (c) 65.49mm, respectively. The structure's movement, as well as the vibration of the impact, are highlighted in red and were determined to go right side and penetrate through the grounds due to the force directly to the impact plate.
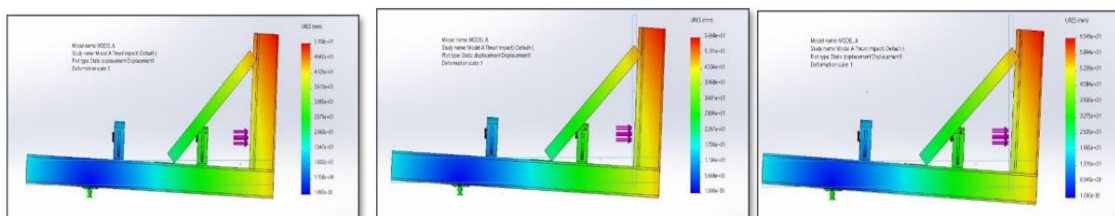
Figure 13 Model A movement due to force simulation

The data from the simulated stress impacts of 1,000.02, 1,305.68, and 2,000 lb. force was limited to the factor of safety (FOS) of 5, all colors light blue to red shown in

figure 14 is below the expected safety factor of 5 and the minimum factor of safety distribution are (a) 0.147, (b) 0.164 and (c) 0.124 respectively.
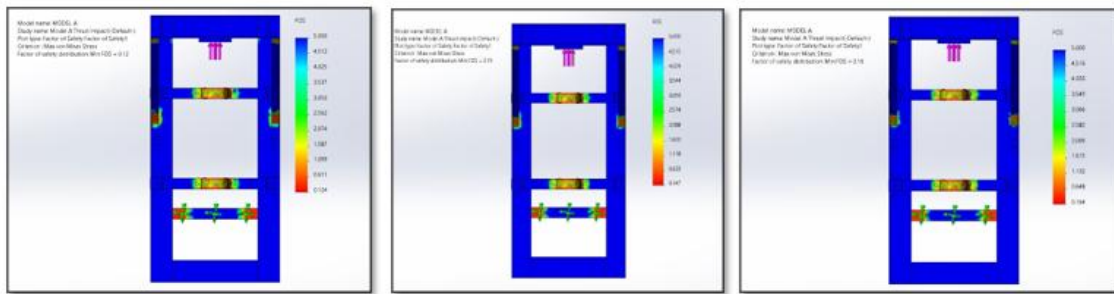
Figure 14 Model A's safety factor

The data from the simulated stress impacts of the same amount of force directly to the impact plate of a 25mm MS plate is colored violet arrow, and the boundary conditions assumed fixed are in color green arrow in Figure 15, and the maximum stress in Mpa was (a) 206.760, (b) 269.725, and (c) 420.982, respectively, and was primarily located at the braces back support.
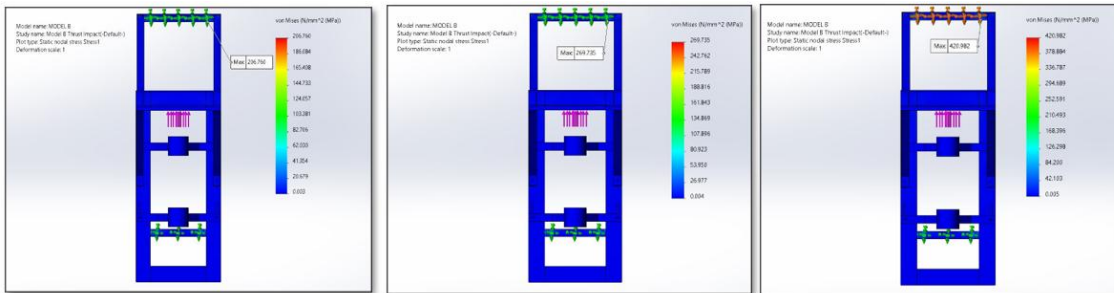
Figure 15 Stress simulated from Model B
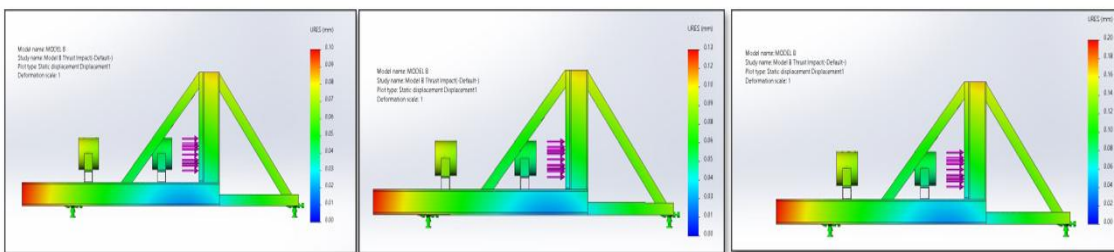
Figure 16 Model B movement due to force simulation

The data from the simulated stress impacts of the same amount of force directly to the impact plate of a 25mm MS plate is colored violet arrow, and the boundary conditions assumed fixed are in color green arrow in Figure 16, The movement of the structure can also the vibration of the impact are highlighted in the color red. The measurements are (a) 0.10, (b) 0.13 and (c) 0.20 respectively.
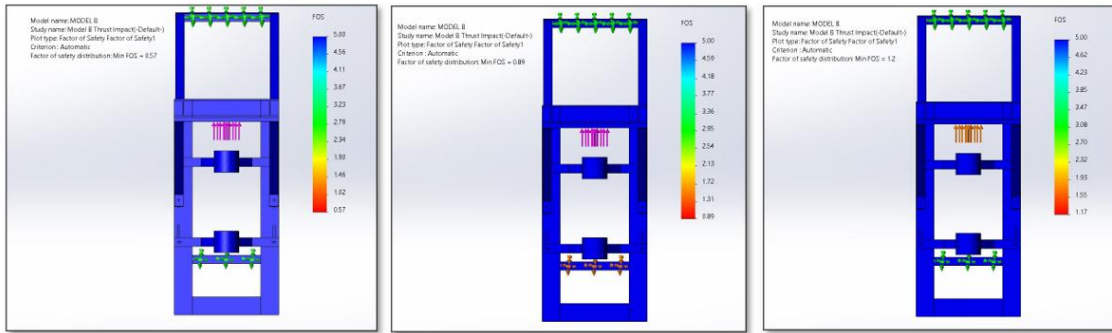
Figure 17 Model B's safety factor

The data from the simulated stress impacts with the same amount of force was limited to the factor of safety (FOS) of 5. All colors from light blue to red are below the expected safety factor of 5. All structures were simulated and above the considered factor of safety.

Table 1 Comparison for both models with same amount force simulated.

Model	Stress Mpa						FOS
	1,000lbf	1,306 lbf	2,000 lbf	1,000lbf	1,306 lbf	2,000 lbf	
Model A	1,467.25	1,638.80	1,949.279	51.58	56.68	65.49	0.164
Model B	206.760	269.725	420.982	0.10	0.13	0.20	1.17

Table 1 shows the comparison of the two models based on the same thrust force condition when the thrust force is applied. These values are estimated by the simulation of the solid work. They obtain the maximum stress at the main support for model A at the front, and for model B, they find the maximum stress at the back brace support. The vibration movement of structure model A or the displacement due to the impact of the thrust force is determined at the vertical platform where the 18 mm welded is shown in figure 13. The movement of the Model B structure due to the thrust force is negligible. However, there is movement or vibration that can be found in the structure that can affect the material behavior. This is found in Figure 16. Also, table 1 shows the specific factor of safety distribution shown in figures 14 and 17. A factor of safety of less than one indicates a high probability of failure. The amount of stress that is within the allowable limit is represented by a factor of safety greater than one. This shows that model A has a significantly lower FOS distribution than model B, which shows primary damage to the motor support and impact plate braces that can decrease the durability of the structure.

The durability of the two-model base on the maximum impact at the first second of the rocket motor was determined by the impulse of 3,501 lbf-sec and was loaded and simulated by both models; the force applied was 3,501 lbf-sec divided by 1 sec, which gave 3,501 lbs, and the green to red highlight in Figure 18 shows the safety factor of 5 being below the threshold. Also, the strain based on the material beginning to deform and decrease its durability was simulated through the maximum force in Figure 19. Model A has a 0.013, while Model B has a 0. 001. The peak strain for mild steel to begin to stretch and not go back to its original dimension is 0.02. Model A is close to the threshold in terms of strain.
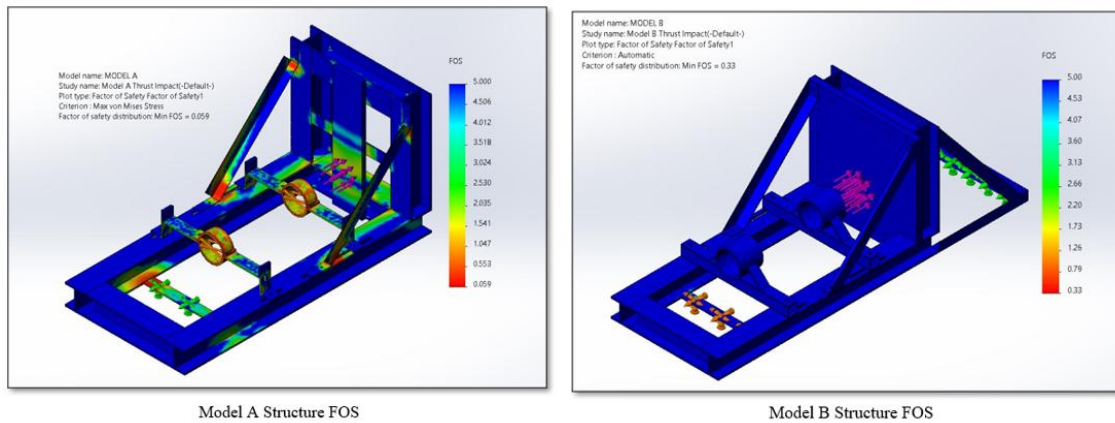
Figure 18 Factor of safety due to the impulse
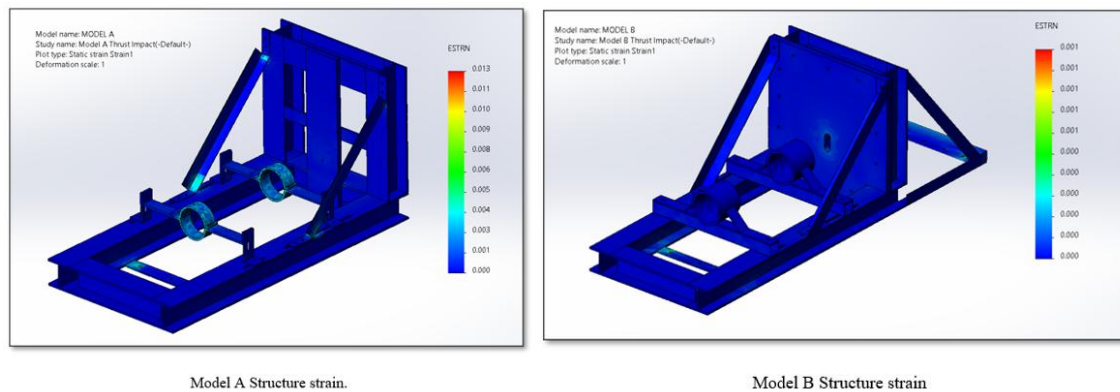
Figure 19 Strain due to the impulse

6. Conclusion

The two models were designed based on the rocket motor design parameters using an MS plate as the impact plate that can go through the average thrust force. The average thrust force was simulated using the ROCKSIM and BURNSIM tools, and the stress concentration was simulated using SOLIDWORKS by the finite element method, which can also affect the MS plate structure's vibration or displacement movement and strain. With the factor of safety data, this simulation shows that thrust events may be identified by a Von Mises stress, which is a value used to assess if a specific material would yield or fracture. The temperature also generated through the time of exposure can affect the safety threshold in the structure, particularly in the motor support.

Both models apply the same amount of force as determined by the structure's behavior. The stress absorbed is directly proportional to the MS Plate structure's force impact. When the force increases, the stress also increases. They obtain the maximum stress at the main support, for model A at the front support, and for model B, they find the maximum stress at the back brace support. With the results observed in Figures 12 and 15, analyzing the stress absorbed in both structures, the stress is highlighted in red. Model A has a red color highlight in its structure than Model B. This estimate that Model A has more stress absorbed than Model B based on the same load applied in Table 1. The movement based on figures 13 and 16, analyzing the displacement in both structures, determined that the movement caused by the applied force can also cause the vibration of

the structure. Movement occurs in parallel to the force acting on it from left to right and penetrates the ground. Model A has more movement than model B. The movement of Model B is negligible, and the numbers in Table 1 indicate that Model B is more stable than Model A when the force is applied. The safety threshold for both models is set at 5. Analyzing the FOS structure in Figures 14, 17, and 18, demonstrates that Model A has a lower FOS of 5 within its area than Model B, even though the Model B has a FOS of 5 for all its areas, which means that model B reduces the risk of failure of the structure more than model A. Also verified in figure 18, when applying the maximum force of 3,501 lbs. The Model B begins to have a specific red highlight in the back support braces. This is an indication of lowering the safety threshold of 5 and its durability. It also determined and justified the deformation in Figure 19. It shows the maximum strain in the material used was 0.02 and model A was close to the maximum strain consideration.

By comparison, based on the results, Model B is the recommended design for the Rocket Engine's Static Firing Test Stand based on the results of stress absorbed by the structure, the movement of the structure when the force is applied, the maximum strain, temperature absorbed in the time of exposure, and the factor of safety distribution measure threshold based on the finite element method.

For future fabrication ensure that all design parameters are considered for the fabrication and supervised by the designer and ensure that the testing site is monitored by a safety officer. The model configuration can add some fixtures to the model B structure. Based on the simulation, the movement of the structure is from left to right, or parallel to the rocket nozzle head. Additional weights at the back and front of the rocket engine's static firing test stand can reduce the movement of the structure.

7. Acknowledgements

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Correlation of Factors as Basis of Understanding Overheating of Induction Motors in Angeles Power Incorporated

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Abstract

In Angeles Power Inc., it was found out that the induction motors, that serve as pump drivers for the cooling system of its diesel gen sets have recorded high surface temperatures which is normally associated with high power consumption. To determine the possible cause of such high surface temperature, the operating condition of the motors were assessed by testing the various factors that may be observed as it operates. These factors include the quality of the input voltage, the quality of the induced current, the motor speed while carrying a load, and surface temperature when running under load. For safety purposes, the motors which operate at 440 V where not considered leaving the nozzle cooling motor the only motor for testing since it operates at 230 V. By setting up a simulation experiment focusing on the nozzle cooling motor, the different factors were measured and gathered. By calculating the correlation of these factors, it was found out that the probable cause of the increase in the surface temperature is the quality of the voltage supplied to the motor after the correlation between the two stood out among the other correlations of all the parameters considered in the study.

Keywords : Overheating, Induction Motors, Correlation, Voltage Unbalance, Surface Temperature

1. Introduction

Induction motors, the most common type of AC motors used in everyday applications, are mainly used in water pumps, kitchen appliances, fans and air conditioners, automobiles and common industrial machinery like boiler pumps and compressors. Though they are less efficient as compared to synchronous motors, this drawback is compromised by its simple construction which requires less maintenance. In addition, the flexibility of induction motors, according to Abdullah (2017), allows them to match the load demand for almost any type of electrical application.

In power generation, particularly in Diesel Power stations, one specific role of induction motors is to drive pumps which provide cooling to the peripherals of the engine. According to Chetwani (2005), induction motors are critical components in many power stations that is why the safety, reliability, efficiency, and performance of this motors should be given much attention.

It is normal for motors to heat up since all rotating electrical machines generate heat because of the electrical and mechanical losses inside the machine (Csanyi, 2011), but operating on high temperatures can harm electric motors (Bishop, 2013). Whenever heat is increased in the motor's periphery, particularly on the windings, copper loss will increase as well resulting to decline in efficiency. Aside from this, excessive heat also causes physical damage to the motor. This was further emphasized by Wiedenburg (2003) that the fundamental reason for the most common motor failures such as bearing and winding failures is excessive heat.

According to NEMA (National Electrical Manufacturer's Association), a motor can only operate within a specified temperature – this is known as the operating temperature. Operating temperature is the sum of the reference temperature, allowable temperature rise, allowance for "hot spot" winding. Allowable temperature rises are based upon a reference ambient temperature of 40 °C, which is the temperature of the air surrounding the motor.

NEMA specifies letter designations for motor insulation temperature ratings. These insulation temperature ratings are denoted as Class: A=105°C, B=130°C, F=155°C, and H=180°C. Further, NEMA specifies allowable temperature rises for motors at full load (and at service factor, if applicable).

Adding the NEMA allowable temperature rise of 105°C (for a Class F insulated, 1.0 S.F. motor), to the reference ambient temperature of 40°C, results in a total operating temperature for the motor of (105+40) = 145°C. The allowable temperature rises for motors are based upon a reference ambient temperature of 40 °C.

Operating temperature = ambient temperature + Allowable temperature rise   (1)
+ hot spot winding allowance

Motors are designed to operate in a maximum ambient temperature of 40 °C (McFadyen, 2013). "As a general rule of thumb, insulation life doubles for each 10° of unused insulation temperature capability. For example, if you design a motor to have a total temperature of 110°C (including ambient, rise, and hot spot allowance), but build it with a Class B (130°C) system, an unused capacity of 20°C exists. This extra margin raises the expected motor insulation life from 20,000 hr to 80,000 hr." (Cowern, 2002)

But on a different perspective, "The insulation life is cut in half for every 10 °C of additional heat to the windings. As an example, if a motor that would normally last 20 years in regular service is running 40 °C above rated temperature, the motor would have a life of about 1 year (Wiedenbrug, 2003).

In terms of heat loss, copper loss which varies directly with the value of the input current should also be accounted. It should also be considered that the resistance the stator windings may also increase if the surrounding temperature becomes high. This is mainly because of the friction within the machine and the ambient temperature. This is known as heat loss. From equation (2) if the resistance (R) increases, the copper loss will increase as well.

$$Copper\ Loss = 3\ x\ I^2\ x\ R \tag{2}$$

Aside from the effects of temperature, the quality of power supplied to the induction motors which is represented by the product of the current and voltage in the terminals of the motor should also be accounted. Since motors are built with windings of balanced impedances, it is important that they are supplied with balanced voltage and current.

According to the US Department of Energy, voltage unbalance has negative impact on the motor's performance and consequently shorten its life span. This is because voltage unbalance can cause current unbalance. This will then yield to torque pulsations, increased vibrations and mechanical stresses resulting to greater electrical and mechanical losses, and hence, lower efficiency.

Based on this article from IEEE, "Voltage unbalance takes place when the magnitudes of phase or line voltages are different and the phase angles differ from the balanced conditions, or both." This article presents the three mathematical definitions of

voltage unbalance by NEMA and IEEE in comparison with the True Definition which considers the effect of phase sequence. It was found out that the approximations formula by NEMA gives a good approximation to the true definition. The NEMA approximation formula, can therefore be used to calculate reliable data for determining voltage unbalance.

$$\%Voltage\ Unbalance = \frac{maximum\ voltage\ deviation\ from\ the\ average\ line\ voltage}{average\ line\ voltage} \qquad (3)$$

When motors are supplied with unbalance voltage, current unbalance will also follow. In reality, a perfectly voltage-balanced circuits are not possible as emphasized in the article, "Unbalanced Voltages and Electric Motors: Causes and Consequences". This why NEMA recommends a voltage unbalance of less than 1% when operating poly-phase motors.

With an unbalanced voltage supply, the induction motor's rotor temperature will increase and thus the losses as well. This will result to a greater drop in speed making the motor turn a little more slowly and do less work in each time. That speed drop is known as the 'slip' which is a good indicator on how well the motor is performing under load since it indicates how much speed was lost during its operation.

$$\%\ slip = \frac{synchronous\ speed - motor\ speed}{synchronous\ speed} \qquad (4)$$

Voltage unbalance is not constant and varies at some point depending on the use of equipment on a given instant e.g., lightings and welding machines, that is why the monitoring and data gathering must be done over a long period of time. Not only voltage unbalance must be monitored but all other factors that are relevant to the operation of induction motors.

Angeles Power Inc. (API), a diesel power plant with an installed capacity of 40 MVA serving as both substation and back-up power source for the Angeles city distribution system, has five generator sets with rated output of 5.3 to 5.5 MW, each driven with Diesel (Sulzer) engines with rated speed of 514 to 600 rpm. It makes use of induction motors as drivers for the pumps of the cooling system and heat exchanger for the operation of their Diesel (Sulzer) Gen-Sets. These induction motors are collectively known as auxiliary motors.

These auxiliary motors are located just a few feet away from the diesel engine, and as a result, the heat being exhausted on the diesel engine's body, which rises to 75 °C, affects the surrounding temperature of these auxiliary motors. These motors were observed to have exceeded their operating temperatures even though the ambient temperature is still way below 40 °C.

When the operating temperature was calculated by adding the body temperature, the winding temperature and the ambient temperature, the operating temperature for each motor was found to have exceeded their insulation capacity in the first hour. The operating temperature continued up until the fourth hour. This may cause damage to the windings. It may also lower its resistance causing higher copper loss resulting to lower efficiency.

According to the Electrical Maintenance Section at API, the current practice is that the motors are ensured to be operating in good condition (such as voltage, current, insulation, alignment) after they have undergone repair or reconditioning, and have had

been reinstalled. Since the diesel gen sets are on standby operation, the operation of these motors will also follow. During operations, an operator (known as the auxiliary tender) is tasked to roam around the auxiliary area on an hourly basis, ensuring that everything is operating well. But since there are no monitoring tools employed on the auxiliary motors, only visual inspection is practically being done.

With monitoring systems for induction motors yet to be integrated in API's current practice, no data is available as baseline data aside from the data gathered from April 9 to 24, 2018. With the use of a more recent data for factors such as temperature, voltage, current and speed; and analyzing them through correlation, the probable cause of overheating of induction motors at API may be identified.

2. Objectives

The main objective of this study is to establish a basis for understanding the overheating of induction motors in API through correlation of the input current, voltage, operating temperature, and motor speed. The study particularly aims to achieve the following:

1. Measure the input voltage and current, and motor speed of induction motors

2. Monitor the winding and surface temperature of motors in response to ambient temperature

3. Calculate the percent of voltage unbalance using the measured input voltage

4. Calculate the percent slip in synchronous speed of the induction motors

5. Assess the operational condition of the induction motor based on the percent of voltage unbalance, slip and operating temperature

6. Document current practice in managing abnormalities in current, voltage, operating temperature, and speed of motors.

7. Compare the current practice in managing abnormalities in current, voltage, operating temperature, and speed of motors to recommended standard practices

3. Materials and methods

INPUT

Line Voltage, x_1

%Voltage Unbalance, x_2

Line Current, x_3

%Current Unbalance, x_4

Ambient Temperature, x_5

Surface Temperature, x_6

Operating Temperature, x_7

Speed, x_8

%slip, x_9

PROCESS

Data Analysis: Multiple Correlation

OUTPUT

Relationship of the Different Factors
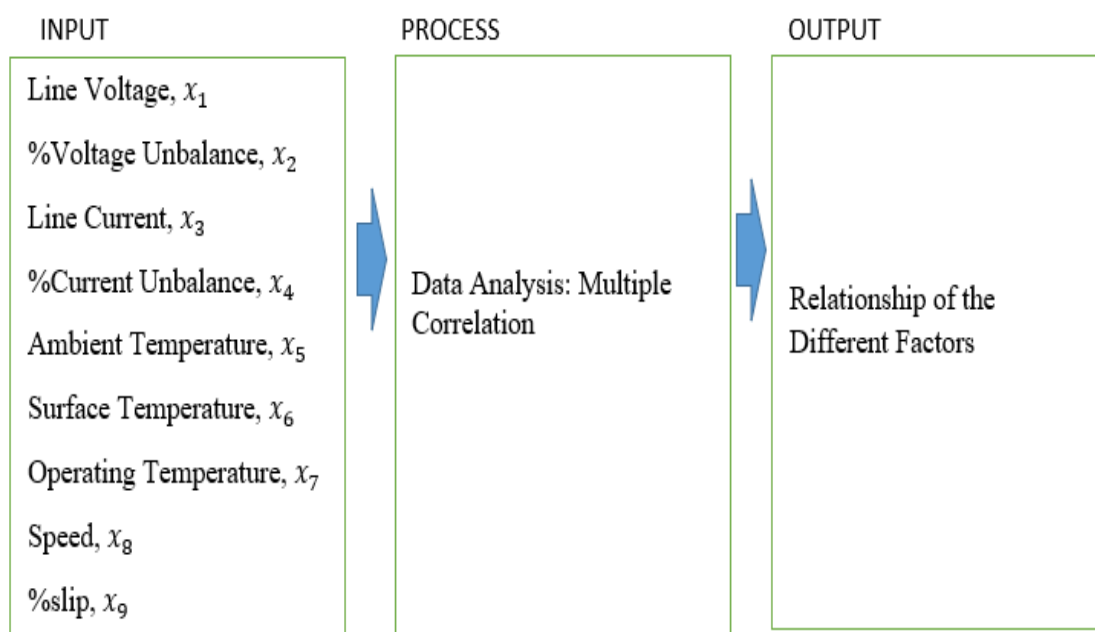
Figure 1 Conceptual Framework

The data on the x_1 and x_2, x_5, x_6 and x_8 were measured using appropriate instruments, while the $x_2, x_4, x_7,$ and x_9 were calculated. For data accuracy, the test was repeated several times on a given period. The environment of the test motor was controlled to simulate the operation of the actual nozzle cooling motor.

The x_8 was measured using a hand tachometer; a digital multimeter in AC Voltmeter mode was used to measure x_1; while a clamp ammeter was used to measure x_3. The x_5 and x_6 were measured using a thermal gun.

Experimental Set-up

A. Selection of Motor for Simulation

The AC motor for the simulated experiment was tested by running a light load to simulate that of a pump. When the chosen motor was initially tested, it ran at a speed of 1790 rpm at almost constant speed. There is difference in the ratings of the actual and the chosen test motor in terms of the input current, but everything else is identical. Since the %unbalance of the input current is more important than its magnitude, the said AC motor was chosen as the test motor for this study.

Table 1 Comparison of the Nameplate rating of the Test Motor and Nozzle Cooling Motor

Motor	Test Motor	Nozzle Cooling
Input Current per phase	5.10 A	10 A
Nominal Voltage	230 V	230 V
Power	2000 W	3000 W
Speed	1800 rpm	1800 rpm
Class	B	B

B. Setting the Load and Motor Speed

The nozzle cooling motor delivers mechanical power that will pump water to regulate the temperature of the nozzle of the fuel injector of the diesel engine. The said load will be simulated using an ac generator which is coupled to the shaft of the induction motor. Initially, the said set-up recorded an average speed of 1790 which is a bit higher than the average 1775 rpm from the actual nozzle cooling motors. Since there is no significant change in speed with reference to the speed of the nozzle cooling motors of units 3, 4 and 5 on the data gathered last April 2018, the load, and hence the speed of 1790 will be the reference speed and all significant changes will be considered.

C. Surrounding Temperature

The surrounding temperature was simulated by incandescent bulbs. Three incandescent bulbs were used to heat up the surrounding of the motor. The maximum temp was limited to 42 degrees Celsius which is the highest recorded surrounding temperature from the data gathered last April 2018. (See Appendix A)

D. Supply Voltage

The system voltage used for the simulation is practically the same system voltage in API. This is due to the fact that API, as a substation, has feeders which directly serves commercial, industrial and residential loads in Angeles city. The same feeder also serves

the Sacred Heart Building of HAU which houses the Electrical Engineering Laboratory where the experiment was conducted.

E. Measuring Instruments

The clamp ammeter, the tachometer and the Multimeters are all available in the Electrical Engineering Laboratory, while the thermal scanner was loaned from the Plasma Laboratory of the same university. This ensures that all measuring instruments are calibrated and are in good working condition.

Statistical Analysis

The nameplate of the motor under test is shown in Table 2.

Table 2 Nameplate rating of the Nozzle Cooling Motor

Input Current per phase	10 A
Nominal Voltage	220 V
Power	3000 W
Speed	1800 rpm
Class	B

The allowable slip for induction motors depends on their size. For class B motors, the allowable slip is from 5% to 6%. Exceeding the said value is an indicator that there is a probable misalignment, or that the motor is carrying more than its rated capacity.

For over/under voltage and Current, Z-test (at 95% level of confidence) was used to test if voltage and current are still within the rated value as reflected in the nameplate of the of the motor. An under/over voltage may indicate that the resistance of the windings and/or the supply voltage are not balanced. Such unbalance may affect the speed and output torque of the motor as well as the occurrence of more losses in the form of copper loss (see equation 2) since a relatively higher current will naturally flow on one phase. The voltage and current were expressed as average voltage and average current, respectively.

Using the values at the column for the average voltage, Z-test was performed with a null hypothesis that the mean of the voltages does not significantly differ from rated voltage of 220 V. As for the average current, Z-test was also performed with a null hypothesis that current does not vary significantly from the rated current of 10 A.

Rejection of both the null hypothesis may indicate that the winding resistance and/or the voltage of the supply might be unbalanced. This will cause unbalanced current to flow through the winding which may cause higher copper loss. Should both hypotheses yield a "do not reject" decision, it means that the motor is working on rated voltage and current. This is an indicator that the motor is in good working condition. If the two (2) test yield contrasting decisions, the motor should be subjected for monitoring to prevent further damage, accidents, and possible loss of productivity.

For the operating temperature, equation (1) was used. For a class B induction motor, the allowable operating temperature will be 130 degrees Celsius plus the reference ambient temperature of 40 degrees Celsius i.e., 170 degrees Celsius. Going beyond the operating temperature will cause damage to the insulation of the windings. This will eventually burn the wires until they become brittle and cause failure.

After testing the voltage, current, speed and temperature, the correlation of the said parameters was tested. All the factors were tested first if they are within normal range to come up with a reliable conclusion in their correlation.

Using data analysis, the Current and Voltage, Current and Surface Temperature, Current and Ambient Temperature, Voltage and Surface Temperature, Voltage and Ambient Temperature, Surface and Ambient Temperature, and % Current and % Voltage unbalance to the surface temperature, were all tested.

It is also important to note that the motor speed was not considered in the correlation since it remained constant for the duration of the test. This is because it was observed that the motor speed for the nozzle cooling motors were found to be constant as reflected in the data gathered on April 2018. (See appendix A)

For the percent slip, percent voltage unbalanced, and operating temperature, the following equations 4, 3 and 1 were used, respectively. For the voltage and current unbalance, the Philippine Distribution code recommends that the nozzle cooling motor is allowed to have a slip of 5% to 6% based on the NEMA table (see appendix K).

4. Results

Using the z -test with a null hypothesis that the average voltage is equal to 230 V at 95% level of confidence, the calculation returned a p-value of 0. Since the p-value is less than the level of significance of 5%, there is sufficient evidence that the average line voltage varies significantly from 230 V. The deviation from the rated voltage of 230 V is also evident in Figure 2.
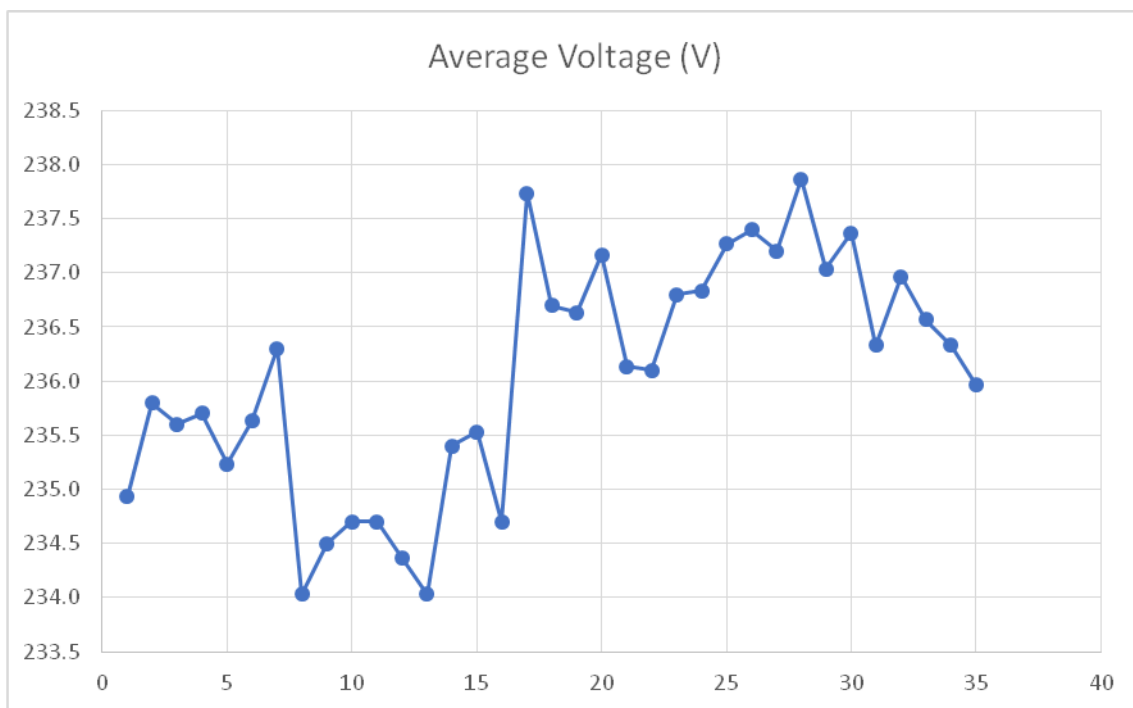
Figure 2 The graph of the average voltage per phase in each observation

The values of the measured current were also tested in the same manner as with the voltage, with a null hypothesis that the average value is equal to 5.1 A, also at 95% level of confidence. The p-value for this test was calculated to be 0.0007% which is lower than the

5% level of significance prompting for rejection of the null hypothesis. The deviation from the rated current of 5.1 A of the measured values can further be seen is Fig. 3.
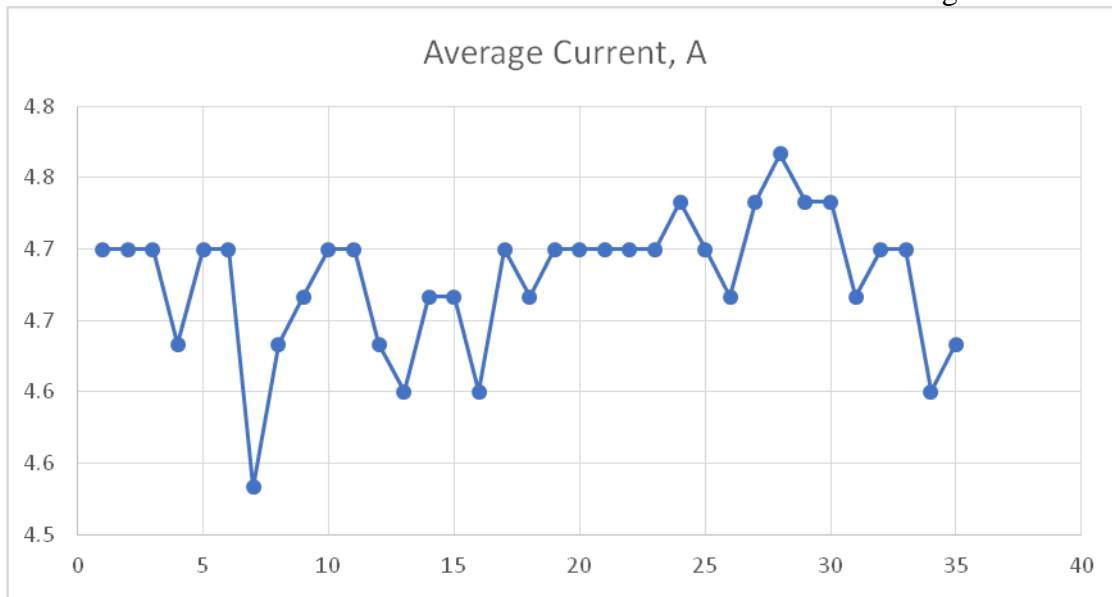
Figure 3 The graph of the average current per phase in each observation

Both tests on voltage and current indicated that the given set of voltage and current varies significantly from the rated values as seen in the nameplate of the motor. (See appendix C for test on voltage of motors and appendix D for test on current of motors). As for the slip, the calculated values indicate that the induction motor is operating at normal speed as seen in Appendix E.

As for temperature, there are no recorded instances of overheating as seen in Appendix F indicating that the operating temperature is within normal range. It can also be seen that all temperature readings started to pick up in the first three (3) observations as seen in Figure 4. This is normal for induction motors since it has just started operating and the surface temperature is expected to increase. It can also be observed that the ambient temperature and the surface temperature steadily increased until it becomes stable, and so is the operating temperature which is dependent on them.
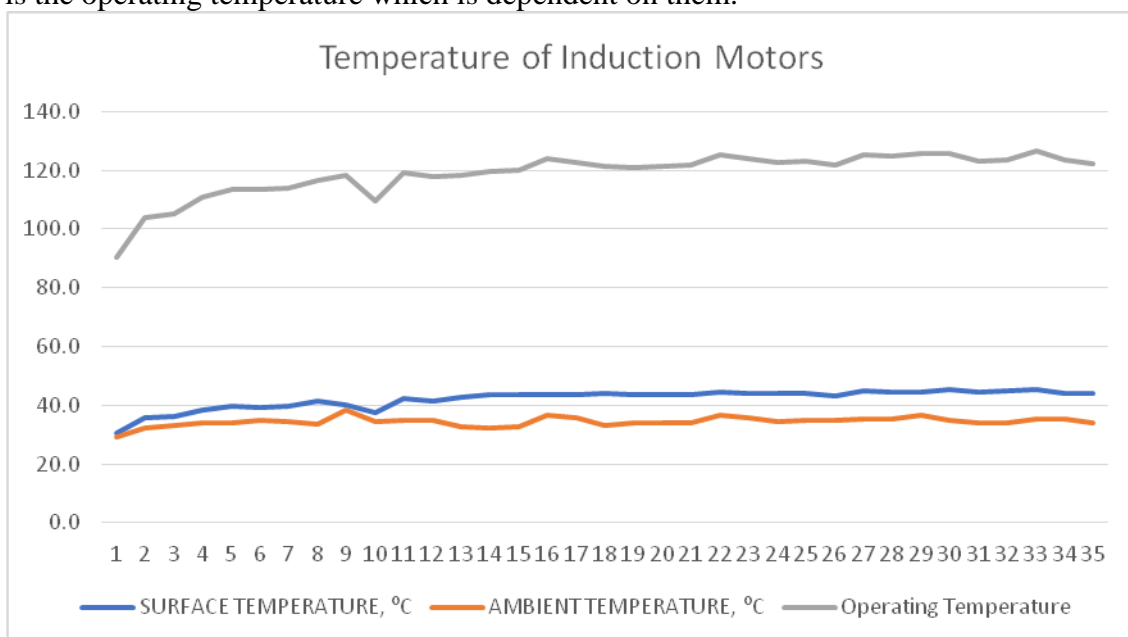
Figure 4 The graph of the Surface Temperature, Ambient Temperature and Operating Temperature

As for the voltage and current unbalance, the voltage was found to be balanced while the current shows a high level of current unbalance (See Appendix G). Although, the voltage and current of the motor are not within the rated value as seen in Appendix C and D, the correlation of the motor's voltage, current, surface temperature and ambient temperature was still calculated as reference for similar studies in the future. The result summary of the calculation of correlation coefficient is shown in the Table 3.

Table 3 Remarks on the correlation of Factors

Correlation	Coefficient	Remarks
Current and Voltage	0.468284657	Strong positive relationship
Current and Surface Temp	0.090605542	Negligible Relationship
Current and Ambient	0.100480588	Negligible Relationship
Voltage and Surface Temp	0.497049791	Strong positive relationship
Voltage and Ambient	0.222903401	Weak positive relationship
Surface and Ambient	0.495664433	Strong positive relationship
%Voltage Unbalance and Surface Temp	0.360583278	Moderate positive relationship
%Current Unbalance and Surface Temp	-0.365119886	Moderate negative relationship

When the correlation among x_1, x_2, x_3, x_4, x_5 and x_6 were calculated in Appendix H, it was found out that there is a strong positive relationship between x_1 and x_6; a moderate positive relationship between x_2 and x_6; and a moderate negative relationship between the x_4 and x_6.

5. Discussion

Since the slip is way lower as compared with the maximum allowable slip for that size of motor, the induction motor therefore is running in normal speed. As for the voltage, it is important that it is within normal range so as not to affect the current. By Ohm's law, the current will be directly proportional to the supply voltage since the resistance of the windings is said to be constant unless the temperature rises to a value more than it can handle. The probable cause of the value of voltage and current deviating from the normal range is the condition of the supply voltage, while the high %current unbalance may be attributed to the unequal resistances of the windings per phase of the machine. With varying resistance, there will be difference in induced current per phase as seen in Appendix B and Appendix D.

From the correlation of factors, the strong correlation of voltage and current is expected since they are directly proportional to each other. As for the current and surface temperature, Appendix H shows no correlation between them This is an indication that the motor is not having difficulty with the load it is carrying. If induction motors are carrying loads beyond their capacity, the tendency is that it will absorb more current and surface temperature will rise. Another data that will support this conclusion is that the slip is in normal condition.

The tests also shows that since no overheating was observed, the operating temperature of the motor is within normal range. Although appendix H indicates that there is a strong correlation on the surface and ambient temperature, it cannot be pointed out as

the cause for the latter since the surface temperature is higher than that of the ambient temperature. In this case, heating in the surface motor is not an indication of lower efficiency, but a manifestation of condition of the voltage being supplied to the machine i.e., the system voltage in the company. Appendix H shows that the correlation of the voltage, particularly its magnitude, and the surface temperature is a strong positive relationship.

6. Conclusion

Based on the tests and calculations performed, the motor was found to be operating in unbalanced system supply which adds to the chance of having a current unbalance regardless of having equal or unequal phase resistance. This agrees with one of the reviewed literatures in this study which is *Unbalanced Voltages and Electric Motors: Causes and Consequences*, which identified unbalanced supply as one of the causes of voltage unbalance in the motor operation.

According to the EMS of API, the auxiliary motors (such as the nozzle cooling motors) are usually operated with a spare motor of the same type so as not interrupt the operation since these motors are vital to the operation of the diesel gen sets. The EMS pulls out and reconditions motors whenever they have observed that there is abnormality. The reconditioning process include the dry cleaning of motors from dirt using solvents and compressed air, replacement of bearings, and checking of contacts and resistances. After reconditioning, the motors are reinstalled, coupled to its load and are aligned manually with the help of the dial gauge. The motor operation of the motor is tested by checking its rotation, the supply voltage, the resulting current, and the grounding. Once the motor has been properly aligned, the motor is run, and the voltage, current and speed are recorded. API follows the industry standard when it comes to installation and reconditioning of induction motors. The only difference is that the use of motor protection such as over and under voltage protections are yet to be integrated in the company's operation.

With the company being fully established in 1997 at a capacity of 30 MW and planning of expansion in the coming years, literatures emphasizing the importance of monitoring and installing protection for induction motors have always been available. Existing literatures include online monitoring by F.C. Trutt et. al. (2002), the use of PLC-based monitoring system by M.G. Ioannides (2004); the use PIC microcontroller-based motor monitoring system which protects the motor from abnormal voltage, current and temperature by M.A. Ayoade (2018); and setting up a wireless control and monitoring system for induction motors by VC Khairnar (2018) and S. Aher et. al (2017).

The quality of supply voltage should be checked because it directly affects the performance of the motors. The use of overvoltage protection will help to prolong the service life of the motors. The use of mechanisms or devices that will help correct or reduce the voltage unbalance can also be considered. Lastly, the company might also consider the balancing of single-phase loads to correct the existing voltage unbalance, as suggested in the literature, *Unbalanced Voltages and Electric Motors: Causes and Consequences*.

API has been installing and reconditioning induction motors based on industry standard as discussed earlier, except for the utilization of monitoring systems such as those mentioned in the literatures. Aside from those, there commercially available devices that may serve the purpose of monitoring and protecting the motor, and hence the operation, which can easily be integrated or installed. The company may also seek the help of

researchers to come up with a monitoring and protection scheme that will fit the needs of the company's operation.

As for research, it is recommended to perform observations with cooling system for the area of the motors considered. The same test can also be performed on larger induction motors, but preferably in the actual site instead of simulated experiments.

7. Acknowledgements

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9. Appendices

Appendix A. Reference Data Gathered in API from April 9, 2018 to April 24, 2018

Appendix B. Data Gathered in Simulated Experiment

Appendix C. Testing the hypothesis that the voltage is significantly different from 230 V using Excel

Appendix D. Testing the hypothesis that the current is significantly different from 5.1 A using Excel

Appendix E. Testing Slip of the induction motor if it is less than 5-6%

Appendix F. Calculation and Testing of Operating Temperature using Excel

Appendix G. % Voltage and Current Unbalance

Appendix H. Calculating the Correlation of the Factors using Excel

Appendix I. Setting up the Simulated Experiment

Appendix J. Equations relevant to the study

Appendix K. NEMA Temperature Ratings for Induction Motors

10. Author's Biodata

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Exploration of Regulating and Accrediting Bodies' Standards: Basis for an Internal Accreditation Framework for Engineering Programs

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Abstract

Accreditation requires higher education institutions (HEIs) to demonstrate that they have procedures in place to ensure that the program is consistently improved. The issuance of memoranda by the Commission on Higher Education (CHED) related to outcomes-based education (OBE) leads the preparation of higher education institutions for international accreditation. Majority of private HEIs with engineering programs in the Cordillera Administrative Region struggle to achieve accreditation requirements. The study explored accreditation standards as basis for the development of an internal accreditation framework. The study employed concurrent mixed-method in the development of the internal accreditation framework for private higher education institutions with engineering programs in the Cordillera Administrative Region. Purposive sampling was used in the selection of participating institutions and respondents. The common standards of accrediting bodies for engineering reflect the requirements in the implementation of outcomes-based education. While there is a very high extent of OBE implementation for document accessibility, HEIs face challenges when it comes to evidence documentation. The factors affecting the accreditation status of private HEIs with engineering programs are related to outcomes-based education, faculty requirement, resources, and licensure examination. The low percentage of accredited engineering programs implies that few higher education institutions are compliant to regulatory and accreditation requirements. The internal accreditation framework introduces internal review and monitoring mechanism for the preparation of accreditation documents. It is recommended that HEIs devise strategies to actively address concurrent accreditation deficiencies.

Keywords : accreditation, outcomes-based education, internal review, framework, quality assurance

Introduction

The International Engineering Alliance (IEA) educational accord outlined educational standards for mutual recognition of educational standards by its member signatories. Educational accords establish and enforce standards for engineering education with expected competence in engineering practice (International Engineering Alliance (IEA), 2021). Membership in the IEA educational accord entails a domestic accreditation system that conforms to standards in providing professional competence to engineering graduates. Conditions for membership in a Mutual Recognition Agreement (MRA), also known as an accord, include a) ongoing profession-controlled domestic accreditation system, b) recognition or authorization of operating status from a national education agency, and c) representation of professions in its governance. An MRA from a home country to a host country allows the international practice of engineers (Trevelyan, 2016).

The Washington Accord of the International Engineering Alliance in engineering programs and technology internationally recognizes tertiary-level engineering

qualifications. Membership in WA expedites the review of academic credentials from one party by the regulatory body of another party (IEA, 2021).

The Philippines' Commission on Higher Education (CHED) issued several memoranda to promote quality assurance and adherence to international standards. CHED memorandum order (CMO) number 37 series of 2012 focused on establishing an outcomes-based education (OBE) system in engineering programs to meet the demands of global equivalency of quality standards and promote continuous quality improvement. CMO #46 series of 2012 stressed an outcome- based quality assurance system to differentiate the type of higher education institution (HEI) with the inclusion of accreditation for vertical typology.

Marcos et al. (2020) emphasized that engineers must strengthen global competencies acquired from academic training and understanding the job's needs. The attributes of an engineer include strong analytical skills, practical ingenuity, creativity, communication, business and management, leadership, high ethical standards, professionalism, dynamism, agility, resilience, flexibility, and being lifelong learners (Beagon et al., 2019).

CHED authorized the Federation of Accrediting Agencies of the Philippines (FAAP) to certify the quality levels of accredited programs at the tertiary level. FAAP accreditation aids HEIs to qualify their status in a) horizontal typology, b) vertical typology, c) center of excellence, and d) center of development. The accrediting agencies of FAAP for private engineering universities include a) Philippine Accrediting Association of Schools, Colleges, and Universities (PAASCU) and b) Philippine Association of Colleges and Universities Commission on Accreditation (PACUCOA). The areas of accreditation include a) mission, goals, and objectives, b) faculty, c) curriculum and instruction, d) students, e) research, f) extension and community involvement, g) library, h) physical facilities, i) laboratories, and j) administration (Tansinsin, 2020).

The Philippine Technological Council (PTC) is the umbrella organization of professional engineering organizations in the country. It acts as the focal point for international linkages and the promotion of the global competitiveness of Filipino engineers (PTC, 2017). PTC represented the Philippines as a provisional signatory in the Washington Accord in 2013. The domestic accreditation of PTC is through its Accreditation and Certification Board for Engineering and Technology (ACBET). PTC-ACBET accredits engineering programs with reference to standard guidelines of the Washington Accord. The PTC is also endorsed by the Commission on Higher Education (CHED) as the sole organization for the accreditation of engineering programs through CMO #37 series of 2012.

The Commission on Higher Education reinforced CMO #37 series of 2012 through the release of CMO #46 series of 2012, which mandated the higher education system to produce globally competitive graduates. CMO #46 series of 2012 demands that higher educational institutions meet widely used national and international standards. CMO #17 series of 2015 integrated the shift to outcomes-based education, typology, and outcomes-based quality assurance in implementing guidelines for selecting engineering center of excellence and center of development.

In the Philippines, only 28.77% (677) of HEIs of the 2353 total number of HEIs qualify the minimum standards set by public and private accrediting agencies in the Philippines. In alignment with international accreditation, only 0.34% (8) have PTC ACBET Accredited Engineering Programs of the 28.77% (677) accredited HEIs qualify

for full PTC-ACBET accreditation, while 0.47% (11) qualify for PTC-ACBET of partial accreditation. Only one of the 14 HEIs in the Cordillera Administrative Region, Benguet, Philippines had program accreditation by PTC-ACBET (PTC, 2017).

Accreditation is a stamp that an academic institution undergoes evaluation, complies with the minimum requirements, and assist in improving the quality of the academic program (Rashideh et al., 2020). Institutions with traditional engineering curricula face difficulties in meeting accreditation requirements leading to deferred or declined accreditation. Last-minute preparations for accreditation lead to failure, while systematic preparation ensures successful accreditation (Al-obaidi, 2021). Qadir et al. (2020) stressed that accreditation results in a better quality of education, professional preparation, and professional practice.

Conceptual Framework

A paradigm shift in engineering education is driven by rapid industry expectations and learning pedagogy changes. A new approach to engineering education and practices must promote the learners' life-long learning. The emphasis of paradigm shift is laid on learning and working together to develop and innovate skills such as critical thinking, creativity, communication, user orientation, and teamwork. The shift in education systems plays a vital role in recognizing the essential role of learning institutions in the training of graduates to be innovative in the practice of the profession (Kalman, 2012). According to industry, students with hands-on learning experience are quicker to adapt to the workplace environment (Baltimore & Mwangi, 2015).

Outcomes-based education (OBE) is a paradigm shift from traditional learning approaches to student-centered learning approaches with competitive assessment (Macayan, 2017). Outcomes- based education focuses on attaining intended student outcomes that students can achieve at the end of a course, at the end of the program, and within a few years after graduation. The paradigm shift to OBE challenged the curriculum offering of HEIs for global competitiveness. Institutions significantly shifted to OBE to be globally competitive.

CMO #37 series of 2012 pursued to transform engineering education into an outcomes-based system to meet the demands of global equivalency and quality standards in engineering programs and to promote continuous quality improvement. It mandated all higher education institutions to shift to the OBE system and submit monitoring requirements of CHED. The OBE system implementation shall be aligned to the accreditation criteria set forth by PTC-ACBET. Concerned HEIs shall ensure the sustainable delivery of an OBE system with an institutional framework.

Quality assurance ensures the existence of mechanisms, procedures, and processes to ensure the delivery of quality outcomes, either internal or external. An internal quality assurance system of an HEI can be used for a) the translation of learning outcomes, b) the implementation of teaching-learning systems, c) the review of performance indicators and standards in the assessment system, and d) program enhancement. An external quality assurance system can be through accrediting agencies. Quality assurance can be carried out by external agencies such as CHED and other accrediting bodies. This calls for accreditation bodies to retrofit towards outcomes-based accreditation (Tansinsin, 2020).
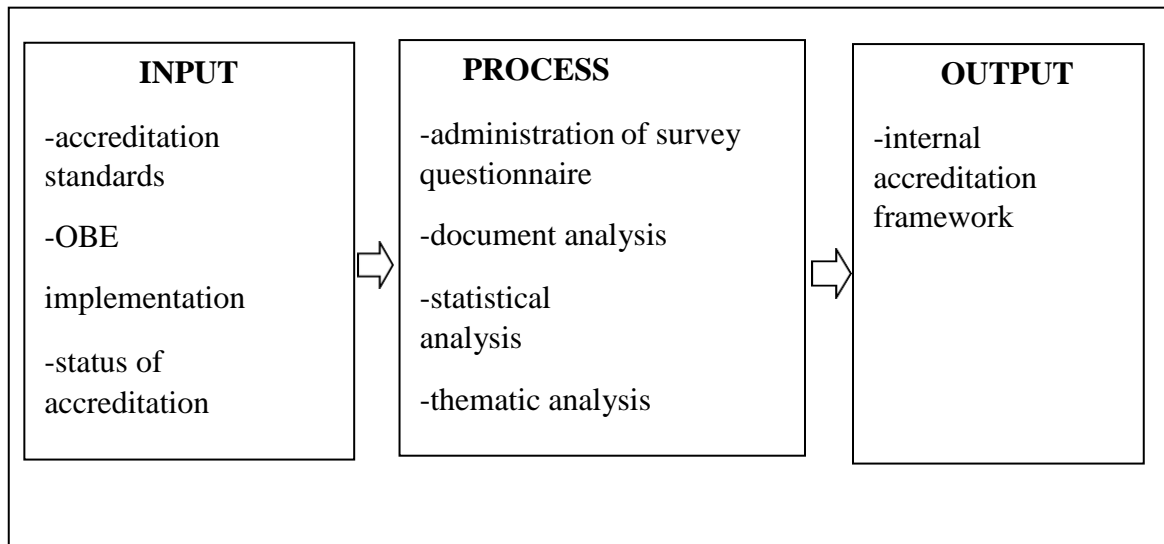
CHED released a series of memoranda for engineering programs in 2017 that mandated HEIs to shift to an outcomes-based approach in the program delivery and adapt global requirements of the engineering profession. Implementing outcomes-based education (OBE) in the engineering program curricula is a minimum requirement for WA

accreditation (Anwar & Richards, 2017).

The paradigm of the study is shown in Figure 1.

Figure 1

INPUT	PROCESS	OUTPUT
-accreditation standards -OBE implementation -status of accreditation	-administration of survey questionnaire -document analysis -statistical analysis -thematic analysis	-internal accreditation framework

Paradigm of the Study

Significance of the Study

The accreditation framework of PTC-ACBET aligns with international standards regarding implementing outcomes-based education. The PTC-ACBET accreditation granted to an HEI is either full or partial accreditation concerning findings indicated as a) Deficiency which indicates the criterion is not in compliance, b) Weakness which indicates the program lacks the strength of compliance, and c) Concern which indicates the program currently satisfies but identified criterion may not be satisfied (PTC-ACBET criteria for accreditation, 2014)**.**

The general criteria for PTC-ACBET accreditation are: 1) Program Educational Objectives, 2) Program Outcomes, 3) Students, 4) Faculty and Support Staff, 5) Curriculum, 6) Facilities and Learning Environment, 7) Leadership and Institutional Support, 8), Extension Service, Community- oriented Programs and Industry-Academe Linkage, and 9) Continuous Quality Improvement.

The output of the study provides background information on engineering HEIs' conformity to the implementation of outcomes-based education concerning CHED policies, standards, and guidelines for engineering programs. The study will develop an internal accreditation framework to guide engineering HEIs in preparing accreditation documents.

Objectives of the Study

The study developed an internal accreditation framework for private HEIs with engineering programs in the Cordillera Administrative Region. The study sought to:

- determine the common standards employed by private accrediting bodies in the Federation of Accrediting Agencies of the Philippines and Philippine

Technological Council Accreditation and Certification Board for Engineering and Technology

- determine the extent of implementation of outcomes-based education in engineering programs
- determine the factors affecting the accreditation status of private HEIs with engineering programs
- develop an internal accreditation framework for private HEIs

Methodology

Study Design

The study used concurrent mixed-method research design. The concurrent mixed-method design was the appropriate method since it involved data collection simultaneously for the quantitative and qualitative indicators needed for the study.

The quantitative design of the study involved the evaluation of the extent of implementation of OBE in engineering programs regarding CHED PSGs for engineering programs; and monitoring indicators for the compliance of OBE-related CHED memoranda through a survey. Qualitative information for common accreditation standards was extracted from published accreditation materials of accrediting bodies. The standards reflected in the accrediting bodies were extracted to prepare common documents. Qualitative information was collected through a survey determining the factors affecting engineering accreditation. Thematic analysis was used to construe the factors contributing to the limited participation of engineering HEIs in accreditation.

Population and Locale of the Study

Purposive sampling was implemented in the study to select private four private HEIs with and without accredited engineering programs, including 29 (five program chairs, three deans, and 21 faculty members) willing respondents. The inclusion of HEIs was based on the willingness of the head of the institution to participate and the respondents in the study for SY 2021-2022. The study included respondents with teaching assignments to professional engineering courses. The exclusion of HEIs included a) declined participation of the institution, b) centralization of engineering program course offerings to the main office, and c) temporary closure of engineering programs due to the Covid-19 pandemic.

The study was limited to a) accessible accreditation documents, b) submitted responses of private HEIs in the Cordillera Administrative Region with active engineering program offering for the academic year 2021-2022, and c) the endorsement of HEI representative for the survey.

Data Gathering Tools

Document analysis was used to determine the common standards of accrediting agencies in engineering accreditation published documents of a) PAASCU, and b) PACUCOA; since ACSCU-ACI has no accredited engineering program. The published self-survey guide for PTC-ACBET and OBE monitoring indicators of CHED-TPET were mapped for equivalency to the common standards of FAAP.

The primary means of gathering data for the extent of OBE implementation and factors affecting accreditation status was a researcher-made survey questionnaire with three sections based on the Commission on Higher Education Technical Panel for Engineering and Technology monitoring report in compliance to CMO #37 series of 2012 and Philippine Technological Council self-survey accreditation guidelines for engineering

programs. The first part of the questionnaire included information on the program accreditation profile. The second part of the questionnaire has five sections, including a) accessibility of documents for stakeholders, b) documentation for instructional quality, c) documentation for research and publication, d) documentation for linkages and community involvement, and e) institutional documents. The indicators focused on implementing the OBE curriculum regarding the CHED-issued policies, procedures, and guidelines of engineering programs. The questionnaire used a 4-point Likert scale using 1) strongly disagree, 2) disagree, 3) agree, and 4) strongly agree. The level of agreement was based either on the accessibility or availability of documents for OBE implementation.

The third part of the questionnaire comprised open- ended questions to determine the factors affecting the accreditation status of HEIs with engineering programs.

The researcher-made survey questionnaire was validated at the University of Baguio. The survey questionnaire was administered to a public engineering institution in CAR and a private engineering institution in Region I for a reliability test. Cronbach's alpha coefficient was used for the internal consistency reliability of the researcher-made survey questionnaire. The Cronbach alpha value was 0.99, representing the very high reliability of the questionnaire.

Data Gathering Procedures

The internet home page of private accrediting agencies (PAASCU and PACUCOA) and PTC were accessed to find available documents for accreditation (accreditation guidebook, manual of accreditation, and survey instrument). The documents for accreditation employed by the accrediting agencies and PTC were analyzed to determine the common accreditation standards.

In determining the extent of OBE implementation and factors affecting accreditation among HEIs, a survey questionnaire was administered to the respondents. The survey questionnaire with the consent form was distributed to the private HEIs through a google form link provided by the researcher with endorsement from the HEIs representative that was accessed and accomplished by the respondents. The researcher extracted the accumulated data from the google sheet of the google form.

Treatment of Data

Document analysis was used to identify common standards for private HEI accreditation from accrediting agencies and PTC accreditation indicators. Emphasis was made on common criteria with standards common to the accrediting bodies, common to two accrediting bodies, and unique to an accrediting body. Weighted mean and standard deviation were used to determine the extent of implementation of OBE in engineering programs with the statistical range and interpretation in Table 1.

The statistical range of the weighted mean was the basis for the extent of implementation of OBE implementation, ranging from very low to very high level of implementation. Thematic analysis was used to identify the factors.

Table 1

Statistical Range and Interpretation

Likert Scale	Statistical Range	Interpretation	Description

Likert Scale	Statistical Range	Interpretation	Description
4	3.26-4.00	Very High Extent of Implementation	Strongly Agree/accessible within/outside School premises/available document is 1-2 years ago
3	2.51-3.25	High Extent of Implementation	Agree/accessible within School premises /available document is 3-4 years ago
2	1.76-2.50	Low Extent of Implementation	Disagree/accessible upon request /available documents is 5-6 years ago
1	1.00-1.75	Very Low Extent of Implementation	Strongly Disagree/not accessible/no available document

affecting the accreditation status of private HEIs concerning the open-ended items in the survey questionnaire. Maguire and Delahunt's (2017) "doing a thematic analysis" with six steps guided the study's thematic analysis.

Ethical Considerations

The researcher sought the permission from the head of the institution for the engineering division of the institution to participate in the study. The study's respondents were informed of the study's objectives to develop an internal accreditation framework that aligns accreditation standards in preparation for accreditation through a consent form. Anonymity and confidentiality of the institution and respondents were observed in the study. The identity of the participating institution and respondents were not disclosed in the discussion and presentations of findings to minimize risks to the respondents. The consent form included provisions for respondents to decline or withdraw their participation in the study at any time. Submission by the respondent of the completed questionnaire signifies their willingness to be included in the study; on the contrary, non-submission of the questionnaire will not constitute any consequence to the respondent. The respondents did not spend any amount on the conduct of the study. The google form was deleted from the cloud upon completion of the study to prevent unauthorized access to the data.

The study's respondents will be informed of the study's results through publication. The researcher will also provide a copy of the study findings to the participating institution.

Results and Discussion

Common Standards of Private Accrediting Bodies for Engineering

The shift from input-based to outcomes-based education system demands the transformation of engineering education to achieve global comparability in the engineering practice through program accreditation. Eventually, accrediting bodies for quality assurance lean towards international standards.

There are 10 accreditation areas with specific criteria for PACUCOA; PAASCU has 12 standards, seven main areas of accreditation, and sub-areas with specific criteria; and PTC-ACBET has nine criteria primarily for the implementation of OBE. Florida and Quinto (2015) stressed that local accrediting bodies have criteria for HEIs to qualify and acquire recognition. As Mariano and Valenzuela (2015) stressed, the differences in accreditation standards and instruments result in non-uniformity in recognition of the quality of engineering programs.

The standards of PTC-ACBET matched to the common standards between PACUCOA and PAASCU resulted to the common standards including a) Publication of the Program Educational Objectives Consistent with the Vision and Mission of the Institution, b) Sufficiency in the Number of Qualified and Competent Faculty, and Professional Development of Faculty, c) Attainment of Student Outcomes, d) Curriculum that Leads to the Attainment of Student Outcomes, e) Availability of Adequate and Updated Laboratory Resources for the Attainment of Program Outcomes, f) Availability of a Research Program for Faculty Participation in Research, g) Library Services must be Adequate to Support Scholarly and Professional Activities of the Students, h) Accessibility of Student Services to Support the Program Needs and Students, i) Services that Entail Involvement in the Community, j) Adequacy of Physical Facilities to Support the Needs of the Program, k) Adequacy of Leaders for Effective Supervision and Institutional Support to Ensure Quality and Continuity of the Program, l) Continuous Improvement of the Program

Extent of Implementation of Outcomes-Based Education in Engineering

The administered researcher-made survey questionnaire to engineering HEIs in CAR for the implementation of OBE yielded the presence of a) an institutional OBE framework, b) monitoring activities for OBE implementation, and c) a monitoring report submitted to the Commission on Higher Education Technical Panel for Engineering and Technology.

All list of documents of HEIs accessible to the stakeholders indicators including a) Institutional OBE framework, b) Institutional Vision statement, c) Institutional Mission statement, d) Program Educational Objectives (PEOs), e) Program outcomes (POs), f) Program Curriculum, g) Curriculum map, h) Course pre-requisite map, i) Program assessment and evaluation matrix plan, j) Historical enrollment data, k) Historical graduation rate data, and l) Syllabi, yielded a very high extent of implementation from the ratings of the respondents. The accessibility of the OBE documents reflects the shift in the engineering program's curriculum from traditional to OBE as mandated by CMO #37 series of 2012 and 2017 CHED memos for engineering programs policies, standards, and guidelines, which essentially mandate the enumerated metrics.

Most instructional quality documentation has a very high extent of implementation except for the licensure performance with a high extent of implementation rating from the respondents. In addition, some faculty response points out that documents prepared five years ago were not updated, particularly on program educational objectives and laboratories, contrary to deans and program chairs. The availability of supporting documentation indicates that the engineering curriculum has developed the main indicators for the OBE instructional delivery of engineering programs. The successful implementation of OBE allows for new ideas and challenges to be developed into an educational model that results in enhanced learning outcomes to prepare the learners in the workforce.

The very high extent of implementation on instructional quality documents means that HEIs have already begun considerable preparation of the engineering programs for the instructional shift from traditional to outcomes-based education. However, students' performance on the licensure examination requires special attention to reviewing the skills acquired by the graduates.

On research and publication documents; only the List of faculty with name of mentees and corresponding title of thesis, and Sample of thesis manuscript of Students had a very high extent of implementation; while high extent of implementation were seen for

indicators in research organizations, presentations, awards, publications, and a list of patents produced by the program. Florida and Quinto (2015) stated that international accreditation places a higher value on citations of published research. According to Welch et al. (2018), research-focused programs must expand with industrial linkages for accreditation to be successful. The added function of faculty delves into active engagement in research.

The bulk of extension and linkages documentation is implemented to a very high level. On the contrary, a high extent of implementation in the indicators a) List of non-degree educational programs, short- courses, and training programs offered to fellow engineers/other professionals, b), List of professional and consultancy services done by faculty & staff, and c) Performance monitoring assessment and evaluation plan of community- oriented programs. Natarajarathinam (2021) stressed that differences in the priorities of educational institutions and community partners hinder the implementation of projects. Schools must form partnerships with organizations and agencies relevant to the program. Engaging in school-community activities is a slow and demanding work, expands the workload, and takes significant time. However, school- community involvement contributes to the positive development of students (Houseman et al., 2017).

Active participation in professional and community service activities aids in the development of a well- rounded engineering personality (Canini & Dalis, 2016). This suggests that the curriculum should encourage active participation in professional and community programs.

Most institutional documentation has a very high extent of implementation except institutional documents for international engagement. Results show a need to increase the visibility of partnerships through an accomplished memorandum of agreement. Considering the internationalization trends in the field of Higher education stipulates the growth of cooperation between higher education institutions through the provision of international accreditation, including regional accreditation (Obolenska & Tsyrkun, 2016). This implies that engineering HEIs should be aggressive in forming partnerships with academic, professional, and research institutions in order to meet international accreditation standards.

Factors Affecting the Accreditation Status of Private HEIs with Engineering Programs

In the Cordillera Administrative Region, no institution (0%) with an engineering program was accredited by PACUCOA, PAASCU accredited two institutions (18.18%) with engineering programs, and one institution (9.09%) was accredited by PTC-ACBET from the 11-private institutions with engineering program offerings.

Despite the high to very high extent of OBE implementation from the respondents, HEIs encounter barriers to accreditation. The resulting themes include a) insufficient paradigm shift, b) Lack of qualifications, c) faculty workload, d) inadequacy of resources, and e) poor licensure examination performance.

Insufficient Paradigm Shift

This includes consultation with the stakeholders to craft its essential components, including program educational objectives, program outcomes, program curriculum, program assessment, evaluation matrix plan, and syllabi manifested in the common accreditation standards. The realization of the OBE framework in instructional quality should be manifested through the availability of evidence. However, the respondents are affected by a) paradigm shift orientation and b) lack of OBE orientation.

The objectives of an OBE system cannot be realized when students have a low level of perception and teachers misunderstands the implementation of OBE. It makes the teacher less motivated in performing teaching and learning tasks. Implementing OBE becomes burdensome due to the lack of skills and training, especially for teachers accustomed to the traditional system (Damit et al., 2021).

The study finds deficiencies in the acceptance of paradigm shift to OBE, which remains a challenge to HEIs. The observed deficiencies necessitate immediate action by HEIs to ensure the transformation of the stakeholders, engage in the HEIs OBE framework, and realize documents for OBE implementation.

Lack of Qualifications

The aspect of academic qualification was embedded at 2017 CMOs on the policies, standards, and guidelines for engineering programs describing the qualifications of the dean, program chair, faculty, and support staff. The respondents are faced with a) failure to meet qualifications requirements and b) a lack of credentials.

The study findings reveal that the credentials of faculty and administrators are a work in progress which contradicts the very high extent of OBE implementation for the documentation of instructional quality. Hence, it is practical to adhere to hiring qualified faculty would be necessary for the sustainability of the program. The faculty must have skills and academic requirements to deliver OBE instruction.

Faculty Workload

The preparation of documents is an essential part of accreditation and OBE implementation that needs the significant contribution of the faculty. The respondents are challenged with a) stressful requirement and b) time constraint.

The implementation of OBE significantly needs commitment and extra work from the teacher since the traditional system differs from the OBE system. Faculty members are burdened by the total change from the traditional to the OBE system. Non-familiarity with OBE and regular updating of the curriculum affect assessment preparation, not within uniform standards (Damit et al., 2021). As such, accreditation success necessitates the submission of pieces of evidence (Al- obaidi, 2021). Obligations from authorities and educational leaders mostly cause excessive workloads. The responsibilities associated with a teacher have some bearing on the success and performance of the school and as a faculty of the institution (Pacaol, 2021).

The study finds that the faculty is not adept with the duties of a faculty in implementing OBE as prescribed in CHED PSG. This is contrary to the respondents' high extent of OBE implementation at the evidence for instructional quality. This suggests the orientation of the faculty to accept the embedded duties and to mentor for the systematic preparation of documents for accreditation. Faculty training for the different OBE components will be necessary to acquire knowledge and skills in OBE implementation.

Inadequacy of Resources

The aspect of this theme is the support structure and mechanism to assist the quality of instruction. The common accreditation standards for resources that need to be addressed include the availability of adequate and updated laboratory resources, research programs, adequate library services, and accessibility of student services. Adequate resources contribute to a conducive teaching-learning environment to support the attainment of learning outcomes that are necessarily evaluated during accreditation. The respondents are faced with a) inadequacy of facilities, b) deficiency of equipment, c) lack

of funds), and d) limited resources.

Lack of equipment disrupts the teaching-learning process, especially with missing and damaged equipment. This defeats the assessment since students are graded, but the student outcomes are not attained. It is encouraged to collaborate with other institutions to supplement the resource deficiency (Damit et al., 2021).

The financial considerations for the deficiencies have to be openly discussed with the administration for the effective implementation of OBE in the course of the institution's mission and preparation for accreditation.

Poor Licensure Examination Performance

The poor performance of graduates in the licensure examination is another key factor for non-submission to accreditation. As such, accrediting bodies require a minimum passing rate in the licensure examination to qualify for accreditation. The respondents seem to be benchmarking at 50% performance in the licensure examination, while the focus area of OBE includes citation as a top-performing school.

Accreditation should be strengthened as a higher level of accreditation is equivalent to higher performance in the licensure examination (Dator, 2016). Rashideh et al. (2020) emphasized that accreditation promotes graduates' competitiveness and results in better professional preparation. This is supported by Qadir et al. (2020), finding that accreditation improves the quality of educational programs.

The study finding is contrary to the respondents' high extent of OBE implementation and remains a challenge for private engineering HEIs in CAR. The faculty and administration should implement sustainable solutions to improve the licensure examination performance.

Application for accreditation is impeded by perceived deficiencies in the implementation of OBE, qualifications of the faculty and administrators, facilities, research engagement, extension and community programs, industry partnership, and licensure examination performance. Uziak et al. (2017) argued that accreditation could catalyze good change for the institution, professors, department, curriculum, academic staff, students, and industry. It covers the challenges that come with the process.

Internal Accreditation Framework for Private HEIs

The accrediting bodies duly recognized by the Commission on Higher Education for engineering programs adapt the implementation of outcomes-based education for quality assurance and international engineering accreditation. Familiarity with accreditation should not be based on weakness but rather on developing strategies and solutions. The conflicting results of the study on the implementation of OBE and accreditation factors necessitate a deeper understanding by the stakeholders on accreditation.

Engagement in accreditation begins with institutional accreditation, in which the institution assesses itself in light of accreditation standards and declared institutional mission (ACCJC, 2020). An institution's proposed internal accreditation framework aims to attain the standards of accrediting bodies. It necessarily dictates that the stakeholders review the processes and documents to implement institutional plans to attain the institutional mission. The internal accreditation framework organizes the steps that must be taken to demonstrate that the institution is on the path to accreditation.

The proposed internal accreditation framework that the institution can use for

accreditation is shown in Figure 3.

Institutional Mission

The heart of an educational institution is its mission statement. It communicates its commitment to the community with alignment to educational best practices in a changing environment (Keefe, 2020), driven by the internationalization process and positioning on a global level (Borsetto, 2021). The mission statement expresses the institution's goal, who it serves, and what it seeks to achieve. Accreditors and institution leaders can use the mission statement for institutional identity and increase transparency among internal and external stakeholders (Marquez, 2016).

Figure 3

Internal Accreditation Framework
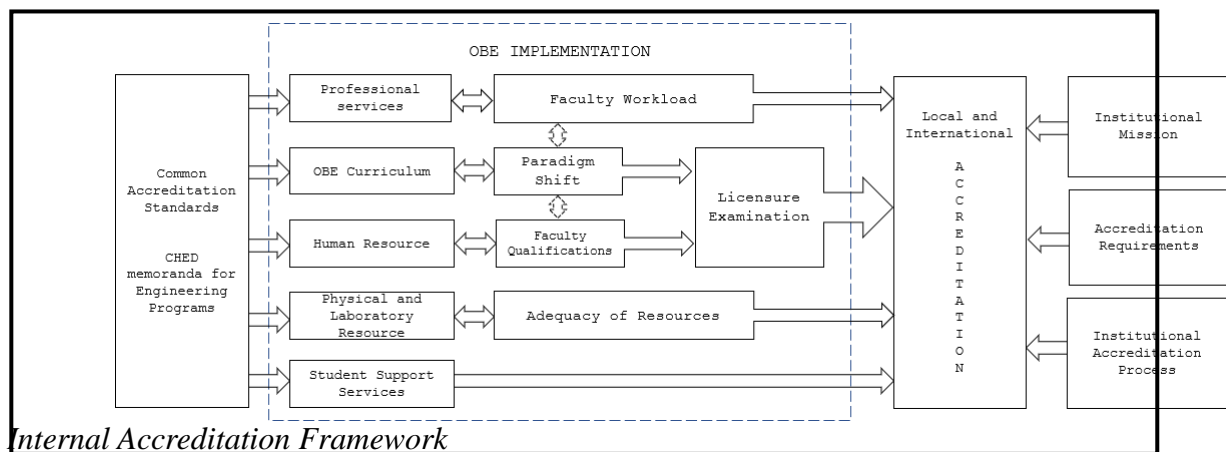
Local and International Accreditation

Accreditation suggests a level of quality consistent with the institution's educational mission. Accreditation seeks program enhancement and compliance with minimum standards set by an external accrediting body. Obtaining an engineering accreditation is a lengthy procedure that requires significant work from all program participants (Rashideh et al., 2020). Accreditation adds value by providing critical suggestions based on self-assessment and external examination (De los Rios & Oviedo, 2021).

Common Accreditation Standards

The development of an OBE framework forms the foundation of the OBE system, and the implementation of OBE is supported by the existence of support systems and mechanisms.

The common standards for accreditation were summarized as a) OBE curriculum, b) human resources, professional services, d) physical and laboratory resources, and e) student support services.

CHED Memoranda for Engineering Programs

The 2017 CMOs for engineering programs emphasized on curriculum and resources needed by the program. The curriculum should have a) CHED recognized outcomes-based curriculum of the program, b) program educational objectives (PEOs), c) program outcomes (POs), d) performance indicators (PIs), e) program assessment and evaluation (for the assessment and evaluation of PEOs/POs), f) continuous quality improvement (CQI), g) program of study, h) curriculum Map, and i) syllabi (with the emphasis of outcomes-based teaching and learning; including teaching, learning, and assessment).

Emphasis on resources includes a) administration (qualification of the dean and program chair), b) faculty (qualifications and duties), c) library and other learning resources, and d) laboratory equipment and resources (facilities for instruction, site and buildings; laboratories; modernization of equipment; and calibration of equipment).

Preparing documents in conformity with CHED memoranda ensures the institution's qualification in offering the engineering program. The institution should undertake strategic and developmental planning for identified deficiencies to comply with CHED memoranda in offering the engineering program.

OBE Implementation

The existence of factors hindering accreditation of engineering HEIs despite the high to very high extent of OBE implementation is contributed by differences in deans, program chairs, and faculty members' perspectives towards the OBE framework and availability of documents. This does not rule out disagreement but rather uncertainty on the implementation of OBE, with some respondents' disagreeing with the availability of documents. The implementation of OBE requires the documentation of pieces of evidence that cater to the common accreditation standards and CHED mandates for outcomes-based education. Addressing accreditation factors improves the preparation of an HEI for accreditation.
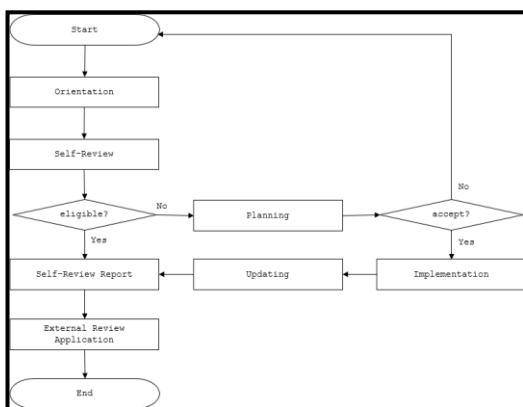
Institutional Accreditation Process

The internal accreditation process is the gradual preparation of the HEI for accreditation, as shown in Figure 4. The internal accreditation process is an institutional self-assessment in compliance with accreditation requirements.

Orientation. The orientation phase includes the students, faculty, staff, and administration to deliberate on a) institutional mission about accreditation, b) common standards for accreditation, c) accreditation requirements, and d) the accreditation process. Awareness of the school administration to regulatory issuances increases the compliance of the HEI, affecting its status.

Awareness of the stakeholders (students, faculty, staff, and administrators) of the common standards for accreditation and accreditation requirements complements the implementation of OBE to avoid information overload. Stakeholders should have a positive response toward accreditation for the success of accreditation (Prado, 2018). It sheds light

Figure 4

Institutional Accreditation Process

on the importance of HEIs commitment to certain standards and accreditation. People generally had favorable attitudes toward accreditation, although their understanding was restricted (Al-khourry et al., 2014).

Hidayat et al. (2018) emphasized that the involvement of all stakeholders in the accrediting process is one of the important success indicators.

Guidance activities by accreditors, including consultancy and preliminary visits, are necessary prior to formal accreditation. The consultancy visit is intended to orient the institution for necessary preparations and documentation for accreditation, including the self-survey report. The preliminary visit validates the self-survey report and exhibits with stakeholder meetings/interviews (faculty, students, staff, and administrators), class observation, examination of documentary evidence, ocular visit, cites best practices, and endorses recommendations for improvement. PACUCOA grants "Candidate Status" for a successful preliminary visit valid for two years. The preliminary visit is the eligibility of institutions to apply for level 1 accreditation.

The formal accreditation visits of PACUCOA and PAASCU are categorized as a) Level I, b) Level II, c) Level III, and d) Level IV.

The process of PTC-ACBET accreditation involves a) request for accreditation, b) pre-visit, c) Program Evaluation Team Site Visit, and d) post-visit.

Self-Review. Conformity to regulatory requirements is an initial preparation of the program to accreditation requirements. Self-study is one of the best practices in preparation for accreditation (Prado, 2018). The stakeholders must be represented in the committee for the assessment and evaluation of readily available documents of the institution.

Planning. A non-eligible evaluation result of the self- survey necessitates planning to address the non-compliant indicators in the self-survey instrument. Accreditation entails financial resources to support human and non-human resources for an improved and quality program. The common problems encountered in accreditation include preparation of documents, administrative support, facilities, and attitude towards accreditation. Problems arising during the accreditation process should be resolved as soon as feasible to prepare the path for future institutional accreditation and challenges (Prado, 2018).

Implementation. Approval of the plan by the administration suggests implementation by the school administrators and concerned offices. Administrators are responsible for the implementation of plans and participation in the preparation of documents. Implemented plans should reflect improvement with supporting documents (ACCJC, 2020).

Updating. The implementation of plans dictates the progress of documentation. This process involves revisiting the self-review documents with the supporting documents of the implemented plan. Regular updating of self-review documents signifies the intent to qualify for accreditation.

Self-Review Report. The self-review report is a summative assessment and evaluation report from the accreditation committee highlighting the compliant indicators, strengths, and improvements from implementing plans concerning submitted documents.

External Review Application. An institution's application to an accrediting body signifies that the institution has prepared for external review.

Conclusions and Recommendations

The common standards of accreditation by accrediting bodies for private HEIs are associated with CHED memos mandating the establishment of outcomes-based education and pursuance of an outcomes-based quality assurance system leading to the attainment of learning outcomes. Capability training activities will promote an institutional culture for the implementation of outcomes-based education. The common accreditation standards include the continuous improvement of the OBE curriculum, documentation of human and non-human resources, and pieces of evidence for the availability of student and professional services.

The factors that inhibit the accreditation of engineering programs are limited conformity to CHED memos, such as lack of OBE orientation, dearth of qualified faculty and administrator to perform duties, and deficient facilities and resources. Additionally, poor performance in the licensure examination contributes to the non-engagement of the institution to accreditation.

The internal accreditation framework necessitates the stakeholders' acceptance of the institutional goal for quality education. The primary features of the internal accreditation framework are a) institutional mission, b) regulatory/accreditation requirements, and c)accreditation process for the preparation of baseline documents and continuity of improving documents.

After a thorough analysis of the data, the following recommendations are hereby made:

1. School management, either through the office of the vice president for academics or the quality assurance office to impose the adoption of the engineering common accreditation standards in preparing documents for accreditation.

2. School management to require the active participation of the faculty and administrators in OBE seminars/training/workshops endorsed by CHED, Philippine Association of Engineering Schools, PACUCOA, and PAASCU.

3. School administrators to orient the faculty on the OBE framework and implementation in the engineering program through faculty meetings. Faculty will orient the student on the OBE framework and implementation specific to the class, emphasizing program outcomes, course competencies, course outcomes, teaching-learning activities, assessment tasks, and course assessment.

4. Adoption of the internal accreditation framework by engineering HEIs administration to be implemented in preparation for accreditation application.

5. Furtherance of the study to all engineering HEIs with the inclusion of administration, faculty, and students to validate the extent of OBE implementation and accreditation factors.

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Nitrate and Phosphate Content Assessment of Soil and Water in an Agri-municipality in Nueva Vizcaya

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Abstract

Water safety and quality are essential, especially to human health, agriculture, aquaculture, industry, and all life forms. Effective crop production depends on an adequate supply of nutrients through fertilizer application to achieve maximum yield. However, farmers must manage soil nutrients appropriately to meet crops' fertility requirements without adversely affecting the quality of our valuable water resources. This research assessed the concentration of nitrates and phosphates in farmland soil and groundwater in the selected agro-ecosystem barangays in Dupax del Sur, Nueva Vizcaya, to ascertain the degree of anthropogenic influence via the application of fertilizer and other agro-chemicals to farmlands by farmers. Results show that the dissolved nitrate concentrations of both water sources and farmland soils for both barangays are below the recommended levels set by the respective standards referenced in the study - with the statistical analysis showing no statistically significant difference in nitrate concentration between both barangays. Also, data indicate that the soil phosphate concentrations on all sampled farmlands in both barangays are below the recommended levels set by the standards referenced in the study. However, the dissolved phosphate concentration in all sampled water sites is significantly above the recommended levels. The differences in soil and water phosphate concentrations can be due to having a separate irrigation source that has experienced multiple runoffs and leaching events, increasing its dissolved phosphate

Keywords : agrochemicals; biogeological processes; fertilizer application;
sustainablefarming

1. Introduction

Nueva Vizcaya is Cagayan Valley's vegetable capital and the country's next "salad bowl" (Department of Agriculture, 2011). In particular, Dupax del Sur is one of the leading vegetable producers. The income of most families is derived from rice farming, onion planting, and vegetable cultivation. Thus, it is inevitable for farmers to use fertilizers to boost crop yield. Farmers across the municipality use a variety of fertilizers to grow crops and to improve and increase the crop yield in every cropping season. Applying these inorganic fertilizers repeatedly for decades pollutes the soil and the water reservoir near it. If there is excessive use of fertilizers, it could potentially cause groundwater contamination.

Among the most pervasive pollutants of freshwater globally today are phosphate and nitrate (Khan & Ghouri, 2011). Sources of nitrates include runoff or seepage from fertilized lands, municipal and industrial wastewater, refuse dumps, animal feedlots, septic tanks, private sewage disposal systems, drainages, and decaying plant debris. Nitrates and phosphates are surplus nutrients that contaminate the soil and affect fertility.

Farmlands are the most common source of nitrates and phosphates (Lemma et al., 2017). Farmers are using organic fertilizers all year-round to boost their crop yields. Esteller et al. (2009) mentioned that this usage of organic wastes in agriculture may

increase the production of crops by incorporating nutrients (such as nitrates and phosphates) into the soil. However, this could also lead to serious environmental concerns such as soil and water pollution, leaching, and eutrophication. Because nitrate can easily be transported from the soil into aquatic ecosystems by surface runoff and leaching, this causes groundwater contamination and aquatic eutrophication of surface waters (Guo et al., 2010). Moreover, according to Yeshno et al. (2019), the concentration of nitrates in soil often changes rapidly, on a timescale of hours to days, and are dictated by irrigation–precipitation pattern, fertilization and cultivation methods, plant uptake, and natural soil biochemical processes.

These nutrients are the main reason for water contamination and eutrophication, which could result from other phenomena that could seriously threaten the environment and its living organisms. Eutrophication happens when a body of water receives an excessive nutrient load, particularly phosphorus and nitrogen, resulting in an overgrowth of algae. This phenomenon often results in an overgrowth of algae. These algae will then cover the entirety of the surface of the water, keeping sunlight from penetrating. This will then cause some aquatic plants to die at the bottom of the water source. When these algae and aquatic plants die and decompose, oxygen is depleted from the water. This lack of oxygen in water causes the death of aquatic animals (Ghosh, 2021).

In the Philippines, there are limited studies about nitrate pollution and its environmental risks, such as groundwater pollution. The study of Bednarek et al. (2014) shows that some of the groundwater sources sampled in a municipality in Laguna were found to be contaminated with nitrate-nitrogen from the use of inorganic nitrogen fertilizers, septic tanks, poor dug wells, and defective sewage systems. This became a significant concern that heightens fear in most communities because of the potential risks of groundwater pollution and the possible consequences it may bring depending on these water sources.

Although there is prior research about this issue in other locales, a study has yet to be conducted in the municipality of Dupax del Sur about the nitrate accumulation in farmlands and its subsequent environmental risks, such as groundwater contamination.

The lack of adequate research and studies regarding this matter in our country is alarming. Nitrates and phosphates pollution monitoring is needed to provide baseline data that can be used by decision-makers and policymakers for sustainable environmental management of river basins and aquatic ecosystems (Oremo et al., 2020).

The findings of the study will be beneficial for the environment and the community. Farmers will be aware of the potential risks of continued usage of inorganic or chemical fertilizers. Hence, they will be encouraged to use alternative fertilizers for more sustainable farming. Local governments could raise awareness about this phenomenon. This could encourage them to devise restoration efforts and formulate eutrophication control programs for affected areas. Lastly, the result of this study could be the basis for further environmental investigation on the excessive accumulation of nitrates and phosphates in soil and water reservoir. The researchers also believe that the study will help promote sustainable farming and is also aligned with risk reduction and mitigation, one of the components of SMU's Project WEALTH VERSION 2.0. This academic endeavor is also associated with the United Nations' Sustainable Development Goals (SDGs) 2, 6, 12, and 13. SDG2 is No hunger: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture; SDG6 is Clean Water and Sanitation: Ensure availability and sustainable management of water and sanitation for all; SDG12 is

Responsible Consumption and Production: Ensure sustainable consumption and production patterns; and SDG13 is Climate Action: Take urgent action to combat climate change and its impacts (UN, n.d.).

2. Objectives

This study focused on the assessment of nitrate and phosphate concentrations in farm soil and irrigation water in Dupax del Sur, Nueva Vizcaya.

Specifically, it sought to answer the following questions:

1. What is the nitrate concentration of the groundwater in different study sites?

2. What is the nitrate concentration of the farmland soil in different study sites?

3. What is the phosphate concentration of the groundwater in different study sites?

4. What is the phosphate concentration of the farmland soil in different study sites?

5. Is there a significant difference on the nitrate concentration in groundwater samples at different study sites?

6. Is there a significant difference on the nitrate concentration in farmland soil samples at different study sites?

7. Is there a significant difference on the phosphate concentration in groundwater samples at different study sites?

8. Is there a significant difference on the phosphate concentration in farmland samples at different study sites?

9. What recommendations in restoration efforts and eutrophication control programs may be proposed to the identified communities?

3. Materials and methods

Research Design

The study utilized a descriptive-comparative research design to assess and compare the nitrate and phosphate concentrations of the farmland soil and ground waters in the two selected barangays in Dupax del Sur, Nueva Vizcaya.

Study Site and Sample Collection

Soil and water samples were collected from four farms, three of which are located in Barangay Mangayang and one in Gabut.

The farmers from Magayang and Gabut are members of the Mangayang-Iñeangan-Duppes Irrigation Association, Inc. and Gabut Farmers Rice and Onion Growers Association, respectively. The farmlands cover an area from 0.8 hectares (8,000 sq. meters) to 1.5 hectares (15,000 sq. meters) with a mean area of 1.15 hectares (11,500 sq. meters).

The common crop planted in Mangayang is sweet potato or commonly called camote. Rice is also grown on the two farms, while corn is on one farm. As one farmer shared, camote is a good alternative to rice since the profit is greater, considering the very low buying price of rice by traders. Vegetables such as tomato, pepper, Kentucky beans, string beans, winged bean (pallang), and bottle gourd (upo) are also planted as additional crops. The only farm visited in Gabut is planted with squash and red onions. To provide additional nutrients to the plants, all sampled farmers commonly use urea fertilizer, one of the most widely used chemical nitrogen fertilizers, according to Zhengzhou Huaqiang (2019). Triple 14 is another growth booster used. The name describes the NPK ratio present in the fertilizer, 14% nitrogen, 14% phosphorus, and 14% potassium. The remaining percent may include other nutrients the plants need (WhyFarmit, 2023). An average of six-seven bags of fertilizer are applied per hectare of farmland.

The plant growers are hesitant to use organic fertilizer, particularly the vermicompost given free by the Department of Agriculture. Vermicompost is the product of the decomposition process using various species of earthworms, which creates a mixture of decomposing vegetable or food waste, bedding materials, and vermicast (vermicompost, n.d.). From what the farmers experienced before, the worms which excrete the vermicast eventually destroyed their crops. For the entire year, the farmers have two cropping seasons or cycles. This is done to give time for the soil to sustain or restore its productivity. To augment their produce from the farms, one farmer has a piggery and another one takes care of ducks.

Water Sample Collection

Water samples were obtained from groundwater sources in the selected study sites. Each borehole was pumped for 3 minutes, and each sample bottle and its cap were rinsed three times with the well water during sampling. Water samples were placed in clean polyethylene bottles, were preserved with 1 mL sulfuric acid (96%, JT Baker) for every 500-mL water sample, and were stored in an icebox maintained at a temperature of about 4°C and were brought immediately to the laboratory for its nitrate-nitrogen determination.

Farm Soil Sample Collection

A manual collection method was used to collect soil samples in the study sites. This method was used primarily to collect surface and shallow subsurface soil samples. The surface was first removed from the sampling plot before collecting. In the sampling spot, a V-shaped cut to a depth of 15cm was made using a spade. Thick slices of soil from top to bottom of the exposed face of the 'V-shaped cut were placed in a clean container. The samples were mixed thoroughly, and foreign materials like roots, stones, pebbles, and gravel were removed. Then, the bulk was reduced by about half to one kilogram by quartering. Quartering was done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters were discarded, the remaining two quarters were remixed, and the process was repeated until the desired sample size was obtained. The collected samples were placed in a clean cloth of polyethylene bag. The bags were labeled with information like the spot's location and the collection date.

Data Gathering Procedure

1. Nitrate Assessment of Water and Farm Soil Samples

Nitrate concentration ([NO3-N mg/L]) was determined using the ultraviolet spectrophotometric screening method (Eaton et al., 2005). For this method, water samples

were analyzed using an Ultraviolet-Visible (UV-VIS) Spectrophotometer in the ultraviolet (UV) range at 220 nm and 275 nm wavelengths. Measurements at both wavelengths correct for possible interference by dissolved organic matter. Dissolved organic matter may be absorbed at 220 nm and 275 nm, while NO3- is only absorbed at 220 nm. The nitrate concentration was calculated by subtracting the absorbance at 275 nm from the absorbance at 220 nm and then comparing the corrected absorbance to a calibration curve developed using standards of known nitrate concentration (Eaton et al., 2005). For this analysis, the Biobase Spectrophotometer UV-1000 was used, and all measurements were read against distilled water set at zero absorbance as a blank. Fifty milliliters of field samples were filtered prior to UV-VIS analysis, and 1 mL of 1N HCl was added to minimize interference from dissolved organic matter. Each sample was analyzed using the UV-VIS spectrophotometer thrice, and the average absorbance was calculated. To prepare the calibration curve, a stock nitrate solution was made by diluting 0.7218 g of potassium nitrate previously dried at 105oC for 24 hours and was cooled in a desiccator to 1 L in a volumetric flask with distilled water. The concentration of the stock solution is 100 mg NO3 - N/L or one milliliter of the stock nitrate solution containing 100 µg of NO3-N. Standards in the 0 to 7 mg NO3-N/L were prepared by diluting the stock nitrate solution. These standards were treated and analyzed in the same manner as the samples. A linear relationship between absorption and NO3-N mg/L, or a calibration curve, was developed and used to convert the absorbances measured for the samples to nitrate concentrations in units of mg NO3-N/L.

First, the chloride concentration in the farm soil sample was determined, the chloride reading was divided by 10, and an amount of silver sulfate equivalent to the amount of chloride was added. Then (2-5) mL of the sample was taken in the centrifuge test tube, and the volume was completed to 10 mL with distilled water. The tube was centrifuged for 10 min until the solution was clear. Five mL of the clear solution was taken in a glass evaporating dish, put in a water bath, evaporated to dryness, and cooled. Then 1 mL of phenoldisulphonic acid was added after 10 min, then 10 mL of water was added and transferred to a 100 mL volumetric flask and made alkaline by adding conc. NH4OH, diluted to volume and mixed. Then the absorbance at 650 nm was measured using Visible Spectrophotometer and cuvette.

2.Phosphate Assessment of Water and Farm Soil Samples

In a 250 mL volumetric flask, 50 mL of distilled water was prepared, with 0.75 g of ammonium sulfate and 5 mL of concentrated sulfuric acid added. The solution was allowed to cool, as the heat was generated upon pouring the concentrated sulfuric acid, and then was diluted to the mark with distilled water.

For water samples, 10 mL of the sample and 200 mL of the ammonium sulfate solution were added to an Erlenmeyer flask and shaken occasionally over 30 minutes. The sample was filtered through filter paper to filter unwanted debris.

For farm soil samples, the obtained samples were oven-dried overnight at 50°C. 10 g of the dried soil samples and 200 mL of the ammonium sulfate solution were added to an Erlenmeyer flask and shaken occasionally for over 30 minutes. The sample was filtered through filter paper to remove any unwanted debris.

A standard solution was prepared by formulating a 300 mg/L stock solution by accurately weighing approximately 0.220g of solid potassium phosphate monobasic (KH2PO4) into a 500 mL volumetric flask and diluting it to the mark with distilled water. 10 mL of the stock solution was pipetted into a 200 mL,250 mL, 500 mL, and 1L

volumetric flask and diluted to the mark to obtain 15, 12, 6, and 3 mg/L standard solutions, respectively. 15 mL of the stock solution was pipetted into a 1L volumetric flask and diluted to mark to obtain a 4.5 mg/L solution.

Using 100 mL of distilled water, 5 g of ammonium molybdate was dissolved. Then, 160 mL of concentrated sulfuric acid was slowly added to the solution and diluted to 500 mL with distilled water. Into a 150 mL Erlenmeyer flask, 10 mL of each standard phosphate solution was pipetted. 20 mL of distilled water, 2 mL of the molybdate solution, and a spatula of ascorbic acid crystals were added to the standard solution and heated slowly until boiling – resulting in a deep blue or green color. The solution was allowed to cool, and its absorbance reading was measured using a UV-Vis spectrophotometer at 650 nm. Into a 150 mL Erlenmeyer flask, 10 mL of each prepared sample solution was pipetted. 20 mL of distilled water, 2 mL of the molybdate solution, and a spatula of ascorbic acid crystals were added to the standard solution and were heated slowly until boiling. The solution was allowed to cool, and its absorbance reading was measured using a UV-Vis spectrophotometer at 650 nm.

Using the standard curve obtained from the absorbance readings of standard phosphate at known concentrations, an equation was obtained from the equation of its trendline using Microsoft Excel data processing software. The equation of the trendline was presented as $y=mx+b$, where y is the absorbance of the sample and x is the phosphate concentration of the sample. The measured absorbance readings of each sample were integrated into the equation, and the phosphate concentration was obtained by solving for x.

Treatment of Data

Mean and standard deviation were used to determine the nitrate and phosphate content of the samples tested in three replicates. The data were tested using a t-test to determine whether significant differences in the nitrate-nitrogen and phosphate concentrations of the farmland soils and groundwater sources at different study sites were present. The groundwater quality criteria used for interpreting the results were obtained from the Department of Environment and Natural Resources (DENR) Administrative Order No. 2016-08 for Class C waters and Nutrient Status Maps for both nitrogen and phosphorus content as of June 2017 in Nueva Vizcaya from the Department of Agriculture - Bureau of Soils and Water Management.

Ethical Considerations

This study was approved by the Saint Mary's University Research Ethics Board (SMUREB) at Saint Mary's University, Ponce Street, DMM, Bayombong, Nueva Vizcaya, with a cellphone number: 09177053041 and email: reb@smu.edu.ph There is no conflict of interest in conducting this study. The study involved the conduct of laboratory procedures on the level of concentration of nitrate and phosphate in farm soil and irrigation water. It did not involve human or animal participants. Since the study dealt with chemicals, the researchers executed standard chemical practices to minimize the risk. Specially, these chemicals posed high-risk hazards to the environment, and non-carcinogenic health risks to laboratory users if accidentally exposed by skin contact, inhalation, or ingestion. The researchers are trained and well-equipped to handing these chemicals and other chemical agents used to analyze the levels of nitrate and phosphate concentration in water and soil samples. The CNS laboratory has an established Hazardous and Biological Waste Management Policy (2020). Lastly, all procedures where infectious/hazardous or possibly infectious aerosols/splashes created were conducted in biologically and chemically safe laboratory benches and/or stations.

4. Results and Discussion

Section 1. Nitrate Concentration

The absorbance readings at 220 nm and 275 nm were recorded in triplicates and averaged to calculate the corrected absorbance reading by finding the difference between the two readings. Table 1 displays the resulting absorbance readings of the standards.

Table 1. Concentrations and Absorbances of Nitrate Standard

Concentration (mg/L)	Absorbance (220 nm)				Absorbance (275 nm)				Corrected Absorbance (A220 - A275)
	Trial 1	Trial 2	Trial 3	Average	Trial 1	Trial 2	Trial 3	Average	
0	0.229	0.188	0.171	0.196	0.004	0.012	0.000	0.005	0.191
1	0.401	0.399	0.406	0.402	0.053	0.056	0.057	0.055	0.347
2	0.628	0.622	0.621	0.624	0.055	0.053	0.053	0.054	0.570
3	0.826	0.830	0.828	0.828	0.054	0.054	0.053	0.054	0.774
4	1.026	1.023	1.023	1.024	0.052	0.050	0.052	0.051	0.973
5	1.203	1.204	1.190	1.199	0.051	0.049	0.052	0.051	1.148
6	1.373	1.370	1.358	1.367	0.052	0.053	0.053	0.053	1.314
7	1.654	1.607	1.588	1.616	0.053	0.053	0.048	0.051	1.565

Plotting the corrected absorbance readings of the standards on a graph yields a trendline, which determines the equation used to find the nitrate concentration of unknown samples. Figure 1 below shows the standard curve for determining the nitrate concentration in both water and farmland soil samples.

Figure 1. Standard Curve of Nitrate Concentration
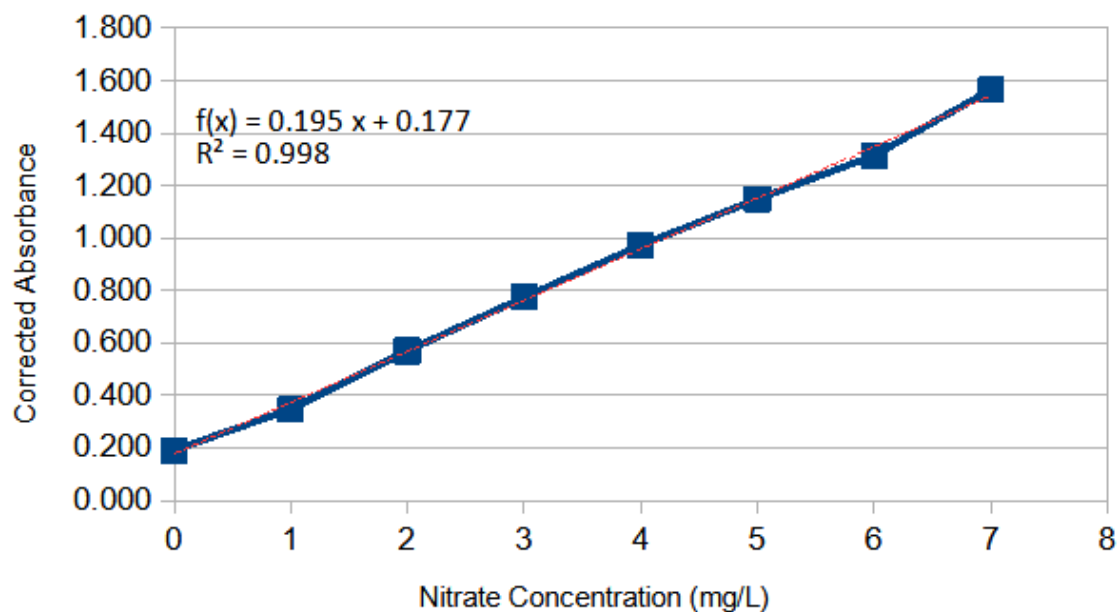
The procedure for determining corrected absorbance for the nitrate standard is applied to the water and farmland soil samples collected from different labeled locations in Dupax del Sur.

A. Nitrate Concentrations of Water Samples

Tables 2 and 3 display the corrected absorbance readings and nitrate concentrations for the ground and irrigation water samples, respectively.

Table 2. Absorbance Readings of Water Samples for Nitrate Test

Location	Sample	Absorbance (220 nm)				Absorbance (275 nm)				Corrected Absorbance (A220 - A275)
		Trial 1	Trial 2	Trial 3	Ave	Trial 1	Trial 2	Trial 3	Ave	
Brgy. Mangayang	MIWS-01	0.354	0.359	0.364	0.359	0.133	0.137	0.137	0.136	0.223
	MGWS-02 RICE	0.412	0.415	0.406	0.411	0.179	0.181	0.180	0.180	0.231
	MIWS-03 CAMOTE	0.333	0.329	0.331	0.331	0.127	0.125	0.126	0.126	0.205
	MIWS-04 MAIN	0.338	0.347	0.369	0.351	0.139	0.143	0.151	0.144	0.207
Brgy. Gabut	GIWS-01 MAIN	0.462	0.454	0.457	0.458	0.172	0.167	0.165	0.168	0.290
	GIWS-02	0.358	0.359	0.355	0.357	0.134	0.132	0.132	0.133	0.225

Table 3. Nitrate Concentrations of Water Samples

Location	Sample	Equation	Nitrate Concentration (mg/L)
Brgy. Mangayang	MIWS-01	$f(x) = 0.195x + 0.177$	0.236
	MGWS-02 RICE	where x is the Nitrate concentration and $f(x)$ is the corrected absorbance	0.277
	MIWS-03 CAMOTE		0.144
	MIWS-04 MAIN		0.154
Brgy. Gabut	GIWS-01 MAIN		0.579
	GIWS-02		0.246

It is worth noting in Table 3 that GIWS-01 MAIN, irrigation water collected from Gabut, contains the most dissolved nitrate per liter of irrigation water. However, all water sites have dissolved nitrate levels that are significantly lower than the acceptable levels of class C waters based on DENR-AO No. 2016-08, which is 7 mg/L.

B. Nitrate Concentrations of Farmland Soil Samples

The corrected absorbance readings and nitrate concentrations for the farmland soil samples are presented in Tables 4 and 5, respectively.

Table 4. Absorbance Readings of Farmland Soil Samples for Nitrate Test

Location	Sample	Absorbance (220 nm)				Absorbance (275 nm)				Corrected Absorbance (A220 - A275)
		Trial 1	Trial 2	Trial 3	Ave	Trial 1	Trial 2	Trial 3	Ave	
Brgy. Mangayang	MSS-01	3.696	3.699	3.701	3.699	3.398	3.398	3.398	3.398	0.301
	MSS-02	3.523	3.523	3.523	3.523	3.301	3.301	3.301	3.301	0.222
	MSS-03	3.620	3.622	3.622	3.621	3.385	3.386	3.388	3.386	0.235
	MSS-04	3.549	3.550	3.549	3.549	3.101	3.103	3.100	3.101	0.448
	MSS-05	3.613	3.611	3.611	3.612	3.370	3.371	3.371	3.371	0.241
Brgy. Gabut	GSS-01	3.319	3.315	3.317	3.317	3.088	3.085	3.089	3.087	0.23
	GSS-02	3.566	3.570	3.566	3.567	3.322	3.322	3.320	3.321	0.246

Table 5. Nitrate Concentrations of Farmland Soil Samples

Location	Sample	Equation	Nitrate Concentration (mg/kg)
Brgy. Mangayang	MSS-01	f(x) = 0.195x + 0.177	0.636
	MSS-02	where x is the Nitrate concentration and f(x) is the corrected absorbance	0.231
	MSS-03		0.297
	MSS-04		1.390
	MSS-05		0.328
Brgy. Gabut	GSS-01		0.272
	GSS-02		0.354

It is also worth noting in Table 5 that MSS-04 has the highest soil nitrate concentration among the farmland soil samples obtained. However, all soil samples fall significantly below the acceptable levels of nitrate in the soil, which is 10-50 mg/kg (HORIBA Instruments Singapore, 2015).

Section 2. Phosphate Concentration

Table 6 shows the absorbance readings of the phosphate standard at 650 nm.

Table 6. Concentrations and Absorbances of Phosphate Standard

Concentration (mg/L)	Absorbance (650 nm)			
	Trial 1	Trial 2	Trial 3	Average
0	0.056	0.050	0.047	0.051
3	0.095	0.098	0.096	0.096
4.5	0.128	0.122	0.128	0.126
6	0.167	0.170	0.165	0.167
12	0.202	0.205	0.202	0.203
15	0.243	0.240	0.248	0.244

A standard curve is constructed based on the absorbance readings of the phosphate standard. The equation of the trendline was used in determining the phosphate concentration of unknown samples. Figure 2 illustrates the standard curve obtained from the phosphate standard.

Figure 1. Standard Curve of Phosphate Standard

f(x) = 0.012 x + 0.066
R^2 = 0.952
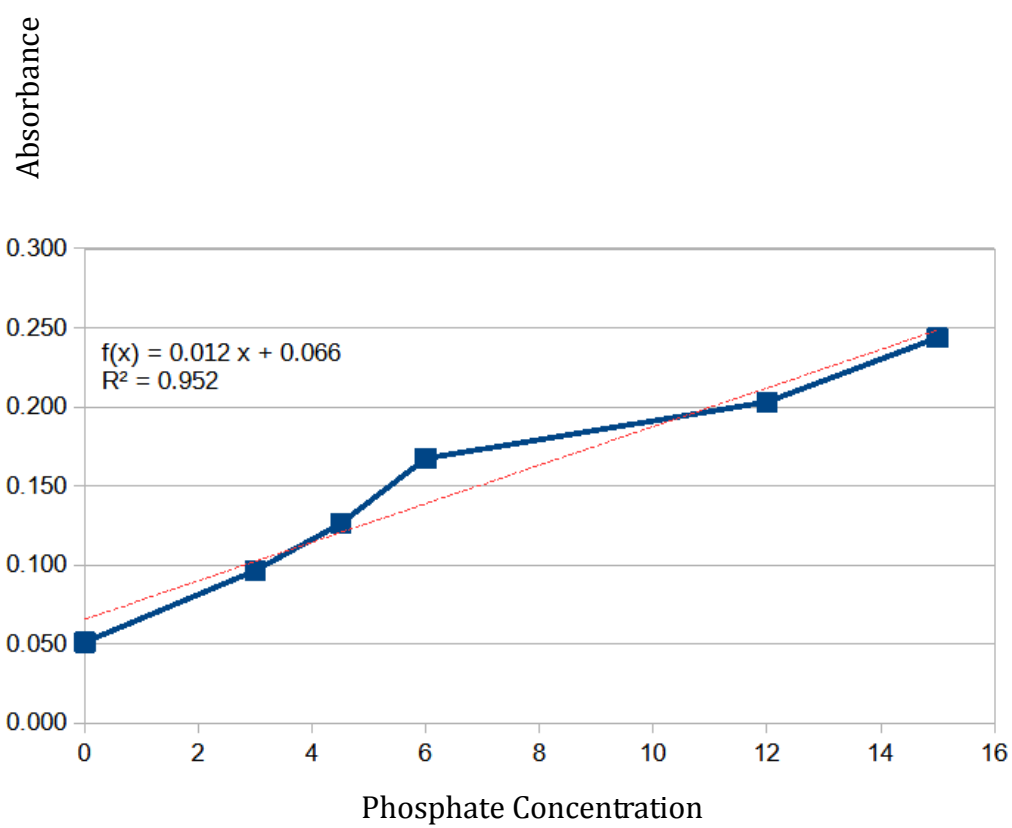
The procedure for determining the absorbance phosphate standard was applied to the water and farmland soil samples collected from different identified sites in Dupax del Sur.

A. Phosphate Concentrations of Water Samples

Tables 7 and 8 display the absorbance readings at 650 nm and phosphate concentrations for each of the ground and irrigation water samples, respectively.

Table 7. Absorbance Readings of Water Samples for Phosphate Test

Location	Sample	Absorbance (650 nm)			
		Trial 1	Trial 2	Trial 3	Average
Brgy. Mangayang	MIWS-01	0.083	0.083	0.082	0.083
	MGWS-02 RICE	0.087	0.088	0.087	0.087
	MIWS-03 CAMOTE	0.089	0.087	0.089	0.088
	MIWS-04 MAIN	0.082	0.083	0.082	0.082
Brgy. Gabut	GIWS-01 MAIN	0.087	0.088	0.087	0.087
	GIWS-02	0.081	0.083	0.081	0.082

Table 8. Phosphate Concentrations of Water Samples

Location	Sample	Equation	Phosphate Concentration (mg/L)
Brgy. Mangayang	MIWS-01	$f(x) = 0.012x + 0.066$	1.416
	MGWS-02 RICE	where x is the phosphate concentration and f(x) is absorbance	1.75
	MIWS-03 CAMOTE		1.833
	MIWS-04 MAIN		1.333
Brgy. Gabut	GIWS-01 MAIN		1.75
	GIWS-02		1.333

It is worth noting in Table 8 that MIWS-03 CAMOTE, groundwater sample from Mangayang, contains the most dissolved phosphate per liter of irrigation water. However, all water samples sites have dissolved phosphate levels that are higher than the acceptable levels of class C waters based on DENR-AO No. 2016-08, which is 0.5 mg/L.

B. Phosphate Concentrations of Farmland Soil Samples

Tables 9 and 10 show the absorbance readings at 650 nm and phosphate concentrations for each of the farmland soil samples, respectively.

Table 9: Absorbance Readings of Farmland Soil Samples for Phosphate Test

Location	Sample	Absorbance (650 nm)			
		Trial 1	**Trial 2**	**Trial 3**	**Average**
Brgy. Mangayang	MSS-01	0.107	0.075	0.080	0.087
	MSS-02	0.118	0.122	0.152	0.131
	MSS-03	0.102	0.136	0.109	0.116
	MSS-04	0.128	0.158	0.129	0.138
	MSS-05	0.073	0.074	0.076	0.074
Brgy. Gabut	GSS-01	0.089	0.087	0.118	0.098
	GSS-02	0.229	0.229	0.226	0.228

Table 10: Phosphate Concentrations of Farmland Soil Samples

Location	Sample	Equation	Phosphate Concentration (mg/kg)
Brgy. Mangayang	MSS-01	$f(x) = 0.012x + 0.066$	1.75
	MSS-02	where x is the phosphate concentration and f(x) is absorbance	5.42
	MSS-03		4.16
	MSS-04		6.0
	MSS-05		0.6
Brgy. Gabut	GSS-01		2.6
	GSS-02		13.5

GSS-02 has the most phosphate present in its farmland soil among the farmland sites the samples are obtained from. Meanwhile, MSS-02 obtained the highest phosphate concentration among farmland sites in Brgy. Mangayang may be attributed to the presence of piggery and duck poultry. However, all farmland sites exhibit phosphate levels below the recommended amount which is 25 to 50 mg/kg.

Section 3. Comparisons of Nitrate and Phosphate Concentrations

Table 11. t-Test Results for Nitrate and Phosphate Concentrations of the Water Samples

in the two Barangays

Concentration in Water Sample	Site	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Nitrate	Mangayang	4	.20275	.064412	-1.237	1.076	.422
	Gabut	2	.41250	.235467			
Phosphate	Mangayang	4	1.5830	.24548	.185	4	.862
	Gabut	2	1.5415	.29486			

The t-test results in Table 11 show that the nitrate and phosphate concentrations of the water samples obtained from the different irrigation sites in Barangays Mangayang and Gabut are not significantly different from each other with p-values greater than 0.05.

Table 12. t-Test Results for Nitrate and Phosphate Concentrations of the Soil Samples

in the two Barangays

Concentration in Soil Sample	Site	N	Mean	Std. Deviation	t (df = 5)	Sig. (2-tailed)
Nitrate	Mangayang	5	.57640	.480772	.731	.498
	Gabut	2	.31300	.057983		
Phosphate	Mangayang	5	6.1660	4.41296	1.365	.230
	Gabut	2	1.6000	1.41421		

Table 12 reflects the t-test results which indicate that the nitrate and phosphate concentrations in the different soil samples gathered in Barangays Mangayang and Gabut are not significantly different from each other with p-values greater than 0.05.

The different nitrate and phosphate concentrations were compared with the acceptable levels. Tables 13 and 14 show the one-sample t-test results for the water and soil samples, respectively.

Table 13. One-sample t-test Results on the Water Samples

Sample	N	Mean	Std. Dev.	Test value	t	df	Sig. (2-tailed)	Mean Difference
NitrateW	6	.27267	.159092	7	-103.579	5	.000	-6.727333
PhosphateW	6	1.5692	.23239	0.5	11.270	5	.000	1.06917

The results in Table 13 indicate that the mean nitrate concentration of the six water samples of .27 mg/L is significantly lower than the recommended level of 7 mg/L (p < .001). While the mean phosphate concentration of 1.57 mg/L is significantly higher than the acceptable level of 0.5 mg/L (p < .001).

Table 14. One-sample t-test on the Soil Samples

Sample	N	Mean	Std. Dev.	Test value	t	df	Sig. (2-tailed)	Mean Difference
NitrateS	7	.50114	.413731	25	-156.667	6	.000	-24.498857
PhosphateS	7	4.8614	4.27551	25	-12.462	6	.000	-20.13857

Table 14 reflects the results indicating that the mean nitrate concentration of the seven soil samples of .50 mg/kg is significantly lower than the recommended level of 25 mg/kg (p < .001). While the mean phosphate concentration of 4.86 mg/L is significantly higher than the acceptable level of 0.5 mg/L (p < .001).

The nutrient status map by the Bureau of Soils and Water Management of the Department of Agriculture (2017) shows low to moderately low dissolved nitrogen levels in Dupax, Nueva Vizcaya farm soils, consistent with the findings of the study. Although nitrates are more soluble in water and can leach towards groundwater or irrigation water, the low levels of dissolvable nitrate and clay-loam soil in Dupax del Sur limit the amount

of leached nitrates in irrigation water, which mainly consist of dissolved nitrates from organic matter that were minimized during analysis (Geisseler & Horwath, 2016).

On the other hand, the nutrient status map by the Bureau of Soils and Water Management of the Department of Agriculture (2017) shows varying but mostly low levels of dissolved soil phosphorus in Dupax, Nueva Vizcaya, consistent with the study results. Despite the low phosphate concentration in farmland soil, the study found high levels of dissolved phosphate in irrigation water in some areas of Dupax del Sur, which could be caused by multiple farmland surface runoff events that have occurred – resulting in low dissolved phosphate in the soil but high dissolved phosphate in groundwater (Chakraborty, 2022).

5. Conclusion

The study found that the dissolved nitrate concentrations in both irrigation water sources and farmland soils for both barangays were below recommended levels, with no statistically significant difference. It can be concluded that nitrates from the soil obtained from the two communities are nearly depleted, and there are low amounts of nitrate that can be leached through various water sources - leading to low concentrations of dissolved nitrate in the irrigation water as well. Soil phosphate concentrations in all sampled farmlands were below recommended levels, but dissolved phosphate concentrations in all sampled irrigation water sites were significantly above recommended. The differences in soil and water phosphate concentrations may be due to a separate irrigation source experiencing multiple runoffs and leaching events, increasing its dissolved phosphate.

6. Acknowledgements

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8. Appendices

None

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Road-FMS: Distributed Road Flood Monitoring and Reroute System with Centralized Warning Network

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Abstract

Flooding is a highly destructive natural disaster that poses a significant threat worldwide. With heavy rainfall accompanying tropical storms, rivers overflow, resulting in widespread flood damage and flash floods that endanger large populations. Tuguegarao City, the capital of the Cagayan province, experiences rapid flood inundation during heavy rainstorms, primarily due to insufficient road infrastructure and environmental deviations. To address this issue, a distributed road flood monitoring and reroute system has been developed, focusing on monitoring flood conditions in specific areas and providing drivers with alternative routes when roads become impassable. The system comprises two deployed devices located in Barangay Atulayan Sur and Linao East of Tuguegarao City. The utilize water-based ultrasonic sensors and ESP8266 Wi-Fi modules, which connect to ThingSpeak, a cloud-based Internet-of-Thngs (IoT) analytics software. ThingSpeak collects and analyzes data from the monitoring stations, offering real-time flood updates through mobile and web-based services. To communicate crucial information, the system leverages the ITEXTMO API service provider to send text messages to residents within the barangay, successfully delivering messages at intervals of one to three minutes. Additionally, when road lanes become inaccessible, the system proposes alternative paths, while the web program provides users with detailed information about flood and traffic conditions in specific areas, suggesting the best alternate routes. The implementation of this system enhances Tuguegarao City's ability to respond effectively to flooding events, ensuring the safety of its residents and mitigating the devastating impact of this natural disaster.

Keywords : road flood, ultrasonic sensor, flood monitoring, text messaging, Internet-of-Things

1. Introduction

Flooding is a globally recognized and hazardous natural disaster, often caused by heavy rainfall during typhoons and monsoons. This leads to river overflow and sediment deposition, resulting in devastating flood damage and flash floods that put a significant portion of the population at risk (Ardales et al., 2016). Tuguegarao City, the capital of the Cagayan province, experienced severe flooding during the 2020 typhoon Ulysses, with some areas submerged by over 4.5 meters of water. The release of floodgates from the nearby Magat Dam exacerbated the situation, making Tuguegarao City particularly vulnerable (Macaraeg, 2020). The extensive flooding rendered bridges and roads impassable, causing significant disruptions to transportation and incurring substantial infrastructural damage, with an estimated cost nearing P6 billion and close to 30 road sections being closed (Manila Bulletin, 2020).

Several technologies already exist for road flood monitoring and information systems. For instance, Abana et al., (2019) developed a system to measure flood depth,

assess road accessibility, and send notifications via social media. However, this paper proposes a novel approach by enabling the system to send warnings directly to residents in specific barangays through text messages. It also features a dedicated website that displays traffic routes with color-coded indicators based on flood levels and suggests alternative routes when road lanes become impassable. Another study in Metro Manila focuses on designing a Remote Station for Real-time Monitoring of Urban Flooding (Retamar et al., 2014). However, the previous research lacks comprehensive data collection during extreme rain conditions and lacks visualization methods such as historical data analysis and smartphone applications for on-the-road alerts.

To address these gaps, this study aims to develop a flood monitoring system that provides an alternate route when water levels exceed a specific threshold, rendering roads impassable. Additionally, it will send text messages to residents of the specific barangay, keeping them informed about road conditions. The study also introduces a centralized warning network where data from the flood monitoring systems will be directly sent to a website accessible to everyone. This website aims to provide motorists and citizens with real-time information about road conditions and flood level estimations, assisting in decision-making and enhancing overall flood monitoring capabilities. By improving real-time flood monitoring, early detection of impassable roads, and suggesting alternate routes, this study strives to mitigate traffic issues and ensure public safety during flooding events.

2. Objectives

This study designs and develops a comprehensive road flood monitoring system with a centralized warning network. Specifically, it aims to achieve the following objectives:

1. Assess the flood level status on the road accurately and effectively.
2. Evaluate the response time and effectiveness of SMS notifications and advisories sent to the constituents of the barangay regarding the road status.
3. Provide real-time updates on traffic routes status and offer rerouting directions through a dedicated website.

3. Materials and methods

Figure 1 showcases the interconnected components of the Road-FMS (Road Flood Monitoring System). The system comprises various electronic modules, including a microcontroller, ultrasonic sensor, LED matrix, and Wi-Fi shield. The microcontroller utilizes the Wi-Fi shield to establish internet connectivity, while the ultrasonic sensor measures the water depth. The collected data is analyzed by the ultrasonic sensor, which then transmits the relevant information to mobile phones. The system utilizes SMS to send warnings and provides more comprehensive details through the dedicated website.

The SMS functionality plays a crucial role in managing safety by facilitating data transmission from the monitoring system to the computer server and delivering notifications to concerned residents. An SMS application is installed on the computer server to process the received data and take appropriate actions based on the information. This systematic approach ensures efficient data management and timely responses to flood-related situations, enhancing the overall effectiveness of the Road-FMS.
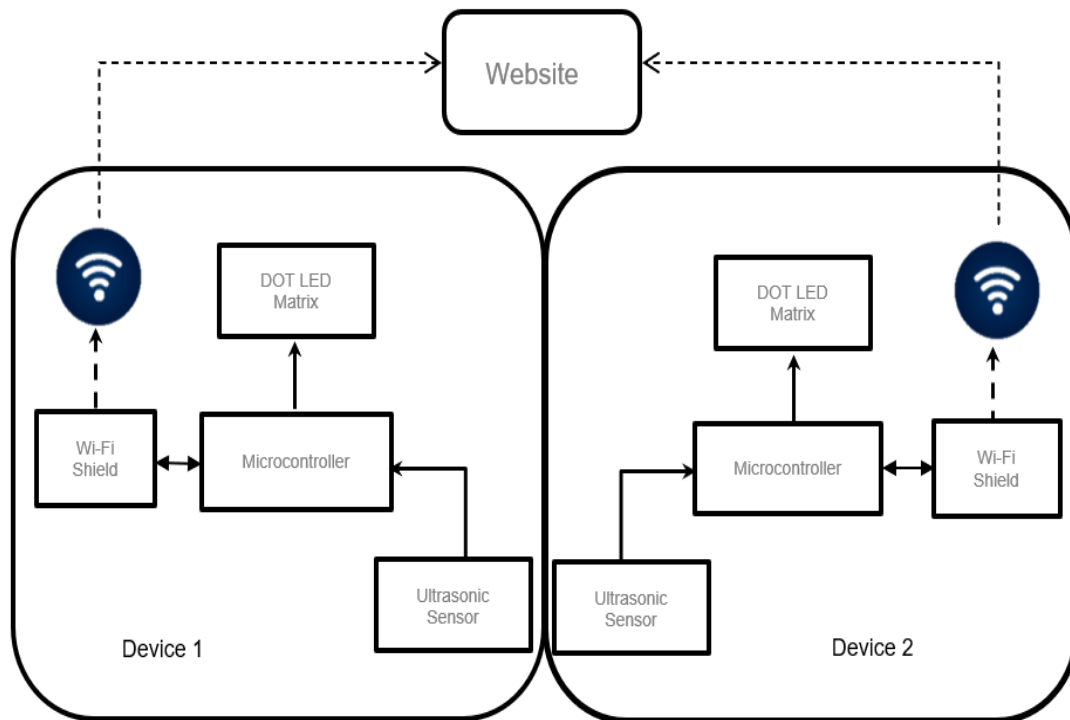
Figure 1 Block Diagram of the System

Figure 2 shows a flood gauge, which serves as the standardized measurement system for assessing flooding in Metro Manila, as implemented by the Metro Manila Development Authority (MMDA). This flood gauge plays a crucial role in evaluating road accessibility by monitoring rising water levels. The estimation of flood depth is determined concerning the average human height, providing a consistent and reliable basis for assessment. According to the MMDA flood gauge, if the flood level remains below half-knee height, which is approximately less than 13 inches, all types of vehicles can still navigate through the flooded lane. However, once the flood level reaches 13 to 19 inches, small cars are no longer able to traverse the road. When the flood depth exceeds 19 inches, the road becomes completely impassable for all vehicle types. This standardized system ensures clarity and uniformity in determining the safety and usability of roads during flooding incidents.

In this study, the MMDA flood gauge was utilized as the primary tool for assessing and reporting flood levels. By incorporating this established measurement system, the assessment and reporting process becomes more accurate and consistent, facilitating efficient decision-making and enhancing public safety during flood events.

**Figure 2** Metro Manila Development Authority Flood Gauge

The development of the system involved the use of various IDEs (Integrated Development Environments) to create and manage the code and components. One of the key IDEs used was the Arduino Uno IDE, which is the official software from Arduino.cc. This IDE allowed for authoring, compiling, and uploading code to the Arduino modules and boards. The system code was created in the Arduino Uno IDE and then uploaded to the microcontroller, enabling it to run and interact with sensors and other components effectively. Additionally, JavaScript was used as a programming language for web page interaction. It provided dynamic behavior and functionality, allowing users to interact seamlessly with web pages. Furthermore, the development process incorporated the CodeIgniter framework, a PHP MVC (Model-View-Controller) framework. CodeIgniter facilitated the rapid creation of web applications, with built-in libraries for tasks such as database connectivity, email handling, file uploading, and session management. HTML5, a programming language for building web pages, was used to customize the appearance and structure of the system's web pages, ensuring an enhanced user experience. Lastly, MySQL, a relational database management system (RDBMS), was utilized for organizing and managing data in databases. MySQL's connectors and drivers made it a popular choice for efficient data management in various applications.

Table 1 Notification Points

Water Level	Indicator	Message
Low (0.5-1.2ft.)	Green	Name of Barangay
		Flood Level in the Road
		Passable to All Types of Vehicles
Moderate (1.3-1.9ft.)	Orange	Name of Barangay
		Flood Level in the Road
		Not Passable to Light Vehicles
High (2 ft. and above)	Red	Name of Barangay
		Flood Level in the Road
		Not Passable to All Types of Vehicles

Table 1 presents a comprehensive overview of the flood status on the road, accompanied by message notifications and traffic route indicators. The indicators use different colors to denote various conditions: green signifies a normal condition, orange indicates a critical condition, and red represents a dangerous condition. The table also displays the specific message that will be sent to constituents when the flood level on the road reaches the water level warning as indicated by the system.
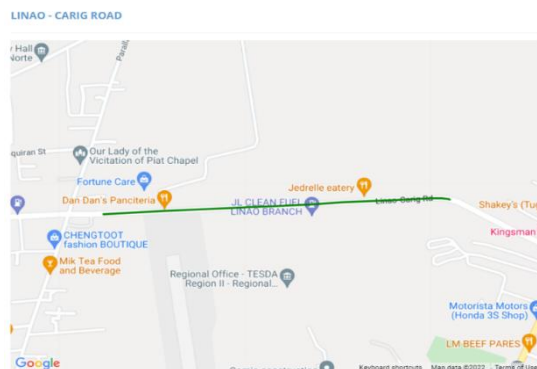
Figure 3 Location of the First System
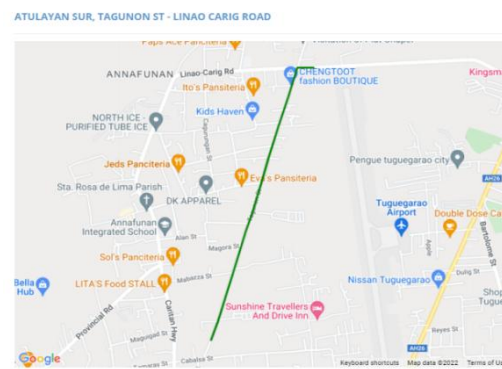
Figure 4 Location of the First System

Figure 3 depicts the placement of the first system along the Linao-Carig Road. This strategic location was selected due to its significance as a primary route frequently used by motorists and drivers, making it highly susceptible to flooding. When this road becomes flooded, the nearby areas are also affected. System 1 serves to monitor and assess the flood situation specifically along the Linao-Carig Road, enabling real-time monitoring and data collection. Similarly, Figure 4 showcases the positioning of the second system in Atulayan Sur, an area with a substantial population and prone to flooding. Once the water level reaches the predetermined threshold set in the system, an early warning signal is transmitted. Should the flood escalate beyond a certain limit, the system will offer an alternative route, mirroring the functionality of the first system. System 2 effectively

monitors and provides critical flood information for Atulayan Sur, encompassing Tagunon Street to Linao-Carig Road. The strategic placement of these systems ensures comprehensive flood monitoring coverage for these vulnerable areas, allowing for timely alerts and the provision of alternative routes to ensure the safety and convenience of motorists and residents.

4. Results and Discussion

Figure 5 showcases the Road-FMS, which plays a crucial role in the flood monitoring system. Upon activation, the system initiates the functioning of the sensor. The ultrasonic sensor, known for its reliability and cost-effectiveness, is employed to accurately measure the water level in the flooded road. This sensor serves as a vital instrument for this specific application. Once the water level is detected, the data is transmitted to the local server and subsequently stored in the database for further analysis. In the database, the sensor measurements are categorized based on the corresponding rainfall measurements obtained from the MMDA flood gauge. This classification allows for a comprehensive understanding of the flood situation. To ensure effective dissemination of information, the system incorporates a centralized warning network. This network facilitates the sharing of detected information from multiple systems, providing people with valuable knowledge regarding the flood conditions. This feature enhances overall awareness and helps individuals make informed decisions based on the real-time data collected from various monitoring points. The Road-FMS system, with its sensor capabilities and integration into the centralized warning network, plays a critical role in the flood monitoring system, enabling prompt responses and enhancing public safety measure.

Figure 4 Road-Flood Monitoring System

To verify the accuracy of the system in calculating the flood depth, rigorous testing was conducted, comparing the measured flood depth obtained from the system with the actual flood depth. In Table 2, the measured flood depth was determined using a measuring tape, while the actual flood depth was obtained through the system's measurement. Through multiple trials, it was observed that the measured flood depth closely matched the actual flood depth, indicating the system's reliable accuracy in its calculations. These results provide confidence in the system's ability to accurately measure and report the flood depth in real-time. The testing process served to validate the system's performance and its suitability for effective flood monitoring applications. By ensuring accurate measurements, the system can contribute to enhanced flood prediction, early warning systems, and improved decision-making processes to mitigate the impacts of flooding.

Table 2 Flood Depth Measures

| Trials	Measured Flood Depth (ft)	Actual Flood Depth(ft)	Accuracy
1	0.42	0.41	97.62
2	0.67	0.64	95.52
3	0.83	0.82	98.80
4	0.92	0.90	97.83
5	1.00	0.98	98.00
6	1.17	1.15	98.29
7	1.25	1.24	99.2
8	1.38	1.37	99.28
9	1.42	1.39	97.89
10	1.55	1.53	98.91
11	1.74	1.71	97.71
12	1.85	1.84	99.46
13	1.92	1.90	98.96
14	2.17	2.15	99.08
15	2.25	2.24	99.5
16	2.33	2.30	98.71
17	2.50	2.47	98.8
18	2.68	2.67	99.63
19	2.87	2.84	98.95
20	3.00	2.96	98.67

The road flood monitoring system demonstrated a high level of accuracy in measuring the depth of the flood using the ultrasonic sensor, with an average accuracy of 98.94%. This accuracy is comparable to the average accuracy of 98.69% achieved by a previous study (Hanshim et al., 2013) that also utilized an ultrasonic sensor for detecting water depth. The use of an ultrasonic sensor proves advantageous in flood depth measurement due to its ability to detect the actual depth of the flood at any given time. In contrast, a water level sensor (Hanshim et al., 2013) relies on the water reaching a certain level before the depth can be accurately detected. Furthermore, compared to a water level sensor (Hanshim et al., 2013) and a barometric pressure sensor, the ultrasonic sensor does not require physical contact with the water to measure the flood depth. This characteristic safeguards it from being displaced or compromised during severe flooding. The exceptional accuracy and non-contact measurement capability of the ultrasonic sensor make it an ideal choice for flood monitoring applications. By reliably capturing precise flood depth data, the system can contribute to improved flood forecasting, early warning systems, and effective decision-making processes aimed at mitigating the impact of flooding events.

Table 3 SMS Latency

Trials	Message Sent	Message Receive	Latency
1	Yes (3:07 pm)	Yes (3:09 pm)	2 minutes
2	Yes (11:45 pm)	Yes (11:47 pm)	2 minutes
3	Yes (11:23 am)	Yes (11:26 pm)	3 minutes
4	Yes (9:25 am)	Yes (9:26 am)	1 minute
5	Yes (9:39 am)	Yes (9:41 am)	2 minutes
6	Yes (9:50 am)	Yes (9:51 am)	1 minute
7	Yes (4:33 pm)	Yes (4:35 pm)	2 minutes
8	Yes (4:50 pm)	Yes (4:52 pm)	2 minutes
9	Yes (5:04 pm)	Yes (5:07 pm)	3 minutes
10	Yes (3:11 pm)	Yes (3:12 pm)	1 minute
11	Yes (3:22 pm)	Yes (3:23 pm)	1 minute
12	Yes (3:38 pm)	Yes (3:40 pm)	2 minutes
13	Yes (6:12 pm)	Yes (6:15 pm)	3 minutes
14	Yes (6:32 pm)	Yes (6:34 pm)	2 minutes
15	Yes (6:47 pm)	Yes (6:49 pm)	2 minutes
16	Yes (9:58 am)	Yes (10:00 am)	2 minutes
17	Yes (10:14 am)	Yes (10:16 am)	2 minutes
18	Yes (10:28 am)	Yes (10:31 am)	3 minutes
19	Yes (2:09 pm)	Yes (2:10 pm)	1 minute

Trials	Message Sent	Message Receive	Latency
20	Yes (2:17 pm)	Yes (2:19 pm)	2 minutes

The SMS latency of the system is shown in Table 3. This latency is the amount of time it takes for the message to be delivered to the intended customer system. The SMS notification integrated into this system provides a valuable means of conveying information to concerned parties in the event of potential floods. Unlike previous studies on early warning systems utilizing GSM modules for message transmission to residents (Pagatpat, Arrelano, & Gerasta, 2015), this system utilizes various platforms to deliver SMS notifications. To facilitate SMS notifications, the system incorporates ITEXTMO, an SMS API service provider that establishes a seamless connection between the system and its recipients through a simple API. By leveraging this approach, the system can send SMS notifications without the need for specific hardware or complex coding requirements, ensuring efficient and reliable communication. The utilization of an SMS notification system enhances the responsiveness and reach of the road flood monitoring system. By integrating with an easy-to-use SMS API service provider, the system can effectively disseminate critical information to concerned parties, enabling timely alerts and proactive measures to be taken in response to potential flood situations.
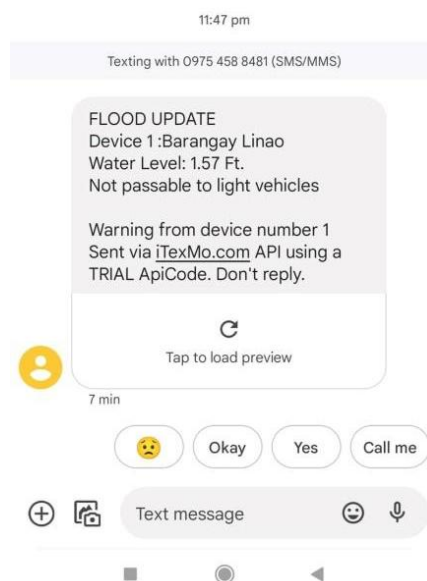

Figure 4 Road-Flood Monitoring System SMS information

Individuals with concerns about potential flood disasters can utilize the SMS application to obtain real-time information. By sending a message with the keyword "Flood Update," the system promptly responds with an informative message containing essential details. These details include the alert level, flood warning status, and the locations of flood-affected roads. Figure 5 visually depicts an example of the "Flood Update" message that is generated when the water depth surpasses the normal level. This feature empowers individuals to stay informed about the current flood situation and take necessary precautions accordingly.
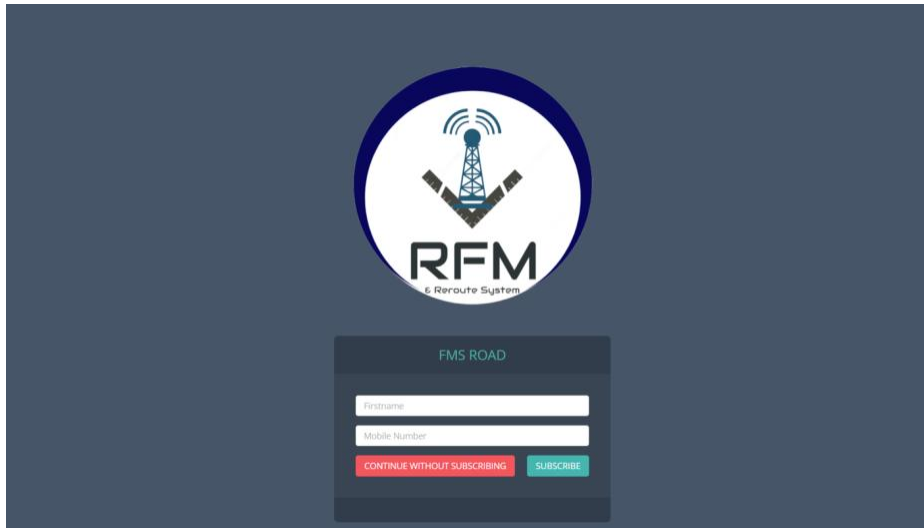
Figure 5 Road-Flood Monitoring System Website

The web-based monitoring system shown in Figure 5 is a comprehensive system that provides users with valuable flood-related information, including water levels, affected areas, and the status of flooded roads. The website features an interactive map that displays traffic routes, with distinct warning colors that dynamically activate based on the measurement readings. This intuitive design allows users to quickly assess the severity of the flood situation and make informed decisions regarding their travel routes.
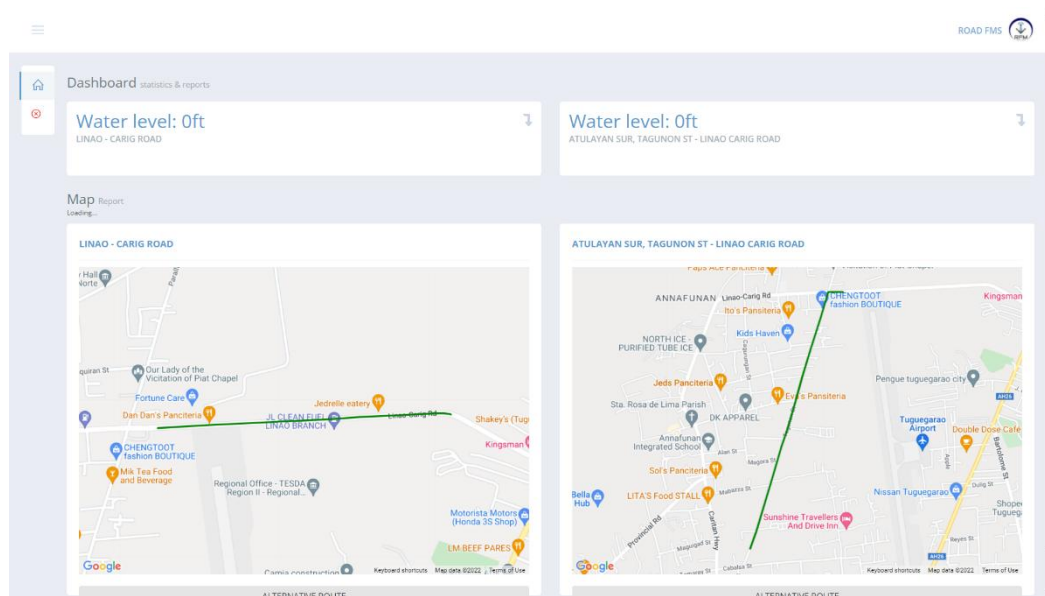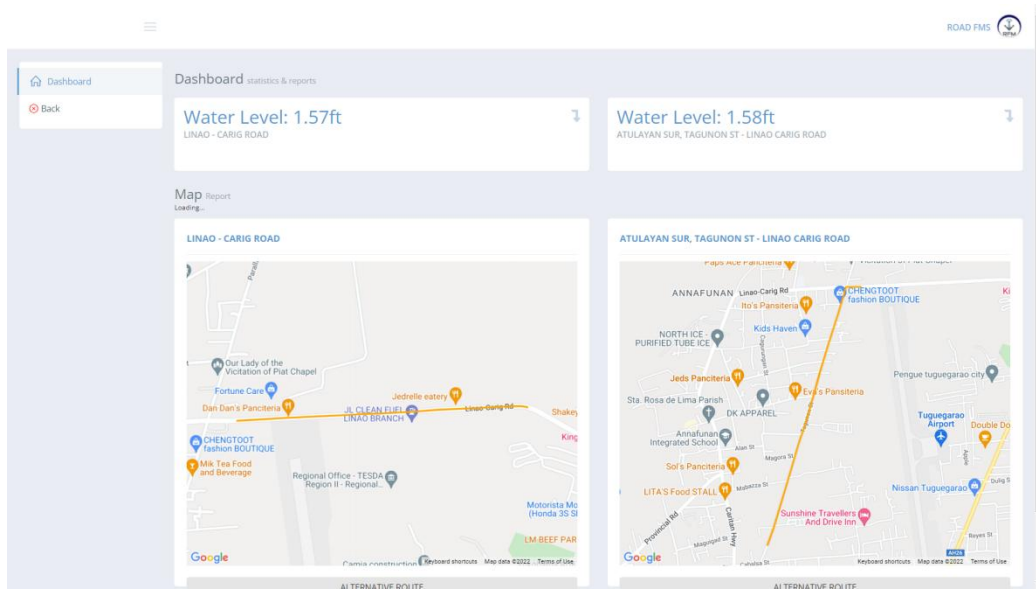

Figure 6.1 First warning indicator

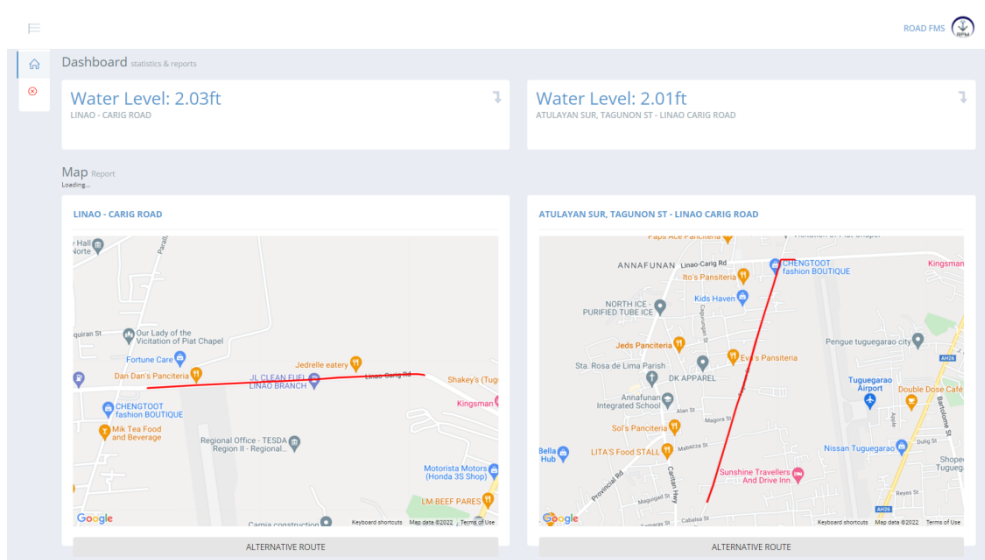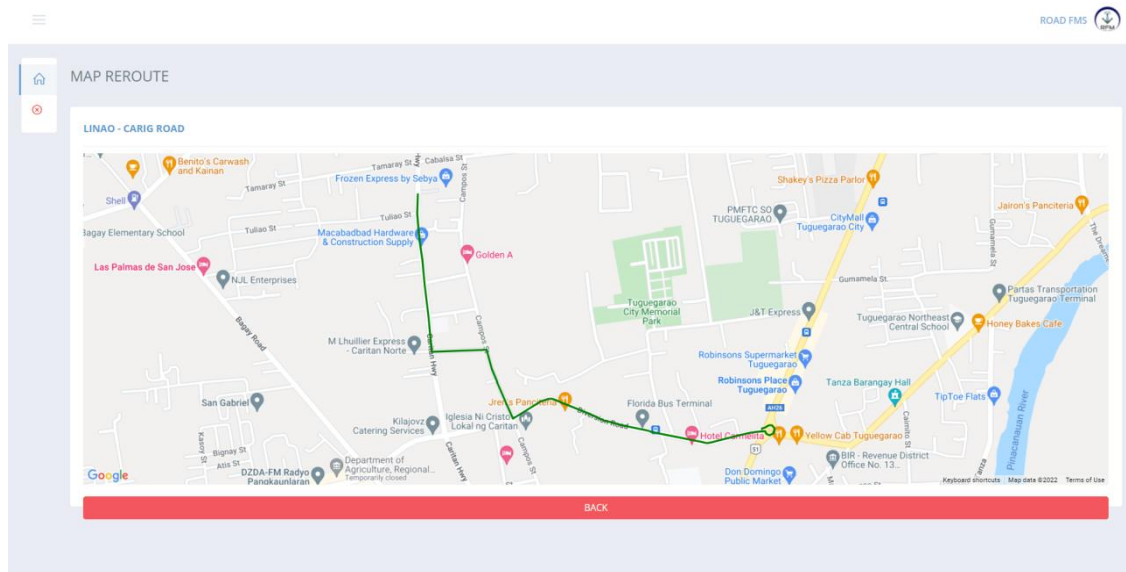**Figure 6.2** Second warning indicator

Figure 6.3 Third warning indicator

Figure 6.4. Alternative Route

Figure 6.1 illustrates both systems positioned in the first warning indicator, denoted by a green color. This indicates that the flood depth is currently at 1 foot or below, allowing all types of vehicles to pass through the road safely. In Figure 6.2, the second warning of the system is displayed, indicating a flood depth of 1.1 feet on the road. When the flood depth ranges from 1.1 to 1.99 feet, the road lane changes to orange, signaling that light vehicles are no longer able to traverse the road. Moving to Figure 6.3, if the flood level in the road exceeds 2 feet, the road lane is shown as red, indicating that it is impassable for all types of vehicles. Additionally, Figure 6.4 showcases the alternate route when the first system located at Barangay Linao becomes inaccessible. The website utilizes a static algorithm to determine the alternative route. Static routing does not require frequent changes to the routing table and provides enhanced security compared to dynamic routing, as it avoids the need for complex routing algorithms.

5. Conclusion

The results showed the effectiveness of the road flood monitoring system in providing real-time flood depth information and corresponding warnings. The color-coded indicators accurately depict the flood levels, enabling motorists to make informed decisions about road accessibility. The system's ability to differentiate between safe, restricted, and impassable conditions enhances overall safety and mitigates potential risks associated with flooding. Furthermore, the utilization of a static algorithm for determining alternate routes ensures reliable and secure navigation, as it avoids the complexities of dynamic routing algorithms.

Based on the findings, it is recommended to further enhance the system by incorporating additional features that promote proactive flood management. Integration of real-time weather data and forecasts can provide valuable insights for predicting and responding to flood events more effectively. Expanding the coverage of monitoring systems to strategic locations prone to flooding would enhance the system's overall accuracy and reliability. Additionally, exploring the possibility of integrating mobile applications alongside the web-based system can extend the reach of flood warnings and facilitate easier access to information for concerned individuals. These recommendations would further strengthen the system's capabilities and contribute to a more robust and comprehensive flood monitoring and warning system.

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Judicial Assimilation of the Mainstreamed Aetas of Cagayan in the Katarungang Pambarangay

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Abstract

Aeta Communities is known for its nomadic lifestyle. Their settlement from one place to another affects their cultural and judicial practices. Contemporarily, Aeta Communities has been assimilated to the justice system of the mainstream society due to their resettlement. With the emergence of Katarungang Pambarangay (Village Justice) as an alternative dispute resolution of the Philippines, it is an interesting study to ponder the judicial profile of the Aeta Community who were assimilated in the Katarungang Pambarangay. This study is a qualitative endeavor to explore the dispute resolution practices of the mainstreamed Aetas when assimilated to the Katarungang Pambarangay. This study utilized a basic qualitative design. The result revealed that the Aeta Communities practices justice system of their indigenous culture and the Katarungang Pambarangay. The blending of both systems allows for a smoother conflict settlement system. This result signifies that despite their judicial assimilation to the mainstream community, their method of conflict resolution is still influenced by their indigenous practices. This provides an empirical understanding on how they are able to settle conflict in a harmonious way without going through the intricacies of formal courts. It allows the local government unit to devise a better framework on alternative dispute resolution.

Keywords : Barangay, Katarungang Pambarangay, Indigenous People, Justice System, Alternative Justice System

1. Introduction

Justice is a fundamental element that maintains the moral balance in a society. It is a legal framework created to determine who shall be accorded with a benefit or burden in a conflict (Wex Definition Team, 2020). Correspondingly, the concept of justice varies across different nations (Parnami, 2019). In the Philippines, the justice system is delivered in the form of an adversarial justice system. In this system, legal offense is applied to a malefactor to pacify the victim and fulfill society's need for retribution (Hand et al., 2012). The Adversarial system is viewed as fair, logical, and worthy to be used for reaching a judgment (Khan, 2012). However, studies show that while the adversarial justice system best caters the conflicts in a heterogeneous society, this system transgresses the conflict management of the Indigenous Peoples [IPs; Alfred, 2009; Friedland, 2014; Green, 2011; Hand et al., 2012; McGuire & Palys, 2020]. Thus, the Philippine Government established an alternative dispute resolution (ADR) which serves as a conflict settlement tool in a community level. ADR includes arbitration, mediation, conciliation, and other alternative means to resolve issues and conflicts within a community. The Katarungang Pambarangay, a restorative justice system, is an example of ADR and is a mechanism of rural conciliatory tools in a community (Guia & Mangubat, 2021). It is a system of dispute resolution at a community level which functions to aid the court in attaining a speedy disposition of justice and unclog court dockets from criminal and civil cases (De Torres & Del Rosario, 2019; Mohammed & Caingat, 2017). Along the contours of these contentions, the lack of commitment in delivering essential social services continuously prejudice the IPs (Drbohlav & Hejkrlik, 2017; Carino, 2012; Rey, 2010).

IPs occupy 10% to 20% of the Philippine population ("Indigenous People," 2020). They are described as indigenous groups in a modern society who have unique languages, traditions, and customs (Ellington, 2019), seek to uphold discrete beliefs (Benter et al., 2020; Bodley, 2008), and have a special relationship with their communal territory (Carino, 2012; Molintas, 2004). One of the most recognizable tribal communities in the Philippines are the Aeta Communities (Balilla, et al., 2013). Political autonomy and self-sufficiency are some of their primary advocacies which are fundamental elements for their right to self-determination (Corntassel & Hopkins, 1995; Rio, 2016). However, in the recent years, roughly 20 million people are forced to be relocated due to development projects (Cernea & Maldonado, 2018) and a proportion of the displaced people are identified as indigenous (Hagen & Minter, 2019; McCully, 1996; UN, 2009). Additionally, there is a paucity of studies addressing the displacement of hunter-gatherers (Athayde & Silva-Lugo, 2018; Hitchcock & Holm, 1993; Tacey, 2013) who arguably are among the most vulnerable and marginalized indigenous populations (Hagen & Minter, 2019; Headland, 1986; Torres, 2012).

Despite these limitations, IPs push toward the embodiment and maintenance of their own indigenous laws, justice system, alternative dispute resolution, and peacebuilding (Benter et al., 2020; Daytec-Yangot, 2019; Guadamor & Martinez, 2017; Naganag, 2019; Ragandang, 2017; Ty & Bibon-Ruiz, 2022). In recent reckoning, restoration of peace and maintenance of moral symmetry are the primary aims of the justice system in an aboriginal society (Benter et al., 2020). This alternative dispute resolution specifically endeavors to reconcile people who are in conflict with the law back to the community. In spite of such movement, the persistent uprooting of the IPs from their ancestral territories undermines their right to life and identity (Drbohlav & Hejkrlik, 2017). Consequently, these struggles inherently affect their preservation of culture and traditions which are visibly derived from these lands. Thus, logically, land loss has resulted in social, political, and economic marginalization (Carino, 2009; Göcke, 2013; Perera, 2009). The ratification of the Indigenous Peoples Rights Act in 1997 (IPRA Law), which guarantees the rights and protection of IPs, was recognized as a pillar in the continuing advocacy towards indigenous rights (Soriano, 2008).

Philippines legally recognizes and supports indigenous dispute settlement as an alternative dispute resolution as their communal and individual rights for self-governance and self-determination in pursuit of their economic, social, and cultural development (Balilla et al., 2013). In contravention, the existence of such law is inadequate in upholding the protection and promotion of the rights of IPs when compared to the mainstream Filipinos (Yang et al., 2020). This explains the presence of various irregularities causing internal and external conflicts in Aeta communities. Even though indigenous justice systems have survived the twenty-first century, only a dearth of literature specialized in exploring the indigenous judicial system of the mainstreamed Aetas exists. Moreover, few literatures delve on the justice system of Aetas while taking into account their constant displacement and assimilation cases. Thus, this present paper investigates how justice is attained in three (3) of the mainstreamed indigenous communities in the Cagayan Province. It specifically explores their conflict resolution practices imbued by their cultural traditions, resettlement issues, and assimilation to the mainstream justice system, and investigates their modern issues and problems in the execution of these practices.

Accordingly, this study is anchored on the Republic Act No. 9285, otherwise known as Alternative Dispute Resolution Act of 2004. Stipulated in its declaration of policy is to actively promote party autonomy in the resolution of disputes or the freedom of the party to make their own arrangements to resolve their disputes. The purpose of this

law is to sustain the sanctity of identity and self-preservation of the culture and tradition of one of the most vulnerable communities in our modern society. Verily, this framework supports the standpoint of this study in which it entails and promotes the right to self-determination of IPs, as enshrined in Section 5, paragraph c of the aforesaid law. Invoking further Section 15 of the same law, it recognizes the unique dispute settlement mechanisms of the IPs and allows the practice thereof. This referenced the objective of the study exploring the judicial assimilation of the Aeta community in the Katarungang Pambarangay.

2. Objectives

This study is a qualitative endeavor to explore the dispute resolution practices of the mainstreamed Aetas of Cagayan province when assimilated to the Katarungang Pambarangay (Village Justice) of their respective local government unit.

3. Materials and methods

This study utilized a basic qualitative design by Merriam and Tisdell (2016) to generate essential accounts on and important understanding of the dispute resolution practices of the mainstreamed Aetas of Cagayan Province. There are seventeen (17) informants of the study who are community leaders, Nataengans (elders), and/or highly aware members of the Aetas residing in the Municipalities of Claveria, Peñablanca, and Gattaran of Cagayan Province. Specifically, the following are the informants of the study: (A) Agugaddan, Peñablanca – Three (3) informants joined the focus group discussion. It was composed of one community leader, one highly involved member, and the eldest member of the community who pioneered their relocated area since 1980s. They have a first-hand experience on their judicial practices, thereby possess specialized knowledge about their cultural practices, traditions, and beliefs; (B) Culao, Claveria – Ten (10) informants joined the focus group discussion. It was composed of ten highly aware members with ages ranging from 30-55 years old who pioneered their relocation from Sanchez Mira, Cagayan. They offered insights into the cultural and historical context of specific events or practices and provided primary source of information to their community practices; and (C) Naddungan, Gattaran – Four (4) informants joined the focus group discussion. It was composed of two (2) nataingan and two (2) highly aware members who were able to witness their traditional justice system prior the assimilation to mainstreamed community. They therefore acquire knowledge and skills through their lived experiences and cultural upbringing in their community.

Focus Group Discussion (FGD) employing the scissor-and-sort technique (Stewart, 2006) was utilized. This is an appropriate instrument which provided an in-depth exploration of a topic about which little is known (Stewart, 2006). Through this technique, the researches first transcribed the audio recording using the Express Scribe Transcription Software®. To codify these data, a Clean Verbatim Transcription was utilized. This type of transcription method removes stutters, run-ons, non-speech sounds, and filler speech that are not necessary in attaining the objectives (Opal Transcription Services, 2018). The researches then analyzed the transcription and coded them based on their recurring idea. Finally, the researchers synthesized them to create themes and sub-themes. The discussion revolves around a semi-structured interview guide question. It collects comparative data from the community leader and the elders regarding their experience in the Katarungang Pambarangay. The guide question answers three major topics that are essential in this study: (1) Old or current practices that the Indigenous People have; (2) their awareness and

judicial assimilation in the Katarungang Pambarangay; and (3) the issues and challenges they experience in this system.

To ensure rigor of the study, the researchers has employed the TACT framework (Daniel, 2019) which consist of Trustworthiness, Auditability, Credibility, and Transferability. To ensure trustworthiness, the researchers has interviewed participants who are really part of the community and is regarded as well-versed to their culture and practices. The researchers have no direct affiliation to the informants as regards to their culture, identity, and demography. To ensure auditability, the researches has secured an archive for all signed informed consent, and recorded audios, documentations, and transcripts. During the data gathering, the researchers were joined by the Local Government Officials to assist. To ensure credibility, the researches ensure that the tools, interview guide question, and procedures employed is inclined with the objective of the study. The researchers returned to the informants after the results were analyzed. The researchers discussed the findings of this study and how it is beneficial to their community in the aspect of dispute resolution. To confirm that the analysis matched what the informants said during the interview session, the researchers also created a copy to be distributed to the community. Lastly, to ensure transferability, the researchers has clearly described the demographics and geographic boundary of the study and utilized appropriate methods so that it may be replicated for other applicable contexts. The research approach of the study may be utilized to determine the case of other Indigenous Communities or for other context such as political assimilation. These four-dimensions ensures that the study is credible, applicability, consistency, and neutrality.

The study has observed optimum due diligence to maintain legal and ethical means of employing the data gathering procedures. Before the actual gathering of data begins, the instrument was first checked and reviewed by the research panel of experts. After which, the pertinent letters were forwarded to the concerned offices for the approval of the conduct of the study. The researchers then secured a proper communication with the village captain and the community chieftain. They are contacted through phone for the initial approval, and a formal letter as soon as they have expressed affirmation to the conduct of the study. The researchers, thereafter, personally visited the community and established rapport in order to gain trust, and so not to arouse any suspicion on the part of the Aeta community. Before the preliminary survey, the researchers sought the informed consent of the participants. All questions were translated into their mother tongue to maximize their understanding of the questions and so as to extract more personal answers from them. Furthermore, the purpose of the study was clearly explained and all questions regarding the study were immediately addressed prior the interview proper. Deception and exaggeration on the objectives of the study were avoided. A preliminary survey was administered to all the IP members which identified the specific people who are qualified to participate in the interview. The qualified members were asked to undergo focus group discussions. The informants were assured that they are free to withdraw from the discussion at any moment if they feel uncomfortable. Permission to record and document was also secured through their consent. To respect the anonymity of the informants, codes were used to identify them. The researchers have given simple gift of appreciation for their participation. Every part of the interview guide and written consent was structured to gather only the data essential for this research.

Thematic Analysis was utilized to determine the alternative dispute practices of the Mainstreamed Aetas of Cagayan when assimilated to the Village Justice. It analyzed the interview transcripts through the three aspects of data analysis: description, analysis, and interpretation (Reeves et al., 2013). Firstly, the description aspect treated the extracted data

as fact. The transcription was translated to a simpler sentence but still retained the thought and essence of the data. It also recounted and described the data in a well-defined body of facts. Each data was labeled according to the question number and the informant number. Secondly, the analysis aspect processed the facts based on their recurring thought and essence across all data points. These groups of data have gone through comparison and contrast to determine their similarities and differences to create major themes and sub-themes. Thirdly, the interpretation aspect analyzed the themes and came up with a comprehensive discussion on the dispute resolution practices of Aetas and produced ethnographic knowledge thereto.

4. Results

At the outset of this research is the quantitative exploration of the dispute resolution practices of the mainstreamed Aetas of Cagayan province when assimilated to their Katarungang Pambarangay. At this conclusory juncture, after a comprehensive review of the focused group discussion with the informants through the interview transcript, pieces of information with similar idea were clustered into themes. Hence, it can be revealed in the following results the different alternative dispute resolution practices of the mainstreamed Aeta Communities.

4.1. Judicial Assimilation of The Mainstreamed Aetas of Culao, Claveria in The Village Justice

In an approximately 20-year-old close community is the Aeta Community of Culao. It is a village composing of only thirteen (13) households residing at a traditional *nipa hut* architecture. Having a nomadic lifestyle (Balilla et al., 2013), they decided to resettle from the upland mountains down to the lowland areas for better access of work. An informant has said that:

CC001: "*Nangatu adyay bantay kit nababa adyay pagubraan. Syempre, adayu. Awan iti lugan mi. Kit nu agubra, Bumaba kami ket nu malim manin, sumang-at kami manin*" (The mountains are high yet our work is situated in the lowland. Of course, it's far. We have no transportation. That's why, when we work, we walk down the trail and, in the afternoon, we go back up again).

Their resettlement has affected some of their traditions which are inherently embedded on their ancestral lands. More specifically, their judicial practices and political self-determination has gradually fade as they move within the mainstream society.

4.1.1. Nadarama Justice System

Before the resettlement took place, their local justice framework is grounded on the system of *Nadarama*. This system is an alternative dispute resolution which places the *Nataengans* (elders) at the forefront of settlement machinery to resolve communal conflicts. The verbalization of the informant is as follows:

CC001: "*Dagiti nataingan, adda mitlang iti role da nga mangbagbaga kadagiti agririnniri nga kunada. 'Suda iti mang-resolve adyay nga pinagririnniri idyay kapulungan mi*" (The leaders are vested with the role of advising us. They are the ones who resolve the commotion in our community).

To ensure their basic human rights and quality of life, the Aetas are increasingly required to participate in the formal and informal non-Aeta economy with whom they share their traditional lands (Bodley, 2008). Having been exposed to the mainstreamed Philippine society, they are also met with different cultural and judicial assimilation which resulted to new alternative dispute resolution method.

4.1.2. Alternative Dispute Resolution through Informal Practice

Despite its relatively small population, the Aeta Community of Culao has shared several issues and conflicts of their village which include land dispute, neighborhood quarrel, drunkenness, and coveting another man's wife. However, these are just light cases of civil conflicts which may be solved within one or two days. These conflicts are solved through a voluntary conflict settlement as they have no leader or chieftain who stands as mediator in conflict resolution processes. However, if such conflict eventually becomes a major issue, then they seek the help of the barangay through the Katarungang Pambarangay.

The Aeta community of Culao is aware of the Katarungang Pambarangay. The Barangay Captain has informed the community of the existence and function of Katarungang Pambarangay. They had advised the Aetas to refrain from fighting and always uphold high level of moral duty. As one informant has stated:

CC001: *"Kanayun da kami met nga sarsarungkaren dituy ser…Ibagbagada [da nga] 'haan kayo aggi-innapa.' Win kuna mi met ta 'awan mitla iti sabsabali kadakayo' kunada"* (They always help us here sir. They advise us that we should not fight. Of course, we listen to them because there is nothing to help us other than us ourselves).

4.1.3. Experiences on the Katarungang Pambarangay

The Aeta community of Culao has experienced no derogatory practice with the implementation of Katarungang Pambarangay. In fact, they are always given a special treatment as the Barangay understood the plight of the community. They are constantly advised by the Barangay to always adhere to the laws and not commit immoral acts.

CC001: *"In-advise da mit nukwa nga dagidyay maar-aramid nga madi, kasla kuma dagidyay agtakaw, kit haan yu nga aramidin kunada. Nu pumatay, haan yu aramidin. Agagaw iti asawa, dagidyay mit iti ibagbaga da nga haan yu aramidin. Nga haan yu agumin dyay kukwa iti sabali"* (They advised us sir that those morally wrong conduct, like the case of theft, murder, coveting another man's wife, and the likes should not be committed).

4.2. Judicial Assimilation of The Aeta Community of Naddungan, Gattaran in The Village Justice

Within the realms of Gattaran is a 20-year-old semi-complex civilization of the Agta Community of Sitio Padongsol. The Sitio, a village situated in-between the locale of Barangay Naddungan and Barangay Basao of Gattaran, houses 108 Agta families. When asked regarding their indigenous practices, they said that as they move, the judicial tradition of conflict resolution has also dissolved. The community leader has stated *"awan tattan ah. Idi un-una na, adda daydyay"* (in the beginning, there is [a tribal justice system]. But today, it's lost).

4.2.1. Ngayaw Justice System

Before they have evacuated from their ancestral land, a judicial tradition called *Ngayaw* is implemented. It is a retaliatory judicial practice which is an unlawful attack to an innocent person when an Aeta have lost their loved ones. The community leader has illustrated that if a person is mourning a deceased family member, even if it's not their fault, they are being attacked at night. The verbalization of the informant is as follows:

NG001: *"…natayan da kuma, uray awan basul mi mut kuma dituy nga banda, sikami iti mapabasul dagidyay minatay da. Sikami iti pabasulin da…Umay da kami nga*

ngay-ngayawin idi. Agtartaray kami iti rab-rabii nu kasdyay idi." (For example, they are grieving, even if we have nothing to do with the death of the deceased, we are the one being blamed. They attack us. If that happens, we try to escape even at the night).

As they traveled away from their highlands to transfer within the civilized areas, they were encouraged to acquire the ways of life of the mainstream community. From work to education and language, the only way to develop their community is to mimic the kind of life that their neighboring community has. This assimilation includes their village justice system.

4.2.2. *Alternative Dispute Resolution through Conciliation*

Aeta Community of Naddungan faces mild civil conflicts which are frequently a case of concubination and altercation. However, these issues do not result to any serious disparity between the parties as these are easily resolved through amicable resolution. The conflict is resolved within a day or two. Once peace is restored, the conflict ceases to exist as if it has not happened. These issues do not happen on a daily basis. Verbalization of the informant is as follows:

NG001: *"Kaasi mit 'ti Apu, kit nu kanya mi lang mit ah kit awan mit iti inaldaw. Nu adda lang mit insigida ma-resolve mit lang iti problema…Ngim nu madamdama mayat da manin kasla kuma sikami nga agkakarubba nu adda kuma agsisinungbat damdama naginnuni da manin…Awan iti pinadimdim ti panunut, kasla ubbing nu agiinappa idi ubbing madamdama aga-ayam da manin kasdyay latta mit"* (Thank God, in our village, it does not frequently happen. If such cases happen, we can quickly resolve it. For example, in our neighborhood, when there are commotions, they can easily go back to what they were before. We do not hold grudges. Just like kids, we fight and then immediately after, we go back to normal).

When asked how does this conflict resolution is practiced, they narrated that both parties talk through it until settlement is reached. For example, when a cow of a resident has eaten the crops of his neighbor, the concerned parties shall talk and reach an agreement. The parties may agree to pay the value of the crops or replace the crop of the same value. Such issues are viewed as mild conflicts that may be resolved within the community. However, there are cases where these are grossly difficult to handle that even the aid of the barangay is required. This kind of practice is termed as Conciliation. It is the amicable, protagonistic adjustment and resolution of a disagreement employed in courts prior to trial in an effort to avoid trial and in labor disputes prior to arbitration (Lara et al., 2016).

When asked if they are aware of the Katarungang Pambarangay, they attested that they are well aware of such system. In cases where issues are beyond the power of amicable settlement, the Barangay may intervene to solve the problem. An informant said that when they cannot solve the issue on their own, then they seek the aid of Katarungang Pambarangay to take cognizance of the case. The verbalization of the informant is as follows:

NG001: *"Nu makaya mi nga solbarin, sikami latta dituy mittin. Ngim nu haan mi makaya nga solbaren, syempre mapan kami idyay barangay. Basta no tawagan dan iti kapitanin, madamdama adittuyin nga mangsolbar iti problema dagidyay haan da nga masolbar."* (If we can resolve it, then we prefer to fix it ourselves. But if we cannot solve it, of course we pass it onto the barangay. As soon as the aid of barangay captain is required, then he/she can easily be contacted for immediate action).

4.2.3. *Experiences on the Katarungang Pambarangay*

The Aeta community of Naddungan has faced no issues and challenges. They experience no prejudice nor any coercion in the assimilation of the institutionalized justice system. In fact, the Katarungang Pambarangay provides swift conflict settlement even in the middle of the night. As they have affirmed, the barangay is very lenient when it comes to conflict resolution. An informant has said that:

NG001: *Wen, palubusan da kami nu daydyay kasla nalag-an nga problema ta awan mit sabsabali…Isu nga nalag-an kin kinna-awatan, alistu lang iti pagkikinna-awatan. Alistu da. Uray rabrabii, uray tingnga iti rabii, alistu da a umay."* (Yes, they will allow us if it is a light conflict because we closely know each other already. That's why it's very easy for us to understand each other and be reconciled. It's [the process] very quick, even during nighttime or in the middle of the night, they will immediately attend.)

4.3. Judicial Assimilation of The Mainstreamed Aetas of Aguggadan, Penablanca in The Village Justice

In a 43-year-old village of Agugaddan is the well-known Aeta Community. These indigenous people were able to proliferate labor vantage points which help their small community develop. They also have strong sense of historical attachment while also strongly assimilated with within the neighboring community. Their literacy skills were further improved when a Learning Center was established within the village. This is where alternative learning system and kindergarten education were being implemented.

4.3.1. Mixed System

Before the establishment of the village, they first resided at Gattaran where both retaliatory and restorative justice system are being enforced. The first system involves *Lallakay* (elder men) and *Babbaket* (elder women) in reaching a verdict in a conflict. They will help reconcile the two parties and reach an agreement as to solve the issue at hand. An informant stated that:

AP001: "*Adda paylaing iti nagkakauna nga sistema. Idyay pagtitinnungtungan iti problema da, ayaban da adyay lallakayin. Ken daydyay umun-una nga lallakay kin babbakit. Pagtutungtungan da, nu enya iti solusyon, nu kasta kit mapagtino da adyay agap-apa… Isuda garud iti mangted iti desisyong tapno kasta nga maamwanan da nu ustu ken saan adyay ar-aramidin da. Isu nga adda mit laing iti lallakay kin babbakit nga mangted iti pagsyaatan da.*" (The old system is still existing, if there is a problem, they will call the elders for an advice to reconcile the disputants. They [elders] will decide if their actions were good or bad. That's why the elders have significant contributions.)

The second system involves brutal disposition of justice which was abolished when the former community has evacuated the village. This is the *Ngayaw* System where they kill an innocent person with a bow and arrow to satisfy their desire for revenge. The community leader has illustrated the system further through the following testimony:

AP001: "*Nu agaapa da idi, dagidyay nagkakauna nga [Aeta], agngayaw da. Kasi nu haan da kayat iti maysa nga tau, hunting-in da iti rabrabii. Panain da. Kasi pana ti usar da idi. Isu nga ti tawag da idi kit Ngayaw. Nu adda matay iti nasakit ta nasakit iti nakim da, ipabasul da iti sabali nga tau. Isu adyay pagngayaw da*" (The ancient Aetas, when they fight, they conduct raids. If they do not want a person, they hunt them at night. They shoot them with arrow and they use bow. That is why they call it *Ngayaw*. If someone dies a natural death and they do not like it, they blame it to others. That's when they will raid).

Due to this retaliatory system, they were required to evacuate for the mean time. However, they never returned as they have established civilization in the resettlement areas.

4.3.2. Alternative Dispute Resolution through Mediation

The Aeta Community of Agugaddan has faced several conflicts especially on assault case of a husband to his wife. Based on practice, these cases are quickly resolved through an effective agreement between the assailed parties for amicable settlement. This community prefers conflict resolution through a peaceful conversation rather than escalating the problem. As they said *"nu ipipipam daydyay sakit ti nakem sir ket talaga nga rumubrubrub nga kunadan"* (if you keep holding grudges, it will eventually become stronger).

This practice is called mediation. It is an alternative dispute resolution method where a mediator, selected by the disputing parties, facilitates communication and negotiation, and assists the parties in reaching a voluntary agreement regarding a dispute (Chap. 1, Sec. 3(q), R.A. No. 9258). In their community, this peaceful conversation involves their Chieftain as the mediator of the conflict, with *Panglakay* as the advisers. Residence of the community may ask the aid of their Chieftain to help them resolve the issue if they cannot settle their conflict. In such system, the Chieftain allows both parties to have an opportunity to share their grievances. The Chieftain will weigh these testimonies and provide the best way to settle the dispute. The informant has verbalized this system below:

AP001: *"Adda laeng 'ti nasyaat nga tungtungan. Nu ittuy community mi ser, adda mit lang iti chieftain mi. Tapnu nu haan nga maayos 'ti, kaspangarigan kuma sir ta nagapa kuma iti nagasawa, ipalagay ku lattan ser siyak kin ni lakay ku. Nu haan mi nga masolusyonan daydyay nga agasawa sir, syempre I danon mi mitlaeng kinni chieftain mi ta ikkanna kami iti advice nu kasanu kasami kami aginnayus."* (There is a peaceful way of conversation. In our community, we also have a chieftain. If we fail to reconcile, for example in my case with my husband, we pass it onto our chieftain whose role is to give us advise on how we can solve the conflict).

Having an important role in the community, the Chieftain has the primary role of supervising its constituents. The Chieftain may be elected in two (2) ways. First, is by appointment of a representative of Barangay and Municipal government. Second, is by direct election by the Aetas. The chieftain has no definite tenure. As long as they still would like to hold the position or until they die. In the verbalization of one informant, she said that:

AP001: "*Dipende sir 'ti kayat na. Nu kayat na 'ti makisinnukat, nu haan na nga makaya ta adda ti trabaho, nu sukatan da, Mabalin lang. Ngem isuna 'ti urayen mi nga mangidding idyay tyempo na ta narigat met nga 'sukatan da kan ta' haan nga kasdyay. Urayen mi daydyay oras na"* (It depends sir if he wants. If he prefers replacement, if he cannot uphold the demands of his position, if they decided to replace him/her, it's all possible. But, in practice, we wait for his declaration to terminate his position).

When asked about their awareness on the Katarungang Pambarangay, they said that in cases where the Chieftain cannot pacify both parties into settling the dispute, they file it to the Katarungang Pambarangay. The barangay captain summons the parties and asks the cause of the problem. After which, their testimonies will be used by the captain to assess the conflict and try to derive settlement therein. If a decision is rendered, a letter shall be signed by the two parties signifying that they will not do it again.

AP001: *Ni Punong Barangay lattan sir…Kit syempre nu damagen na met nu anya nga gapu nga agap-apa kayo, syempre istoryain na met adyay gapu. Tapnu ammu mit ni kapitana. Tapnu masolusyonan na. tapnu nu agayus kayu, agpirma kan, ta haan mu ul-ulitin ti kastuyin, ay kit nasiyaat iti kasdyay sir. "Aginnayus kayun" ag-shake hands dan, eh di nalpas* (It's the barangay captain sir… of course, if he asks the cause of the conflict, they will narrate it. The captain understands that they can solve it. So, if they are able to resolve it, they will sign and pledge not to repeat it. "Reconcile now" they shake hands, and then it ends).

4.3.3. Experiences on the Katarungang Pambarangay

In the present study, the Aeta community of Agugaddan has faced no problem dealing with the Katarungan Pambarangay of their Local Government Unit. As the Barangay has constantly reminding them, as long as they can solve their own conflict, issues, or problems, then they should be the ones who shall fix it. They encourage them to find the best and most convenient way for peacebuilding and conflict settlement.

AP001: *"Kuna da ngarud sir, nu makaya yu nga solbarin iti problema yu, apay kitdi nga haan nga dakayo iti mangsolbar? Basta makaya yu. Isuru da mit lang sir adyay pakalag-anan mi. Syempre sir, bassit met laing nga [problema] daydyay. adda met ti chieftain ti community mi. kit syempre, ikaming mi met laeng kanyayu. Daydyay laing naunig sir nga problema nga haan mi makaya, i'pan mi talaga idyay barangay"* (they said sir, that if we can solve our problem, then why is it that we are not the ones solving it? As long as we can, they direct us to what is the most convenient for us. Only those difficult problems that we cannot solve, are passed onto the barangay).

4.4. Synthesis

The three mainstreamed communities of Aeta practice two (2) existing methods of alternative dispute resolution namely – modified indigenous judicial practices and the judicial assimilation in the Katarungang Pambarangay. As to the judicial practices, the three communities employed different methods, namely Nadarama, Ngayaw, and Blended Justice. Previous studies claim that there are variations in principles of Indigenous legal systems because they are based upon a relationship to Indigenous languages and Indigenous peoples' linkages to their lands and territories, has been supported by earlier research (Acuña, 2009; Hewitt, 2016; Rio, 2016).

4.4.1. Indigenous Judicial Practices

One judicial practice revealed the system of Ngayaw. It is a peculiar justice system practice in the Aeta community as it promotes killing as tribal settlement. The term ngayaw (sometimes spelled ngayao) is the active verb of the proto-Austronesian base kayaw, which means 'to go headhunting', 'to raid', 'to capture', and 'to engage in piracy' (Angeles, 2013; Gowey, 2015; Minter, 2010). Definitions are not always mutually exclusive, with most providing multiple contexts for the behavior(s) in question (Gowey, 2015). For example, studies show that *ngayaw* has a variety of root causes including the urge for vengeance after any death within own group, whether it be accidental or not, and the fact that raids were only carried out when a member of the rival group had violated the territory of the former (Gowey, 2015). This is relative to the finding of this study where the informants have narrated that this practice is used as a means of revenge. The reason why it is a judicial system is because of its distinct settlement patterns (Minter, 2010). Many studies contend that Ngayaw does not always connote negative meaning (Angeles, 2013; Gowey, 2015; Minter, 2010; McMahan, 2005) as it is usually motivated by spiritual belief

or may have been served to defend territories and perhaps even explored new ones (Minter, 2010).

Also revealed in the findings is the system of Nadarama. This restorative system is tantamount to the assertion that the political foundation of the Aeta is largely built on respect for elders who are in charge of judicial matters and are responsible for maintaining the band's peace and order (Balilla, et al., 2013; Yodisphere, 2020). This Indigenous political institution is primarily composed of elderly Aetas revered for their years of accumulated of knowledge, wisdom, and ability (Balilla et al., 2013; Naganag, 2019; Tebtebba Foundation, 2008). Other tribal societies, like those of the Ifugao, may have similar justice system. This method is defined as the procedure by which peace and harmony in the Ifugao community should be protected and maintained, through a peaceful resolution of a dispute over an improper behavior that raises the possibility of conflict (Co, 2020). The Upland Kalinga region of the Northern Philippines also uses this method. It is an assembly of the village's elders (*pangat)*, made up of elderly men who have gained knowledge and expertise in tribal rules by extensive experience and involvement in the resolution of inter- or intra-tribal conflicts (Naganag, 2019).

4.4.2. *Judicial Assimilation in the Katarungang Pambarangay*

The resettlement of the three communities sets in motion an irreversible process of tribal justice system and the introduction of a new one influenced by the standard legal remedies and proceedings of the mainstream community. Accordingly, without the aid of written literatures and documentation, the practices are dissolved and the contemporary method of conflict management offsets these historical traditions (Naganag, 2019). Hence, the inevitable assimilation to the judicial principle of the mainstreamed community is existent. Importantly, the assimilation shows no problem in terms of dispute resolution machination among the Indigenous People. In fact, their experiences with the Katarungang Pambarangay have been inclusive and cooperative. This is tantamount to the finding that members have no problem in the implementation of the Barangay Justice System and its processes (Lupao & Alejandro, 2022).

In fact, whenever a tribal conflict is serious or non-indigenous people are concerned, or both, the village government leader (Barangay Captain) is requested to settle the dispute (Ty & Bibon-Ruiz, 2022). Forms of conflict resolution depend on the nature of parties involved. In most cases, conflicts are settled within the tribe before being brought to the village level for amicable settlement. There are two recognized alternative dispute resolution methods which were revealed in the focus group discussions – mediation and conciliation.

Conciliation is the adjustment and settlement of a dispute in a friendly, protagonistic manner (Lara et al., 2016). A conciliator may be a specialist in the area of conflict typically offer guidance on the problems and possible solutions (New South Wales, 2023). A conciliator won't, however, render a verdict or take a position on the conflict. As expressed in the findings of this study, both parties are given the autonomy to agree on the stipulations binding only to them. The role of the elders is reduced to advisership.

Mediation, on the other hand, means a voluntary process in which a mediator, selected by the disputing parties, facilitates communication and negotiation, and assists the parties in reaching a voluntary agreement regarding a dispute (Chap. 1, Sec. 3(q), R.A. No. 9258). The voluntariness in mediation must be possessed by both parties (Lara et al., 2016). The fact that the parties are ultimately responsible for resolving a disagreement and creating a consensual and unforced solution is unaffected by the mediation process (Chap.

1, Sec. 3(q), R.A. No. 9258). This is relative to the finding of the study where the community treats their chieftain as the mediator and helps them arrive to an agreement.

Illustrating the generated results and discussions, the following figures are the judicial framework that visually explains the dispute resolution mechanism of the mainstreamed Aetas of Cagayan.
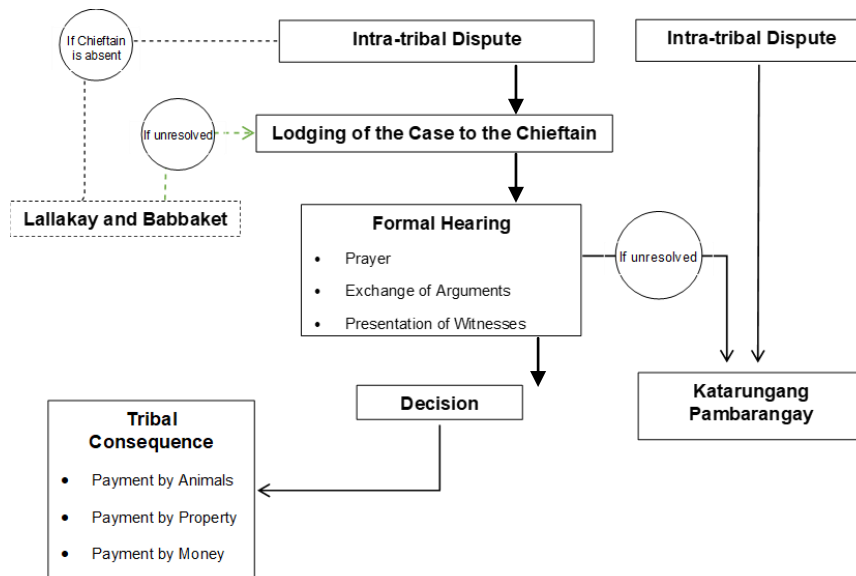
Figure 1 Aeta Community of Agugaddan Judicial Framework
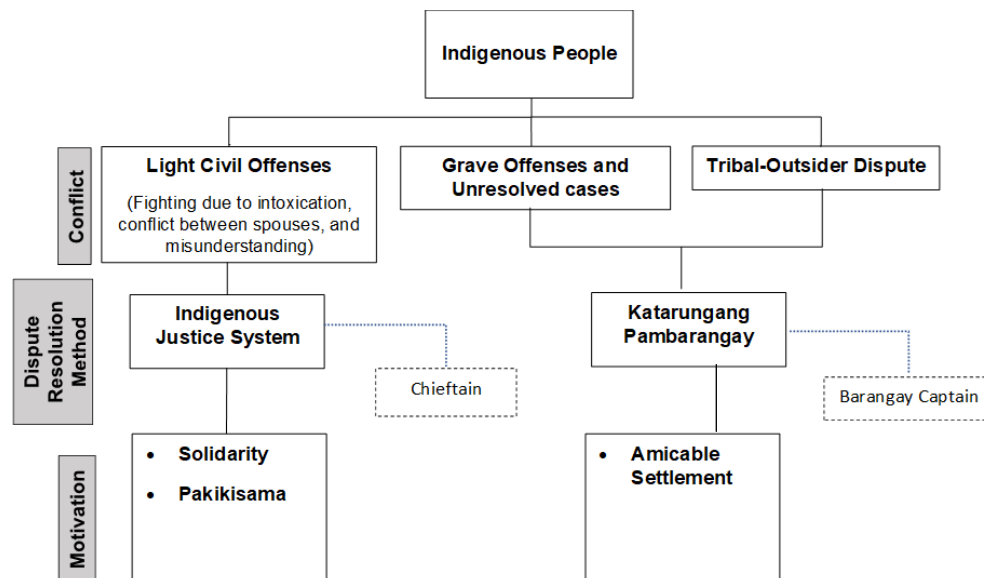
Figure 2 Aeta Community of Gattaran and Culao Judicial Framework

6. Conclusion

Based on the findings deduced from the indigenous informants, the researchers were able to generate the following conclusions: The findings of this study depict an important implication of the current status of the alternative justice system of the Aeta Community of Cagayan. There is no dichotomy between the customary law and the state law of the IPs. Their resettlement from a secluded and remote place to the mainstreamed community has affected their justice system. Accordingly, there are two systems that the Aeta community blends together to achieve a value-based conflict resolution. These two

systems – Modified Indigenous practices (customary law) and alternative dispute resolution methods (state law)- are the co-existing justice system in settling dispute of the Aeta Communities. The first system relies on the solidarity and sense of belongingness which influence the effective peacebuilding methods of Aetas. The second system relies on the aid of Katarungang Pambarangay to solve a difficult dispute. Understanding this legal landscape of the mainstreamed indigenous people, they experience no issues, more so prejudice, in the Katarungang Pambarangay.

In regard of its limitation, the study was not able to elaborate the motivations behind the principles employed in their justice system. It fails to explain how such motivations contributes to the dispute resolution mechanisms utilized by the Aetas and how it is applied in Katarungang Pambarangay. Furthermore, the study was not able to ponder on the history and background of the communities as it may have an influence to their contemporary judicial system.

Based on the generated findings and conclusions drawn from the study, the researchers strongly recommend the following: (1) The Aeta Community and Indigenous Peoples should strengthen the influence of a value-based justice system to properly build the principles of restorative justice and community involvement which can help promote justice, reconciliation, and empowerment within the communities; (2) The Local Government Units should engage in support and collaboration with Indigenous communities to understand their unique justice systems and the challenges they face in accessing justice. This includes respecting and acknowledging Indigenous laws, traditions, and cultural practices; (3) The Barangay should help and give assistance to the community chieftain as a political leader vested with vital role in reconciling and arbitrating the disputed parties within his domain, by teaching the chieftain strategic and effective mediation; (4) The National Commission on Indigenous Peoples may improve and organize the planning and monitoring of the existing Indigenous Peoples Justice System to bring out genuine IP self-governance and empower, and at the same time conserving traditional and legal peacebuilding mechanisms of IP that would, in turn, decrease the dockets of the courts; (5) The Political Science students of USL should further study the Indigenous justice systems which are often focused on understanding the relationship between Indigenous communities and the state, and the ways in which Indigenous justice systems have been suppressed or marginalized; and (6) Future Researchers may use this study to broaden the scope of their research by examining the practices of justice system of other IP communities in the Philippines.

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Informal Sector Towards Local Development: The Case of a Component City

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Abstract

This study was conducted to determine the perceived effects of the informal sectors to local development of Tuguegarao City. Mixed-research method was used in the study. The study was conducted in Tuguegarao City. For the quantitative aspect of the research, there were 500 respondents who were selected through purposive sampling method. The study utilized survey questionnaire for the profile. For the qualitative aspect of the study, focal persons from the Local Government Unit, Department of Labor and Employment and Department of Trade and Industry were interviewed on the perceived effects of informal sectors on local development. Also, some of those engaged in the informal sectors were also interviewed to verify the information gathered from the implementers. Results reveal that there are push factors or necessity-driven factors and pull factors or opportunity-driven factors affecting the engagement of the respondents in the informal sector. Topping this is the need to provide for the daily needs of the family, for the education of the children and debt payments. Also, results reveal that there are positive and negative effects of the existence of informal sectors to local development. To mention, for the positive effects, there is (1) generation of employment opportunities, (2) sustainable source of income, (3) community participation and environmental responsibility, (4) market opportunities and convenience and (5) transition of informal sector to formal. Lastly, for the negative perceived effects, informal sectors create (1) unfair competition between informal and formal sector (2) waste management problems, and (3) cause of traffic.

Keywords : Informal Sector, Informal Sector Engagement, Local Development, Perceived Effects, Tuguegarao City

1. Introduction

The informal economy, also known as the grey economy or the informal sector, is a sector of the economy that is not regulated or taxed by the government. The activities or characteristics of the grey economy are never accounted for in the country's GDP (GDP). The term "informal sector" was first used to refer to self-employment in a variety of unregistered businesses, but it was later expanded to include all wage jobs in the unmonitored sector (Migiro, 2017). In the developing world, informality is a much more pervasive phenomenon, with more than 2 billion people, representing 60% of workers and 80% of enterprises (ILO, 2020).

Informal sector plays a crucial role in local development particularly in urban poverty alleviation through creating jobs and reducing unemployment. As literature shows there are a number of reasons that drives the informal economy participants to enter to the informal sector and also there are a number of constraints that faces the informal economy participants when engaged in this sector (Adamu & Muguleta, 2018). The informal economy is an important part of local development in terms of economic, social and political life in most developing, as well as some developed economies. In countries with high rates of population growth or urbanization, the informal economy tends to absorb most of the growing labor force (MoLSA, 2013). Informal economy is continuously expanding in developing countries and providing employment and income to the poor. It is stimulating the growth of the market economy, promoting flexible labor market, stimulating and absorbing labor than the formal economy. Specifically, urban informal

economy is a major source of employment and income in developing countries. The sector has helped the impoverished groups of the urban population to improve their business skills and income levels required for business development (Asaminew, 2010).

Informality, according to Garcia-Bolivar (2006), can be a problem for governments. Governments are unable to collect taxes from informal businesses and, as a result, are unable to fund the provision of adequate public services. In some cases, governments may push businesses into informality due to a lack of good public services, such as the rule of law. Governments then raise tax rates on those who continue to be formal, creating an additional incentive to be informal. For governments, the informal sector could be a solution to unemployment. Where the formal economy is unable to absorb the excess labor due to its own constraints, the informal sector is the ideal solution. Perhaps it is for this reason that some governments tolerate informality to a large extent. Others have even gone so far as to see informality as a solution to the problem of unemployment, and have created a favorable framework for promoting the informal economy. That was the case in China following the mid-1990s (Garcia-Bolivar, 2006).

In the Philippines, the number of people working in the informal sector is growing year by year. According to records, millions of Filipinos earn a living from unregistered businesses. The Philippine government has made efforts to move workers from the informal to the formal sectors of the economy. In fact, the labor department has held consultative workshops in collaboration with the National Anti-Poverty Commission Workers in the Informal Sector Council (NAPC-WISC) to identify key policy gaps and challenges related to the government's emphasis on addressing informality, as well as strategies and models to operationalize the transition from an informal to a formal economy. The Department of Labor and Employment (DOLE) launched the Trabaho, Negosyo, Kabuhayan (TNK) initiative in collaboration with the Department of Trade and Industry (DTI), with key outputs including the Blueprint for Decent Employment and Entrepreneurship for 2017-2022 and the Livelihood Agenda for 2017-2022. Through full implementation of the GoNegosyo Law, the MSME Development Plan, and the Asia-Pacific Economic Cooperation (APEC) 2015 Action Agenda to Globalize MSMEs, the initiative sought to transform livelihoods into competitive, resilient, and sustainable enterprises by encouraging the formalization and growth of micro, small, and medium enterprises (MSMEs) (Department of Labor and Employment, 2017).

Tuguegarao City is a landlocked component city in the coastal province of Cagayan. It serves as the provincial capital as well as the regional center of Cagayan Valley. Its population as determined by the 2020 Census was 166,334. This represented 13.11% of the total population of Cagayan province, or 4.51% of the overall population of the Cagayan Valley region. The population as of 2020 shows an increasing percentage from last year (Tuguegarao City, Cagayan Profile – PhilAtlas, 2020). The Cagayan Valley Region has registered 11.7% poverty incidence rate based on the 2021 Family Income and Expenditure Survey, Philippine Statistics Authority (PSA) Region 2 revealed. Marilyn T. Estrada, regional director of Philippine Statistics Authority, said the province of Isabela registered the highest rate at 15.9%, followed by Nueva Vizcaya at 10.8%, Cagayan at 7.3% and Quirino at 6.2%. On the subsistence incidence among families, Estrada said the provinces have the same standing in which Isabela has the highest rate at 4.0%, followed by Nueva Vizcaya at 2.9%, Cagayan at 1.2%, Quirino at 0.9% and Batanes with only 0.2%. The subsistence incidence is defined as the proportion of Filipinos whose income is not enough to meet even just the basic food needs, Estrada said (Philippine Information Agency, 2022). From Cagayan, Tuguegarao City the poverty incidence was 4.19% as of

2018. For this reason, some families' income is not enough to meet the even just the basic food needs, some are forced to enter the informal sector as their source of income. And entering informal sector is their only means to survive.

In the context of high unemployment, underemployment, poverty, gender inequality, and precarious work, the informal economy thrives. It plays a significant role in such circumstances, particularly in income generation, due to the relative ease of entry and low requirements for education, skills, technology, and capital. The majority of people, however, enter the informal economy not because they want to, but because they need to survive and have access to basic income-generating activities (International Labor Organization, 2014). One of the main characteristics of the informal sector that has contributed to its growth is a lack of entry barriers. Anyone who wants to work in the informal sector can find work and earn a living (Migiro, 2017). However, the city's development has been hampered by the fact that the informal economy is unregulated. To achieve long-term development of the city's economy and services, the municipality must work with the informal sector, create services to support, monitor, and regulate informal activities, and simplify the registration process. More information about the sector's needs, obstacles, and behaviors is required in order to create an effective legal framework for informal activities (Heinonen, 2008). A proliferation of informal activity in an economy reflects systemic failures, leading to weak institutions, endemic corruption, and large bureaucratic obstacles (and high entry barriers) to formal activity (Narula, 2020).

As there are various and varying research findings on the factors or reasons on the informal sector engagement and literatures on the effects of the existence of the informal sectors to local development as established in the paper, thus this study was conducted.

2. Objectives

This study aimed to document the effects of the informal sectors to local development. Specifically, it aimed to answer the following questions: (1) What is the profile of the respondents according to: a. socio-demographic characteristics and b. informal-sectoral characteristics (2) What are the factors affecting the engagement of the respondents in the informal sector? (3) What are the perceived effects of the informal sector on local development? (4) Is there a significant association between the profile of the respondents and the factors affecting their engagement to informal sector? and (5) What proposed policy may be recommended to manage the informal sectors?

3. Materials and methods

The study used mixed-method of research employing both quantitative and qualitative research designs to determine the effects of the informal sector in the local development. Due to the nature of the economic activity the researcher tried to examine; it was impossible to compile a comprehensive list of businesses established informally to provide a basis for selecting a representative probability sample. Therefore, the researcher used a purposive sampling method. The researcher selected respondents of whose business is not regulated or is not registered and operating a small-scale business. Moreover, in order to determine the perceived effects of the informal sector in local development, focus-group discussions were done among the focal persons or participants working in the Local Government Unit of Tuguegarao, Department of Trade and Industry and Department of Labor and Employment and among the informal sectors. A questionnaire consisting of three parts was used in the study. Focus-group discussion was conducted among the focal persons or participants who are in-charge of the informal sectors or economy. In like manner, focus-group discussion was performed among some of the informal sector-

respondents on their perceived effects to local development. This served as a verification on the information gathered from the implementers. Documents on the programs, policies or efforts done by the Local Government Unit of Tuguegarao, Department of Trade and Industry and Department of Labor and Employment were requested. Data gathered were analyzed using descriptive statistics such as frequency and percentage for the socio-demographic characteristics and informal-sector characteristics of the respondents, factors that affect the engagement of the respondents in the informal sectors and the assistance they receive from the city government. Binary Logistic Regression was used for determining the significant association between profile of the respondents and the factors that affect their engagement to informal sector. Document analysis and thematic analysis were done to determine programs, policies and/or efforts done for the informal sectors.

4. Results

Table 1a. Socio-Demographic Characteristics of the Respondents

Variable	Frequency	Percent
Age		
< 20	25	5.0
20 - 29	152	30.4
30 - 39	128	25.6
40 - 49	105	21.0
50 - 59	68	13.6
≥ 60	22	4.4
Mean Age=37		
Sex		
Male	291	58.2
Female	209	41.8
Civil Status		
Single	182	36.4
Married	269	53.8
Widow/er	40	8.0
Separated	9	1.8
Place of Origin		
Tuguegarao City	355	71.0
Outside Tuguegarao City but within Cagayan	121	24.2
Outside Cagayan	24	4.8
Highest Educational Attainment		
No Formal Education	23	4.6
Elementary Undergraduate	26	5.2
Elementary Graduate	30	6.0
High School Undergraduate	141	28.2
High School Graduate	113	22.6
College Undergraduate	102	20.4
College Graduate	65	13.0
Highest Educational Attainment of Spouse		
No Formal Education	49	15.5
Elementary Undergraduate	25	7.9
Elementary Graduate	13	4.1
High School Undergraduate	70	22.1
High School Graduate	96	30.3
College Undergraduate	20	6.3
College Graduate	41	12.9
Others	3	0.9
Combined Monthly Income		
$\leq 10,000$	24	12.9
10,001 – 20,000	118	63.4
20,001 – 30,000	27	14.5
30,001 – 40,000	8	4.3
40,001 – 50,000	5	2.7
> 50,000	4	2.2
Average Combined Monthly Income = 18, 986.00		
Number of Dependents		
0	7	2.2

1	52	16.4
2	105	33.0
3	82	25.8
≥ 4	72	22.6
Average Number of Dependents = 3		
No. of Dependents in School		
0	61	19.2
1	115	36.2
2	92	28.9
3	37	11.6
≥ 4	13	4.1
Average Number of Dependents in School = 1		
Other Source of Income		
Yes	38	7.6
No	462	92.4
Monthly Earning from Other Source of Income		
≤ 1,000	7	18.5
1,001 – 2,000	7	18.5
2,001 – 3,000	3	7.9
3,001 – 4,000	5	13.2
4,001- 5,000	13	34.2
> 5,000	3	7.9
Average Monthly Earning = 3,426.00		
Previously Employed in Formal Sector		
Yes	30	6.0
No	468	94.0
Investment*		
Gadgets	158	31.6
Appliance	236	47.2
Housewares	55	11.0
Clothing	57	11.4
Vehicle	123	24.6
Housing Renovation	66	13.2
Land	16	3.2
Furniture	38	7.6

Table 1a showed the socio-demographic characteristics of the respondents. The table showed that the mean of the respondents is 37. Results further revealed that there are more male respondents than female respondents. In addition, along the civil status, majority are married respondents, and along with the place of origin, most of the respondents reside in Tuguegarao City and very few reside outside Cagayan. Furthermore, majority of the respondents were high school undergraduate, while few were college graduates. For respondents who are married, most of their spouses were high school graduates. For the combined monthly income, the respondents are earning ₱18, 986.00 on average. Moreover, of the non-single respondents, majority of them have two (2) dependents. It can be further seen from the table that the average number of dependents is three (3) dependents. For those respondents with dependents, majority of them have one (1) dependent who is attending school, further revealing an average number of dependents in school of one (1). Furthermore, the table revealed that majority of the respondents have no other source of income. On the other hand, for those respondents with another source of income, most of them are earning a monthly income of ₱4,001-₱5,000, further showing an average monthly earning from other source of income of ₱3,426.00. Meanwhile, it can be gleaned from the table that almost all the respondents have no previous employment in the formal sector. Lastly, the table reveals that most of the respondents have invested in appliances, gadgets and vehicles, among the top 3 investments.

Table 1b. Informal-Sectoral Characteristics

Variable	Frequency	Percent
Nature of Business		
Ambulant Vending	271	54.2
Selling of Staple Foods	117	23.4
Cart Selling	68	13.6
Sidewalk Vending	90	18.0
Kalesa Operator	18	3.6
Shoe Repair Service	10	2.0
Manicure/Pedicure, Barber	2	0.4
Watch Repair	1	0.2
Sources of Capital		
Loan/Credit	235	47.0
Government Assistance	68	13.6
Personal Savings	268	53.6
Salary	8	1.6
Donated by Friends/Family	46	9.2
Negotiated	22	4.4
No. of Years Engaged in the Informal Sector		
< 5	163	32.6
5 - 9	122	24.4
10 - 14	94	18.8
15 - 19	55	11.0
≥ 20	66	13.2
Average No. of Years in the Informal Sector = 10 years		
Status of Engagement		
Full-Time	463	92.6
Part-Time	37	7.4
Total Monthly Income		
$\leq 10,000$	187	37.4
10,001 – 20,000	250	50.0
20,001 – 30,000	41	8.2
30,001 – 40,000	11	2.2
40,001 – 50,000	7	1.4
> 50,000	4	0.8
Average Total Monthly Income = 14,425.00		
Monthly Expenses		
$\leq 10,000$	199	39.8

10,001 – 20,000	243	48.6
20,001 – 30,000	42	8.4
30,001 – 40,000	9	1.8
40,001 – 50,000	5	1.0
> 50,000	2	0.4
Average Monthly Expenses = 13,426.00		
Assessment of Financial Status		
Financially Surviving	443	88.6
Financially Struggling	57	11.4
Coping Mechanism of Struggling Respondents		
Apply for Loan/Credit	27	47.4
Working Harder in Selling	30	52.6
Income Allocation*		
Food and Daily Needs	265	53%
Education	40	8%
Business	120	24%
Gas/Fare/Gasul	40	8%
Utilities	55	11%
Debt Payment	40	8%
Savings	20	4%

Table 1b showed the informal-sectoral characteristics of the respondents. It can be seen that majority of the respondents are into ambulant vending followed by selling of staple foods such as vegetables, fruits, meats. It can be further seen in the table that most of the respondents used their personal savings as their source of capital while some had applied for loan or credit for their capital. Moreover, the results reveal that most of the respondents are engaged in the informal sector for five (5) years and below, while few are into the informal sector for more than twenty (20) years. It can be further seen from the table that the average number of years in the informal sector is ten (10) years. In addition, almost all the respondents are doing business in the informal sector as full-time. Furthermore, the table showed that on average, the respondents are earning ₱14,425.00 as the average total monthly income and are spending ₱13,426.00 as average monthly expense. This is along the level of poverty threshold in the Philippines as of 2021 which is ₱14,498.00. Lastly, the table showed that almost all the respondents consider themselves as financially surviving. On the other hand, the respondents who consider themselves as financially struggling have coping mechanisms of working harder in selling and applying for loan or credit. Moreover, the table indicates the income allocation of the respondents. It can be seen that respondents allocate 53% of their income for food and daily needs of the family, followed by 24% income allocation for business needs. Moreover, the table showed that 11% of income of the respondents are allotted for their utilities, while 8% of their income is allotted for education or school needs, for gas/fare or transportation needs/gasul or LPG needs and settling their debt payments. Meanwhile, 4% is allotted for savings of the respondents as revealed in the table.

Table 2. Factors Affecting the Engagement of the Respondents in the Informal Sector

Factors Affecting the Engagement	Frequency	Rank
Necessity-Driven Factor (Push Factor)		
Daily Needs of the Family	500	1st
Education of Children	256	2nd
No Jobs Available	39	5th
Buy Appliance, Furniture, and Other Things Needed in the Family	9	7th
For Self-Support	53	4th
To Pay Debts	236	3rd
For Investment Purposes	10	6th
For Medication of Family Member	5	8th
Opportunity-Driven Factor (Pull Factor)		
The Easiest Way to Earn Profit	80	1st
Very Easy to Manage	74	2nd
Serve as Sideline Business	13	3rd

Table 2 showed the factors affecting the engagement of the respondents in the informal sector along necessity-driven and opportunity-driven factors. It can be seen in the table that along necessity-driven factor or the push factor, all of the respondents are engaged in the informal sector for the day-to-day needs of the family, followed by the need to provide for the school needs of their children, then entering informal sector in order to pay debts. Meanwhile, along opportunity-driven factor or the pull factor, the table showed that some of the respondents answered that they entered informal sector because engaging in this sector is the easiest way to earn profit, and it is very easy to manage.

Table 3a. Predictors of Engagement in Informal Sector (Necessity-driven)

Variables	Educ. of Children		No Job Available		Buy Other Needs (appliance, etc.)		Self-Support		Pay Debts		Investment		Medication of a Family Member	
	B	Sig.	B	Sig.	B	Sig.	B	Sig.	B	Sig.	B	Sig.	B	Sig.
Age	-.112	.784	.037	.868	**.972**	**.037**	-.180	.472	-.105	.410	.876	.078	1.478	.542
Sex (Female)	.096	.897	-.481	.286	18.366	.994	**1.167**	**.022**	.357	.145	1.526	.205	56.435	.979
Dependents	.209	.481	-.401	.071	**-1.829**	**.042**	-.117	.575	-.058	.565	.021	.960	-.574	.293
D-School	**6.165**	**.000**	.364	.162	.249	.744	**-.602**	**.043**	-.033	.791	-.361	.459	15.162	.975
TI20,001 – 30,000	1.641	.226	-.427	.629	18.802	.996	.366	.671	**1.099**	**.014**	17.516	.997	-47.328	.994
TI30,001 – 40,000	.737	.801	-19.69	.999	1.415	1.000	**2.392**	**.027**	-.235	.760	-.315	1.000	-3.678	1.000

As shown in the table, age, sex, number of dependents, number of dependents in school and total monthly income are predictors in the engagement of the respondents in informal sector in terms of necessity-driven factors. Additionally, the table revealed that older respondents are more likely to engage in the informal sector in order to buy their other needs such as appliances, gadgets, etc. Moreover, it can also be gleaned that female

respondents are more likely to engage in the informal sector in order to support their needs than male respondents. Also, respondents with more dependents are less likely to engage in the informal sector to buy other needs such as appliances, gadgets, etc. On the other hand, respondents who have more dependents enrolled in school are more likely to engage in the informal sector to fund the education of their children. It can also be seen in the table that respondents having more dependents attending school are less likely to engage in the informal sector to support their needs. The table further showed that those respondents with total monthly income between ₱20,000 to ₱30,000 are more likely to engage in the informal sector to pay off debts than those whose total monthly income is not more than P10,000. In addition, respondents whose monthly income is between ₱30,001 to ₱40,000 are likely to engage in the informal sector in order to support their living.

Table 3b. Predictors of Engagement in Informal Sector (Opportunity-driven)

Variables	Easiest Way to Earn Profit		Easy to Manage		Sideline Business	
	B	Sig.	B	Sig.	B	Sig.
Age	**-.547**	**.007**	.231	.178	.056	.936
CS (Married)	**1.528**	**.002**	.425	.390	-17.528	.997
D-School	.270	.154	-.023	.895	**1.807**	**.032**

As shown in the table, age, civil status and number of dependents in school are predictors in the engagement of the respondents in informal sector in terms of opportunity-driven factors. It can be gleaned from the table that older respondents are less likely to engage in the informal sector because it is the easiest way to earn profit. Moreover, respondents who are married are more likely to engage in the informal sector because it is considered to be the easiest way to earn profit compared to single respondents. Moreover, having more dependents who are attending school are more likely to engage in the informal sector as their sideline business.

Positive Perceived Effects of the Informal Sector to Local Development
   A. Generation of Employment Opportunities
      One of the positive perceived effects of the informal sector to local development is the generation of employment opportunities. One of the indirect effects of the operations of informal sector in the economy is the increased flow of operating income in the city. As there are increased engagements of the informal sector, collections and money supply tend to increase as well. This favorable economic condition results to investment opportunities, thus increasing employment opportunities to both in informal and formal sectors. Same views are shared by some of the informal sectors: that they are able to be earn through engaging in the informal sectors, and that they need not to be employed in formal sectors since there are less to no opportunities for them. The verbalizations are as follows:

INF01: "Did you know that, according to former City Mayor Jefferson Soriano, P32.2 billion is circulating here in Tuguegarao and any one time. There is more money circulating here than in Santiago, City of Ilagan and Cauayan. That's why if you notice, there are so many banks here. China bank? How many branches, Metro bank, how many branches, BDO, how many? BPI? How many? BPI already has three. So if you see, the economy is good when there is a lot of money circulating. So, in a way, they, what I'm saying is P372,000 per day of circulating money, they help the economy, we just don't know how…"

INF01: "It's okay that they are there (informal sector) .. because that's also their job, they also help the economy, they just need a little discipline. We will not stop them because they

are the polluters, no. We have to help them, because that's all they make a living from. That is why we help them to help themselves, and in return, when they are helped, and in return, they also help the community.

B. Sustainable Source of Income

One of the positive perceived effects that one of the informants shared is that, the engagement of the respondents in the informal sector, tends to become their sustainable source of income. This affects the local development economically as they are contributing in the good flow of funds and consumption in the economy. Also, most of the informants in the informal sector convey that through their operations in the informal sector, they are able to sustain their day-to-day needs and some are also able to send their children to school. One of the aspects of local development is the improvement in the quality of life of the population, resulting to positive effect along this area. The verbalizations are as follows:

INF01: "It's also big, even so, it also contributes to our economy, whether we like it or not. Because like this, when you are in the informal sector, you are an ambulant vendor, even if you don't have a license, okay, you don't have a business permit to pay for, but you make money. Once you earn something, when you buy what you earn, you earn what you sold. And you earn, others earn too. Once you move the money, it's good… that has an effect on our economy. Imagine, 186 beneficiaries, they sell at a minimum, let's say, an average of P2000 (let's compute), P2000 times 186 they are, that's how much? P372,000. That is, they will not hold that, they will also buy raw materials, when they buy that, that will have an effect on our economy. The money has circulated. Because when the money circulates, it has an immediate effect, because it moves. Here they are, they will use the money to buy their food, their merchandise, their raw materials. Imagine the P372,000 to circulate… even if they are only informal. That's what you're saying, they are just the ambulant vendors specifically, earnings from talipapa, food vendors, fruits and vegetables vendors, sidewalk vendors because we also have vendors in Ugac, in Pengue, they are not even included here in the ₱372,000.00. That's so big, in fact, we are talking of millions. Worth millions of circulating goods"

IS25: "I sell face towels even if we make sacrifices every day as long as we earn something to buy our necessities in life."

IS27: "Even if we are only here on the side selling, we are able to help people. For our future and for our children to see that we are doing everything for their school needs."

C. Community Participation and Environmental Responsibility

Informal sectors, though not registered, are still part of the community. Through their engagement in the locality, they contribute to the community where they operate. One of the perceived effects of the informal sector to the local development is their civic participation to special calls of the local government such as cleaning the market. Also, as part of the community, the informal sectors abide with their environmental responsibility such as having waster bins in their area. Aside from the fact that the availability of four sets of trash cans per business sector is a city ordinance, the informal sectors voluntarily comply to this ordinance as well. The verbalization is as follows:

INF01: "One time, these ambulant vendors, when Ma'am Maila won, they were the ones who cleaned up. They clean the whole area. So now, at the night market, it's just on one side, for example, purely ambulant vendors, purely selling street foods, they also only have a portion to put, then after they leave, there's a dumptruck, they'll take one by one. So they are fine, but we can't avoid, that the others are really stubborn, you can't do anything"

IS01: "I have a trash bin here and I can't damage the environment here because I'm close to the school so it must always be clean."

IS03: "There is a trash bin here to keep the surroundings clean."

IS06: "I have a trash can here to avoid pollution around"

D. Market Opportunities and Convenience

Most of the informants shared that one of the perceived effects of the informal sectors in the local development is the provision of the avenue to where varied customers may choose to purchase from. There are some consumers in the market who cannot afford to purchase from formal sectors thus resorting to purchase from informal sector due to some reasons such as price, access and image. With this, market segmentation arises. Through their informal sector engagement, some members of the community who cannot

afford to engage in the formal sector are given the choice and opportunity to engage in the informal sector. This improves the quality of life as some basic needs are provided by the informal sectors. Moreover, most of the informal sectors mentioned that they provide variety of choices to varied markets (eg. students, professionals, passersby, etc.) and also, they provide convenience to the market as they are held accessible, easy to transact with and less hassle in purchasing. The verbalizations are as follows:

INF01: "Because when it comes to the formal sector, their client is different. The target customers of those are different. Other... For example, let's say, here's a turo-turo, Pension Roma. It's different. Only for those who can afford, those people living in, say above average income. Here is for the general public. This is what tricycle drivers eat, don't expect a tricycle driver to go to Roma. For me, we can't compare these two eh. The customer of the formal sector is different; the customer of the informal sector is different. Although, it's okay, there are just as many people, even the rich, who go there (informal sector), just enjoy eating fish balls, But the definite thing for me is that the poor, can't go at Pension Roma, in the formal sector. Or at least in a restaurant that is pretty nice. Db? So their target customers are different."

IS08: "I sell various vegetables that I bring from house to house. I help my customers because they don't get tired anymore, I bring them vegetables."

IS09: "The dish we serve to our customers is delicious and clean. Many people are enjoying our food. We help because we can give satisfaction of food to our customers."

IS13: "Almost everyone who works (divine mercy) doesn't have time to buy food from distant fast food restaurants when in fact they don't eat like that, just on breaks. That's my help, selling is not only for me but also for them because they get enough."

E. Transition of informal sector to formal sector

Some of the informants mentioned of the intention to transition the informal sector to formal sector. This mandate of the different agencies will eventually affect the local development as everything in the economy is held legal and all transactions are transparent and documented. There are lots of benefits, like, when you are part of the formal sector, there will be less barriers, less restrictions, more access to capital, safer environment, more regulated transactions, among others. Meanwhile, none of the informal sectors shared about their views along this theme. Some of the verbalizations are as follows:

INF01: "Actually the others, you say informal, they are becoming formal especially the talipapas, because the city government has already required them to secure a business permit. But it depends on the capital. If you have a bbq, worth of your goods is let's say, P1000, will you still get a permit? Then you get a permit, but the permit, already lessened, they have a special discount, I don't know if we call that as a discount. So most of them, because I was with the meeting of BPLO and Market Administrator, they said, one year they will pay, something like ₱2500-₱3000. But BPLO said, just register, just get a permit. Because what you pay is more expensive, because if ₱20 per day, ₱20 times 30 days = ₱600 times 12 months is ₱7,200. But they don't pay that ₱7200 daily, but this ₱ 3000 business permit is cash, it can't be paid in installments of twenty pesos every day. But then, maybe it's better if the others, as long as they are already big, if they can afford it, they are already selling a lot, it's better if you're registered. First, you are legal. Whatever happens, you can't be banned. You cannot be banned because you are paying for a business permit. Whereas, if you are an ambulant vendor, when it is said that it is not allowed there, it is not allowed there."

Negative perceived effects of the Informal Sector to Local Development

A. Unfair competition between informal and formal sector

Two of the informants among the government sectors mentioned that the existence of the informal sector in the economy, results to unfair competition between them and the formal sector. Some of the informal sectors are earning even higher compared to the formal sector. There was also a complaint to the agency that it is also unfair on the part of the formal sector since they are spending for the permits and licenses in order to operate while others are not. Meanwhile, none of the informants shared this theme because for them, they believe they are not into competition since the markets have their choice. Also, most of the informants in the informal sector shared their positive insights about the competition since they are not in any means competing with the formal sector since they are operating in a small-scale only. The verbalizations are as follows:

INF01: "One of the effects of this is like... it happened last year or pandemic because, some people complain that online sellers who are unregistered earn more than legit or registered businesses, so there are complaints. That's right, they're just online, they're just there at home. But we don't have any form of monitoring because eh. I also asked the BIR how you can visit them, they are online, there is no visible address to go to. So that's the problem too, because online, those

are the complaints. The informal sectors have more income and the one that is losing money are those business that are legit."

B. Waste Management Problems

One of the negative perceived effects of the existence of the informal sector to local development affecting the environment is the waste management problems. It happens that when the informal sectors, especially ambulant vendors and street food vendors operate in the city, there are some who are not mindful of their and their customers' wastes. One informant from the informal sector also shared that sometimes they could not manage their waste well due to some customers who do not dispose well their trash. Some of the verbalizations are as follows:

INF01: "It's like this, back then, they were restricted, they had to be in one place, because sometimes, they became messy. That is why, we required them then, that they have a trash bin, or trash container… they have a garbage bag. So that, it's a bit restricted because, they're one of the polluters. And then, aside from that, so it was restricted then, there was a time when ambulant vendors were banned, those that are banned are those who are not from Tuguegarao, so you must have a valid ID to prove that you are from Tuguegarao"

IS15: "Sometimes it got bad because our goods were not disposed of properly. Not us, but our buyers."

C. Cause of Traffic

Two of the informants from the informal sector mentioned that due to their engagement in the informal sector and their operations within the city, some are not mindful if they cause traffic. In the city, peak hours start during the closing of office hours, business hours and school hours. During this time, many customers avail of the streets as pedestrians, walkers and passengers. Some customers rush home and some buy their stuffs for dinner and other things. Some of the verbalizations are as follows:

IS34: "when we were not yet moved here (pertaining to the inside of mall of the valley where different informal vendors are being relocated), we were able to cause traffic because of course we were only on the side and people really flocked to us."

IS17: "Sometimes we are blocking the way. Especially that I am selling in the sidewalk."

5. Discussion

Factors Affecting the Engagement of the Respondents in the Informal Sector

There are various factors affecting the engagement of the respondents in the informal sector. As enumerated, engaging in the informal sector is attributed to necessity-driven factors (push factors) or opportunity-driven factor (pull factors). For necessity-driven factors, respondents engage in the informal sector for day-to-day needs of the family, for the education of children, for the payment of debts, for self-support, for investment purposes, for buying appliance furniture and other things needed in the family and for medication of family member and because of the unavailability of jobs. For the opportunity-driven factor, respondents engage in the informal sector because it is the easiest way to earn profit, it is very easy to manage, and this serves as sideline business.

There are two major factors that significantly impacted entrepreneurs in the informal sector. Push factors, also known as factors of necessity, and pull factors, also known as factors of opportunity (Williams, 2008; Bora, 2014). According to Williams (2008) push factors can be understood as unemployment, underemployment, and dissatisfaction with current employment. "Necessity" entrepreneurs were forced into entrepreneurship due to a lack of alternatives. These are defined as a desire for independence, self-actualization, financial benefits, and a desire to achieve a better balance between family and work obligations. Entrepreneurs seize such an "opportunity" because they want to be self-sufficient or own a business. People engage in the informal economy because they can't look for a formal job to sustain their living (Elgin and Oyvat, 2012). Also, supported by Sibhat (2014) the main reason of informal sectors to be informal is seeking of employment. This is similar to the finding of Ogbuabor and Malaolu (2013); Jie et al., (2010) that unemployment is one of the causes for informal economy engagement. Tambunan (2009) also revealed that they cannot find employment in the formal sector.

The result of Willemse (2011) shows that the limited ability of the government and the formal business sector to provide sufficient employment opportunities to people in the economically active age categories is the main reasons for informal trading. Ebisa (2012) assessed that informal sector is the only hope for a large number of women who are not able to find employment in the formal sector also from Sibhat (2014) lack of job opportunity in the formal sector.

Moreover, economic players of informal economy are forced to participate not by choice, but more likely by necessity (Williams & Round, 2007; Pfau-Effinger, 2003). Moreover, informal economy is displayed "as a new form of work emerging in late capitalism as a direct by product of the advent and deregulated open world economy" (Williams & Round, 2008). In this by-product understanding, informal economy is enormous in marginalized groups of western and developing nations due to weak status of formal economy (Williams & Round, 2007; Amin, et al., 2002). Marginalized populations engage in the informal sector in order to survive in this sphere as a last resort (Williams, 2008). Some workers with jobs in the formal sector also engage in informal economic activity to reduce the risks associated with formal employment (Edgcomb &Thetford, 2004). Push factors have overriding importance; however, the importance of pull factors shows that their relative influence is greater when income earning and employment opportunities are concerned (Bora, 2014). Also, on the opportunity factor or pull factors, the respondents engaged in the informal sector due to ease of management and the ease of earning money. Becker (2004) also mentioned that the obvious benefit for entrepreneurs who operate in the informal economy is avoidance of costly and burdensome government regulations, as well as high and complex taxes. He also said that the reason why the informal sector is so large in developing countries is that the benefits of formality are dwarfed by its costs. Also, majority of the respondents in the study of Sibhat (2014) perceived that they become informal sector because of the difficulty of entry into the formal sector. This is due to their inability to fulfill minimum criteria of the sector or alternatively due to the ease of entry into the informal sector.

Predictors of Engagement in Informal Sector

There are various predictors affecting the engagement of the respondents in the informal sector. The current study reveals that age, gender, number of dependents, number of dependents in school and total monthly income are predictors of engagement along necessity-driven factor such as for buying other needs, for self-support, for education of children, for paying off debts. While civil status and educational attainment are not predictors in the engagement of the informal sector along necessity-driven factors. In details, the study implies that older respondents are more likely to engage in the informal sector in order to buy their other needs such as appliances, gadgets, etc., as compared to younger respondents. As the respondents grow older, they are more likely to engage in the informal sector due to the need of buying appliances, gadgets and others. Meanwhile, female respondents are more likely to engage in informal sector than male respondents do due to self-support needs. Other than the daily needs of the family, female respondents enter the informal sector in order to finance their own needs presuming that they are also single. Also, respondents with more dependents are less likely to engage in the informal sector to buy other needs such as appliances, gadgets, etc. since this is not considered as primary needs for those families with more dependents. Having more dependents has more priority needs to consider over the need to buy appliances, gadgets, etc. Lastly, respondents who have more dependents enrolled in school are more likely to engage in the informal sector to fund the education of their children. For this reason, respondents with more dependents in school enter the informal sector in order to support the school needs of their children.

Meanwhile, results reveal that age, civil status and number of dependents in school are predictors of engagement along opportunity-driven factors such as engaging in the informal sector is the easiest way to earn profit and it serves as a sideline business. Lastly, results also reveal that sex, educational background, number of dependents and monthly income are not predictors of engagement in the informal sector along opportunity-driven factors. In details, older respondents are less likely to engage in the informal sector because it is the easiest way to earn profit; married respondents are more likely to engage in the informal sector because it is considered to be the easiest way to earn profit compared to single respondents and respondents with more dependents who are attending school are more likely to engage in the informal sector as their sideline business. This is so, since engaging in the informal sector will serve as an additional source of income for families with more dependents in school. This finding supports Sarreal's (2019) study, which found that the significant variable for deciding to be an informal entrepreneur is necessity, with no other option for work as the primary motivation and goal of being an entrepreneur.

Perceived Effects of the Informal Sector to Local Development

As defined, local development refers to participative process to address and solve a diversity of socio-economic, cultural and environmental problems with the aim of producing sustainable development and improve the quality of life of the population (Jover et al., 2016). Results revealed that there are positive and negative perceived effects of the informal sectors to local development.

Through the existence of the informal sectors, there is an employment generation. As it is a desire for any given government to achieve high employment rate, this aim is realized through the existence of the informal sectors. It can be noted that some of the informal sector respondents in the current study mentioned that they engaged in the informal sector since they cannot find jobs or there are no jobs available for them. Lack of jobs can also be attributed to slow economic activities as a result of COVID-19 pandemic which caused many businesses to shut down and to temporarily close. Not finding a job can also be attributed to the qualification of the job where the respondents seem not to be qualified. Therefore, their only means is to engage in the informal sector. At the macro level, employment refers to the application of production factors to efforts that generate income for the benefit of citizens (Atoloye, 2007).

Moreover, an indirect effect of the existence of the informal sector in the economy, facilitates the ability of the spending and consuming units to spend and consume. This is a good indicator in the economy. Since there is a good flow of spending in the economy, there are some businesses who are benefited. The cycle continues, as there is a good business activity, which would translate to business opportunities, thus may result to generation of employment opportunities or income opportunities. The informal sector's productivity contributes immensely to the economic growth that will in turn generate employment opportunity (Yusuf, 2014). As a result, enhancing the productivity of informal traders and making them competitive is crucial as it absorbs the job-seeking and able-bodied people who in turn produce thereby increasing national output and speeding up economic development (Tshuma & Jari, 2013). When looking at the issue of employment, Aswani (2007) stresses that the informal sector should not be viewed as a sector that offers jobs per se, but as one that offers income opportunities. Furthermore, it acts as a cure to many ill effects of globalization by accommodating the retrenched, uneducated, unskilled, displaced workers, etc. (Aswani, 2007).

On the other hand, the proliferation of the informal sector in Tuguegarao City is perceived to positively affect the local development. The engagement to the informal sector is seen to be a sustainable source of income or has the ability to generate income. In

Tuguegarao City, most of the respondents engaged in the informal sector mentioned that the factor for their engagement is due to the necessity-driven factor. This is where the respondents get the money for their day-to-day needs, for the school needs of their children and for debt payments, among many others. The ability of the informal sector to sustain for their daily needs is a good indicator that they are at least surviving in their day-to-day living. This is a good indicator for local development since the quality of life of the respondents can be considered good. Schmögnerová (2004) considers the informal sector to be one of the primary driving forces in economic development due to its role in many developing economies such as South Africa. Other than providing income for the less educated and unskilled, it serves a variety of functions. Businesses in this sector are adaptable and can quickly respond to changing market demand and supply situations; they create jobs, help diversify economic activity, contribute significantly to exports and trade, supply raw materials to local producers, and aid in poverty alleviation (Tshuma & Jari, 2013). Local development may include participative process to address and solve a diversity of environmental problems with the aim of producing sustainable development and improve the quality of life of the population (Jover et al., 2016). This activity in the city was participated into voluntarily among the informal sectors. If this activity will be done regularly, it is obvious to note that these informal sectors are participating positively in the community towards local development.

Meanwhile, through the existence of the informal sectors, income-segmented customers may have the opportunity to choose where to purchase from. In order to improve the quality of life, the ability to survive every day is a factor. Looking into the capacity and the ability of different market segments in the community, not all can afford to engage in formal sectors. There are products being sold in the informal sectors that are not provided in the formal sector, or vice versa. Also, there are market segments who cannot afford to engage in the formal sector. For this reason, the informal sectors are considered as options, if not, the only option. There are various reasons why other market segments purchase from the informal sectors. One important role played by the informal sector is the provision of cheap and low-quality goods and services compatible with the incomes of the majority of the population. Informal sector activities play an important role in absolute poverty alleviation by providing additional cash income to households (Bagachwa, 2019). From a rational economic view, consumers will be more likely to engage in informal transactions if they can obtain better value for their money. As such, they will do so if they can obtain a faster delivery or provision or if the quality of the goods and services provided is better (Williams & Martinez-Perez, 2014). Therefore, consumers will continue making purchases in the informal economy as long as it is more convenient either due to a lower price or due to obtaining better value for money (i.e., faster provision and/or better quality of provision). Another explanation for consumers purchasing from the informal economy is that these transactions exist because the formal economy is flawed. It can also be argued that consumers who make purchases in the informal economy are making a rational decision because the formal market is underserved or unavailable, leaving the consumer with no choice but to engage in transactions in the informal economy (Horodnic, et al., 2021).

Meanwhile, another perceived effect of the informal sector to local development is the mandate to slowly transition these informal sectors to formal sector for various reasons. In order to achieve an improved quality of life, manner of engaging in the economy should be sound, safe and legal. According to International Labor Organization (2014), by its very nature, the characteristics of the informal economy are largely negative. It can trap individuals and enterprises in a spiral of low productivity and poverty. A coherent national strategy to facilitate transitions to formality needs to recognize that the

costs of working informally are high for businesses, workers and the community. Most people working in the informal economy do not enjoy secure property rights, which deprives them of access to both capital and credit. They have difficulty accessing the legal and judicial system to enforce contracts, and have limited or no access to public infrastructure and public markets. The biggest and probably the most dominant constraint faced by the informal business sector is lack of finance which is very much needed to bear possible losses. It is difficult to obtain credit from the formal financial sector such as banks due to the lack of enough collateral (Adisu, 2006). With time, some of the small businesses grow and try to join the formal sector. However, this transition into the formal sector brings with it many constraints such as the complicated and expensive legal requirements for registration (Tshuma & Jari, 2013). Having said all these cons in doing business informally, the Local Government Unit of Tuguegarao, DOLE and DTI are working closely towards the transition of some informal sectors to formal sectors through its programs, policies and efforts being implemented in the city in order to achieve local development.

On the other hand, there are also negative perceived effects of informal sectors in local development. One of which is the unfair competition between the informal and formal sector. Formal sectors tend to feel that there is unfair competition between the informal sector as the former needs to secure permits and licenses and pay taxes while the latter can freely engage in selling without paying for regulatory fees. This may affect the local development negatively as formal sectors may choose to later engage in the informal sector when the earning capacity is at stake. Additionally, shifting from formal to informal may cause negative effect to the economic development of the locality as revenues derived from these formal sectors may be reduced. According to Levy (2008, as cited in Rothenberg et al., 2016), informal businesses typically do not pay official taxes. This is because the government cannot recognize each of the businesses that are part of the informal sector. In effect, most businesses that are unregistered tend to be free from paying taxes. On the other hand, it also affects the registered businesses. As informal businesses tend to have a lower cost (i.e., production cost), they can offer relatively lower price compared to registered businesses. In effect, there would be an unfair competition between the two (Farrell, 2004, as cited in Rothenberg et al., 2016). Lastly, it also affects the informal business itself. Given that they do not have any license to operate, it would be difficult for them to obtain credit from banks and other financial establishments (Rothenberg et al., 2016).

Policy Recommendation Towards Informal Sector

With the findings of the study, the researcher proposes a slow transition from the informal sector to formal sector. To be able to do this, the researcher proposes the following policies:

Registration of Business. A simple registration without taxation and monetary cost involved is the first stage towards transition. This will serve as documents on the statistics and existence of this sector as baseline data on the number of operating informal sectors in the city. Such registration will need basic data as to the socio-demographic profile of the business owner and informal sector profile such as nature of business, number of years in operation among others. The government should be able to undertake a proper assessment and diagnostics of factors, characteristics, causes and circumstances of informality in the city to inform the design and implementation of laws and regulations, policies and other measures aiming to facilitate the transition to the formal economy. It can be further proposed that the office of City Development and Planning should take charge of this acitivity as this form part the local development of the city.

Business Monitoring. Once the city is able to identify the proper office to be in-charge of informal sector, it will be easier for the local government to monitor the business engagement of these informal sectors. The government should look into how it can support operations of this sector in a win-win situation with the formal sector. It can be proposed that the government should conduct seminars on the different areas of business management such as capital acquisition, sanitation, safety, marketing and many others to the informal sectors in order to guide them as they are encouraged to enter in the mainstream of the economy. The government should actively champion informal sector, even though, unlike formal firms, there is likely little revenue benefit (but increased costs) to the local government in the short and medium run. Also, business monitoring of informal sectors should be aided in providing higher workplace safety standards and better worker protection, for example, by providing training or subsidizing certification. In other words, the government should assist informal sector firms in gradually integrating some business practices in preparation for a possible slow transition to the formal sector.

6. Conclusion

With all the findings of the study, it can be concluded that informal sectors in Tuguegarao City have engaged in the informal sectors due to necessity-driven factors (push factors) and opportunity-driven factors (pull factors). Topping these factors, respondents enter informal sector in order to provide for the daily needs in order to survive, for the education of the children and for debt payments. Also, entering the informal sector is the easiest way to earn profit. Moreover, some socio-demographic variables such as age gender, number of dependents, number of dependents in school and monthly income are predictors of engagement along necessity-driven factors, while for opportunity-driven factors, age, civil status and number of dependents in school are predictors of engagement. Lastly, the study concludes that there are positive and negative effects of the informal sector in the local development of the component city-Tuguegarao City. Informal sectors in the economy generate employment opportunities, serve as a sustainable source of income and provide wide range of choices available for customers from both informal and formal sector. However, informal sectors create unfair competition with the formal sector, cause waste management problems and traffic.

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Eco-Raincatcher: A Rainwater Harvesting System

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Abstract

This study designed an efficient rainwater harvesting system (RWHS) using polyethylene barrels and environment-friendly filters, such as biosand and non-woven geotextile, while also assessing its efficiency and economic viability. To evaluate the system's performance, water samples were collected from the RWHS and subjected to various tests. After passing through the filtration process, the pH level of the rainwater showed a decrease of 1.64%. The color of the water also decreased by 54.17%, indicating a substantial improvement in its visual appearance. However, the total dissolved solids (TDS) value increased by 72.1 mg/L, suggesting the presence of dissolved substances in the filtered rainwater. Despite this increase, other parameters such as turbidity, arsenic, cadmium, and lead showed no significant changes. One of the critical aspects of water quality is microbial contamination. The study revealed that the filtration process effectively reduced the total coliform and fecal coliform counts from 8.0 to less than 1.1. Moreover, there was a significant decrement in heterotrophs from 6.6×104 CFU/mL to less than 30×100 CFU/mL. These results indicate that the filtered rainwater from the RWHS met the standards for potable water. In addition to assessing the efficiency of the system, the study also evaluated its economic feasibility. The cost of implementing the eco-raincatcher system was compared to that of commercial RWHS options. Remarkably, the eco-raincatcher system was found to be 55.624% cheaper, making it a cost-effective alternative for rainwater harvesting.

Keywords : rainwater harvesting, polyethylene barrel, filter, geotextile, water quality

1. Introduction

Water scarcity worsened by climate change and population growth has become a global threat that demands attention. Rainwater utilization presents a reliable alternative to alleviate this issue by harnessing a valuable resource that would otherwise go to waste as runoff. Rainwater Harvesting Systems (RWHS) serve as collection and storage systems for rainwater, which can be used for non-potable purposes and even treated for drinking water.

Previous studies have highlighted the effectiveness of RWHS in water conservation. For regions experiencing a wet season, RWHS implementation has been shown to save 500-800 m3 of water annually (Bashar, Karim, & Imteaz, 2018). The size of the storage tank plays a crucial role in the amount of water saved (Semaan et al., 2020; Khan et al., 2017; Abas & Mahlisa, 2019). However, designing an optimal RWHS requires detailed rainfall information, which may not always be available (Liaw & Chiang, 2014). In such cases, estimation techniques for storage size are necessary. Considering cost optimization from the customer's perspective is also important in determining the size of the system (Semaan et al., 2020; Oviedo-Ocaña et al., 2017). To improve the quality of harvested rainwater, filtration facilities are commonly incorporated into RWHS. Various filtration methods, including ultraviolet light, chlorine, and natural filtration using materials like gravel and sand, have proven effective in removing microbial pathogens (Das et al., 2018). However, these facilities can be expensive, prompting the need for low-cost alternatives.

In the Cagayan Valley Region of the Philippines, water supply shortage poses a significant and urgent challenge (Paguigan & Afidchao, 2020). The region is heavily reliant on traditional water sources, such as rivers and groundwater, which are facing depletion due to factors like climate change and population growth. As a result, many communities within the region are grappling with inadequate access to clean and reliable water. While some individuals in the community have taken the initiative to collect rainwater as a means of supplementing their water needs, rainwater harvesting as a viable solution to address the water scarcity problem remains largely overlooked.

To address the need for rainwater harvesting while mitigating the cost of RWHS, the researchers developed the eco-raincatcher. Unlike previous studies, this system employs inexpensive and environmentally friendly materials. It operates without the need for electricity or water treatment chemicals, making it energy-efficient and environmentally sustainable. In this study, the size of the storage tank was estimated based on limited rainfall information and common usage, considering the cost of materials.

2. Objectives

This study aims to design a rainwater harvesting system incorporating geotextile and biosand filters and evaluate its efficiency. The specific objectives of the study were as follows:

1. Evaluate the potability of both the untreated rainwater and the rainwater filtered through the designed system by analyzing their chemical and microbiological properties.
2. Calculate the cost associated with implementing the rainwater harvesting system, taking into account the materials, installation, and maintenance expenses.
3. Develop an informative and comprehensive eco-raincatcher assembly guide pamphlet.

3. Materials and methods

The proposed design of the RWHS is shown in Figure 1 and the filtration system is illustrated in Figure 2. Figure 1 shows the different components of the RWHS. Figure 2 shows a more detailed view of the filtration tank.
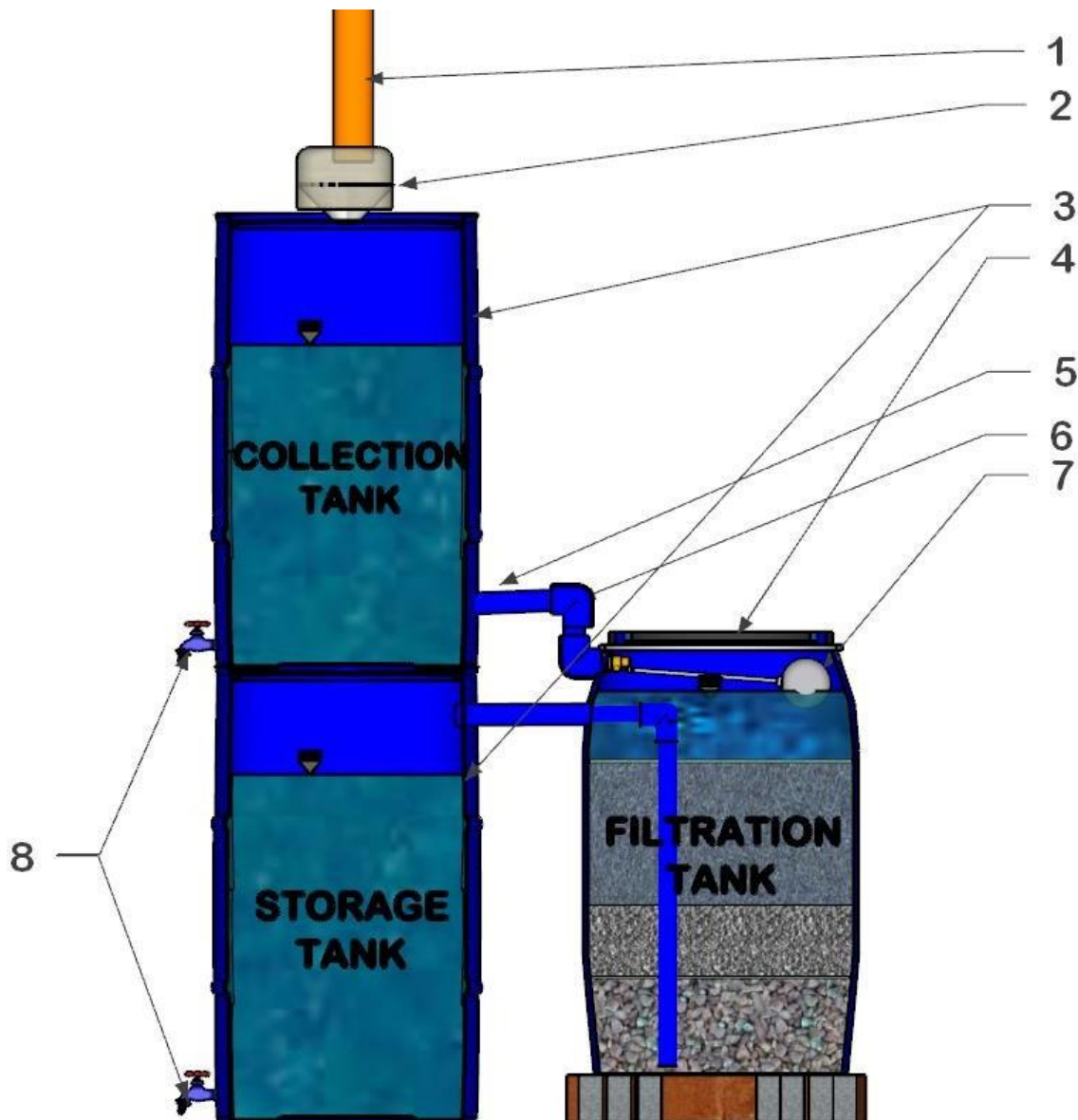
Figure 1 The Rainwater Harvesting System

Blue plastic barrels or food-grade drums, 200 liters (3) and 160 liters (4), were used in the system. These drums are made from High Density Polyethylene (HDPE) which makes it inert and resistant to high pH contents and easy to recycle. The water treatment shown in Figure 2 is composed of geotextile, sand, and gravel to naturally filter impurities from the rainwater. The researchers used a 1.5 mm thick standard non-woven geotextile fabric having 180 μm pore size, which is best for filtration, that was placed on top and bottom of the BSF with fine sand, S1 sand, and 3/4-inch gravel layered with a scaled height based on a past experiment (Heirloom Builders, 2020). Polyvinyl Chloride (PVC) pipes with a diameter of 3 inches (1) served as the passage of water in entering the system, 1-inch pipe (5) was used to transfer the water from one tank to another, and 90° elbows (6) were utilized to change the direction of water flow. This kind of pipe is durable and free from bio-film contamination making it suitable to be utilized in the system. A float valve (7) was installed to control the amount of water in the filtration tank. A DIY drain inlet filter (2) was installed to avoid large particles from entering the system. Finally, faucets (8) were placed on the collection and storage tank for water release.

The rainwater flowed from the gutter to the downspout and strained in the drain inlet filter before entering the collection tank. To avoid clogging, the gutter must be cleaned once a month. The rainwater went to the filtration system. The non-woven geotextile fabric on top of the BSF trapped tiny particles and avoid them from being mixed in the sand. It will be changed every after three (3) months for maintenance. The other geotextile in between the sand and gravel helped separate the aggregates. Moreover, gravity feed caused the water to transfer from the filtration tank to the storage tank.
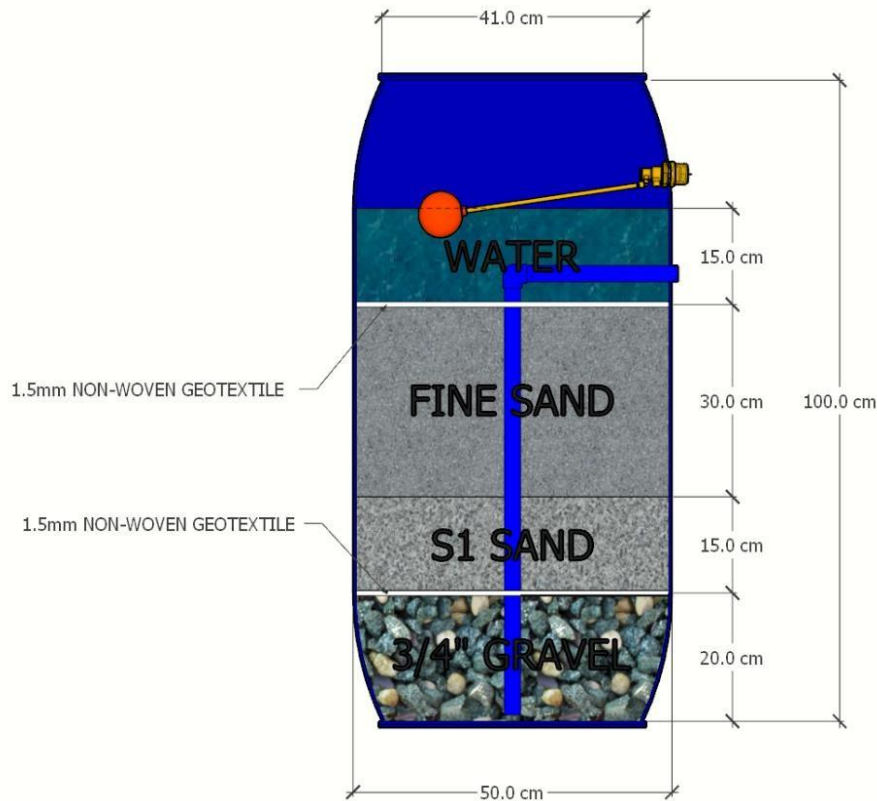
Figure 2 The filtration tank of the rainwater harvesting system

Project Development

The researchers selected a two-story, seven-meter-high residential building around Ugac Sur, Tuguegarao City, Cagayan, that was suitable for RWHS installation. The height of the house, roof structure, and availability of gutter were considered. Using the data gathered, enhancement for the initial design of the system was done. This served as the basis for determining the actual number of materials to be utilized. As preparation for the system building, listing the needed materials and canvassing for the prices were done. The creation of the RWHS was undertaken once the necessary materials were bought.

The initial step in the creation of the system was cutting the pipes to attain the necessary lengths. Then, boring holes in the drums that fit the pipes and faucet is the next step. The cleaned sand and gravel were layered inside the 160-liter drum together with the non-woven geotextile fabric which served as the treatment facility of the system. Lastly, permeability test was undertaken and connecting the parts was the final step.

Testing and Evaluation

The system underwent a preliminary test before installation to ensure that it was properly working. Water was poured until the system was full before releasing it from the faucets. After checking if it was functioning well, the system was installed in the selected house for a week. After one week, the researchers visited the system to record the data needed in the analysis.

The samples shown in Figure 3 were taken from the first and third drums to determine the property changes of the rainwater after passing into the filtration tank, and to test if it is suitable for drinking. The bottles labeled as 'pure' contain the water samples taken from the collection tank, while the bottles labeled as 'filtered' contain the water samples from the storage tank. The samples were given to the testing facility of the Department of Science and Technology (DOST) to measure the quality of water in terms of its chemical and microbiological constituents.

Figure 3 Water samples taken from the system

pH level is a measure of the water's acidity/alkalinity in mg/L that can be determined using a Conductivity meter. The neutral pH level of water is 7, pHs below 6.5 is acidic, and pH level above 8.5 is alkaline (Cirino, 2019).

TDS are the amount of materials, organic or inorganic, dissolved in water that are measured using TDS meter (Hancock, 2018). Generally, the TDS level between 50-150 is considered as the most suitable and acceptable for drinking purposes (Bisleri, 2020). However, the set TDS level in the Philippine National Standard for Drinking Water (PNSDW) can range up to 600 mg/L.

Turbidity is the measure of how clear a liquid is. It can be determined using a TDS meter (US Geological Survey, 2018). The World Health Organization (WHO) establishes that the turbidity of drinking water should not be more than 5 NTU, and should ideally be below 1 (World Health Organization, 2019).

Using a Spectrophotometer, water color is captured and evaluated. The standard color for a potable water is 10, according to PNSDW. But according to the United States Environmental Protection (U.S. EPA) Agency for Secondary Drinking Water Regulations, drinking water should possess less than 15 units in color (Environmental Protection Agency, 2022).

The only inorganic chemical parameters accessible at the DOST testing facility were arsenic, cadmium, and lead. The samples were digested and directly aspirated using Graphite Furnace-Atomic Absorption Spectrophotometer (GFAAS). A study proved that there is no arsenic content in rainwater, but it was found in the roof runoff. When the rainwater flows from the roof, it washes off dust particles that have settled on the roof or have collected in the gutter or the dust present in BSF (Quaghebeur, 2019). PNSDW recognized that arsenic content must be less than 0.01 mg/L. However, according to WHO, long-term consumption of water with arsenic over many years can increase the risk of cancer (Minnesota Department of Health, 2018).

Cadmium may harm living organisms in both chronic and acute ways. Cadmium is mostly obtained through municipal solid waste incinerators. Automobile tires and dumping of cadmium batteries are two further sources of cadmium (Anabtawi et al., 2022). The maximum permissible cadmium content in PNSDW is less than 0.003 mg/L.

Air contamination causes rainwater to become acidic and cloudy, and adds heavy metals such as lead in rainwater (Khayan, et al., 2022). The presence of lead in rainwater will have an impact on the health of the community. It is recommended by PNSDW that the presence of lead in drinking water is less than 0.01 mg/L.

Total coliforms are bacteria that are present in water and soil contaminated by surface water and animal waste, while fecal coliforms are total coliforms found in gut and feces of animals (New York State Health Department, 2022). These parameters are tested using the Multi-Tube Fermentation Technique. The standard count of total coliform and fecal coliform in drinking water is less than 1 MPN/100 mL.

Heterotrophs are water microorganisms that consume organic carbon measured through the Pour Plate Method (H2O Distributors Inc., 2022). Generally, the accepted number of heterotrophs in drinking water is less than 500 CFU/mL, to which the filtered rainwater conformed to.

4. Results and Discussion

Figure 4 shows the eco-raincatcher installed at Pauly's Residence, Ugac Sur, Tugugegarao City. The system has a total height of 97cm excluding the elevation of the pipe.

Figure 4 The installed eco-raincatcher

Based on the analysis shown in Table 1, the pure and filtered rainwater's pH levels are 6.1 and 6 (1.64% reduction), respectively, which indicate that both samples are acidic but not acidic enough to be harmful in the body. The decrease in pH level may be attributed to the acid-forming reaction occurring within the filter medium (Duran Romero et al., 2020).

It can be noted that the TDS of rainwater increased after the filtration, as presented in Table 1. The laboratory analysis revealed that the TDS of pure and filtered rainwater are 13.4mg/L and 85.5 mg/L, respectively. Both samples met the standard specification. The main reason for the TDS increase is that the aggregates were cleaned with water the same

day the RWHS was assembled. The water remains in the aggregates mixed with the rainwater, which caused the increment of TDS value. To achieve a lower TDS level, it is recommended that the rainwater should be boiled for at least 20 minutes (Organization of American States, 2016). Although some highly resistant organisms may survive after boiling for this length of time, it is believed that such presence is rare and so is acceptable (Environmental Protection Agency, 2021).

Table 1 shows an identical result in terms of pure and filtered rainwater turbidity. Both rainwater samples have a turbidity of less than 1 NTU which conformed to the standard specification. BSF has been proven to reduce turbidity by 90% to 95%. BSF can reduce turbidity by 64% on average (Duran Romero et al., 2020; Das et al., 2018). However, in this study, it did not show any relevance to the result.

It can be seen in Table 1 that the filtered rainwater achieved a 54. 17% reduction of color in the result. The pure rainwater has a color unit of 24 CU. After filtration, it changed to 11 CU which gave a better result for the filtered rainwater than the pure rainwater.

The results obtained from the method utilized as indicated in Table 1 for the inorganic chemical parameters (arsenic, cadmium, and lead) are lesser levels for both pure and filtered rainwater compared to the standard. The result suggests that BSF has no impact on the inorganic chemical characteristics of rainwater. The rainwater samples are safe to drink and will not create harmful side effects since these do not exceed the inorganic chemical content provided by PSNDW.

Table 1 Chemical Test Result for Pure and Filtered Rainwater

Parameter	Result		Standard Specification	Method Used
	Pure	Filtered		
pH @ 24.8°C	6.1	6	6.5-8.5 5.0-7.0**	Potentiometry
Total Dissolved Solids (mg/L)	13.4	85.5	600 10***	TDS Meter
Turbidity (NTU)	< 1	< 1	5	Nephelometric
Color (CU)	24	11	10	Platinum-Cobalt Standard Method
Arsenic (mg/L)	< 0.005	< 0.005	0.01	GFAAS
Cadmium (mg/L)	< 0.0005	< 0.0005	0.003	GFAAS
Lead (mg/L)	< 0.005	< 0.005	0.01	GFAAS

The employment of geotextile, together with BSF, can reduce the number of bacteria present in water (Duran Romero et al., 2020). Employing BSF alone can reduce total coliform and fecal coliform bacteria in water by 91.52% and 91.39%, respectively. Results showed that the total coliform and fecal coliform counts, in MPN/100mL, of the rainwater both decreased from 8 to < 1.1 after filtration, as presented in Table 2. The level of coliform in the filtered rainwater coincided with the standard specification provided by PNSDW. Furthermore, the laboratory analysis revealed that the heterotrophic plate count

of the pure rainwater (6.6×104 CFU/mL) is significantly higher than that of the filtered rainwater (< 30×100 CFU/mL).

Table 2 Microbiological test result for pure and filtered rainwater

Parameter	Result		Standard Specification
	Pure	Filtered	
Total Coliform Count (MPN/100mL)	> 8.0	< 1.1	<1.1
Fecal Coliform Count (MPN/100mL)	8	< 1.1	<1.1
Heterotrophic Plate Count (CFU/mL)	6.6×104	< 30×100	< 500

A RWHS with pumps and associated components that is sold in the market typically costs ₱157.55 to ₱315.10 per gallon (Hammerstrom & Pushard, 2022). The eco-raincatcher can save 102.24 gallons of water, therefore buying a commercial RWHS that can save the same amount of water will cost ₱16,107.91 to ₱32,215.82. In addition, since it is electricity operated, the electric consumption must be settled monthly anticipating rate changes over time. In this study, the eco-raincatcher costs ₱7,148.00 which is 55.624% cheaper than the commercial RWHS. The total cost of the system is shown in Table 3.

Table 3 Materials Used and their Prices

Quantity	Unit	Material	Unit Price	Amount
1	pcs	160-liter blue drum	1300.00	1300.00
2	pcs	200-liter blue drum	1400.00	2800.00
1	pcs	Float valve	450.00	450.00
2	pcs	Faucet	50.00	100.00
2	pcs	Female adapter for faucet	20.00	40.00
3	pcs	1-inch coupling	30.00	90.00
2	pcs	1-inch 90° elbow	30.00	60.00
1	pcs	1-inch 90° elbow with thread	30.00	30.00
2	pcs	3-inch 90° elbow	75.00	150.00
2	m^2	1.5mm non-woven geotextile	148.00	296.00
3	m	3-inch PVC pipe	100.00	300.00
3	m	1-inch PVC pipe	33.33	100.00
1	pcs	Screen	150.00	150.00
2	m^3	Fine sand	300.00	600.00

Quantity	Unit	Material	Unit Price	Amount
1	m^3	S1-crushed sand	300.00	300.00
1	m^3	3/4" gravel	300.00	300.00
1	pcs	Teflon tape	15.00	15.00
1	pcs	PVC pipe cement	42.00	42.00
1	pcs	Sealant	25.00	25.00
			Total	**7148.00**

The pamphlet shown in Figure 5 and Figure 6 is to be used for the Service-Learning Program (SLP) of the Community Engagement and CICM Advocacy Office (CECAO). The pamphlet presents the materials used in the system, installation process, connection details, how the system works, and its maintenance. It will serve as a guide for the target community on how to create their own RWHS which will aid their water insufficiency problem.

Figure 4 Eco-raincatcher Pamphlet

5. Conclusion

The study concludes that the eco-raincatcher is efficient with regard to its function and cost. BSF with geotextile layers improved the quality of water in terms of its chemical and microbiological properties, except for the pH level and TDS. Although the pH level and TDS in the filtered rainwater increased, the result still suggest that it is potable. Moreover, when compared to the commercial RWHS, the eco-raincatcher is more economical considering that both harvesting systems can reduce the impurities present in the rainwater.

Although the overall result suggests that the water is potable, it is better to further enhance the parameters to reduce health risk when consumed. It is recommended that the storage for the filtered rainwater should be cleaned thoroughly in order to prevent water contamination. In addition to that, the sand and aggregates should also be dried out before settling inside the filter tank. This will restrain the rainwater and tap water from mixing and creating improbable pH and TDS results. To prevent the collection tank from falling, it should be permanently attached to the storage tank. Furthermore, it is ideal to consider the size of the storage tank and the amount of rain experienced in the selected area to save more water.

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Enhancing Resilience: A Contemporary Approach to the Disaster-Resistant Bahay Kubo

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Abstract

The Philippines is witnessing a rise in losses and destruction due to increasingly frequent and intense typhoons, resulting in floods and landslides. To address this issue, a previous study proposed a lightweight bamboo-based hybrid amphibious house that utilizes a buoyant foundation of HDPE sewer pipes enclosed in a steel cage, along with easy base isolation. The main objective of the project was to design a disaster-resistant modern Bahay Kubo using bamboo as the primary material. By obtaining wind load, dead load, and live load data from the National Structural Code of the Philippines 2015, the study found that the forces applied to the structure were sufficient to withstand the challenges posed. Through STAAD analysis, it was determined that the design could endure wind speeds ranging from 240 to 320 kilometers per hour, with a maximum displacement of approximately 0.099mm at 320 kph. This research presents a promising solution for enhancing resilience against typhoons and reducing the impacts of floods and landslides, offering a durable and sustainable housing option that aligns with the specific needs of the Philippines.

Keywords : bahay-kubo, bamboo, typhoon, house structure, flood

1. Introduction

The Philippines, being highly susceptible to natural disasters such as typhoons, faces significant challenges each year. These typhoons pose a severe threat to livelihoods, shelters, and even lives, resulting in devastating consequences for rural communities (Cantiveros, 2020). Historical data reveals the extensive damage caused by typhoons like Rolly, Yolanda, and Ulysses, which resulted in the destruction or damage of millions of houses and substantial losses to the country's infrastructure (Morella, 2018; Deiparine, 2020; Nepomuceno, 2020). While some researchers have explored resilient housing structures as a potential solution, a significant gap remains in providing improved construction methods to the impoverished population, who are particularly vulnerable to such disasters (Das & Mukhopadhyay, 2018; Shih & Ravina, 2020).

The concept of developing disaster-resilient housing has gained attention from various studies. For instance, researchers have proposed incorporating an amphibious foundation into traditional Assamese buildings to enhance their resilience against hazards, utilizing cost-effective bamboo-based hybrid facilities (Das & Mukhopadhyay, 2018). Another study suggests the construction of a lifelong typhoon shelter, utilizing locally abundant Coco lumber and employing a design that reduces the impact of prevailing winds during typhoons (Ray, 2019). Similarly, amphibious foundations have been proposed as an alternative to permanent static elevation, allowing houses to float during flooding and settle back into place afterward (Shih & Ravina, 2020).

Amidst these innovative approaches, the iconic Bahay Kubo, a symbol deeply ingrained in Philippine culture, emerges as a potential solution. This traditional dwelling constructed using bamboo, nipa leaves, and other indigenous materials, reflects the rich

heritage and practical applications of bamboo in the Philippines (English, 2009). Bamboo is recognized for its strength and flexibility, boasting higher compressive and tensile strengths compared to concrete and steel, respectively (De Jong, 2010). Leveraging these properties, the researchers aim to construct a modern Nipa Hut, or Bahay Kubo, with the objective of mitigating wind-related disasters, promoting safety, and fostering sustainable societies.

By addressing the enormous losses inflicted on the country's infrastructure by typhoons, this study seeks to contribute to the development of a modern Nipa Hut that can withstand future wind-related disasters. The ultimate goal is to create safer and more sustainable communities that are resilient to the adverse effects of natural calamities.

2. Objectives

This study aims to design a disaster-resistant modern Bahay Kubo and accomplish the following objectives:

1. Conduct simulation and analysis to evaluate the structural response of the modern Bahay Kubo under varying wind loads.
2. Estimate the cost of constructing the disaster-resistant modern Bahay Kubo.

3. Materials and methods

Due to the limited material options available in STAAD Pro, such as concrete, aluminum, steel, and timber, the researchers conducted a comprehensive investigation into the characteristics and compositions of bamboo, focusing specifically on the Bambusa blumeana variety, which is abundant in the Philippines. By exploring the properties of Bambusa blumeana presented in Table 1 and integrating this information into the analysis within STAAD Pro, the researchers aimed to accurately assess the structural behavior and performance of the modern Bahay Kubo. This investigation ensures that the unique properties of bamboo are appropriately considered and incorporated into the design, enabling a comprehensive evaluation of the disaster-resistant housing structure's response to wind loads and other relevant forces.

Table 1 Properties of Bambusa Blumeana

Property	Specification	Literature
Young's Modulus (E)	$10034000 kN/m^2$	Abdullah et al. (2019)
Poisson's Ratio (nu)	0.013to0.278	Takeuchi et al., (2015)
Density	$8.3552537487 kN/m^3$	(Salzer et al. (2018)
Thermal Coeff (a)	$65x10^{-6}$	Hebel et al. (2013)
Critical Damping	0.00152	Kakkad (2011)
Shear Modulus (G)	$2200 kN/m^2$	Bautista et al. (2021)

Table 2 presents the various load combinations as prescribed by the National Structural Code of the Philippines. Load combinations occur when multiple types of loads act upon a structure simultaneously. These combinations are defined in building codes to ensure the safety and structural integrity of the building under different anticipated maximum loading scenarios. To account for the complex nature of loads, building codes specify load factors or weightings for each type of load, considering the structure's response to various loading conditions. By incorporating these load combinations and factors, the design process addresses the necessary safety requirements to withstand a range of expected loading situations. In the table, dead load (DL) refers to a constant and

predictable load that must be supported at all times, while live load (LL) is transient and can vary depending on the usage of the structure. On the other hand, wind load (WL) refers to the force exerted by the wind on the structure.

Table 2 Load Combinations

Number	Load Combinations
1	1.4 DL
2	1.2 DL + 1.6 LL
3	1.0 DL + 1.6 LL + 1.0 WL (windward)
4	1.0 DL + 1.6 LL + 1.0 WL (leeward)
5	1.0 DL + 1.6 LL + 1.0 WL (sidewall)

Wind Load Simulation

After gathering the data needed for the structure's design, the researchers utilized the provisions of the Philippine National Structural Code (NSCP) to determine the external forces required for calculating the loading applied to the structure. The Directional Procedure was used to calculate the wind pressure, starting with the determination of the basic wind parameters, including the occupancy category, structure type, exposure category, topographic effects, gust effect factor, and enclosure classification as specified in the NSCP 2015. Subsequently, the researchers computed the wall pressure by setting the structure's leeward, sideward, and windward directions, with the assistance of the Structural Analysis and Design application. After assessing the combination of loads on the structure, STAAD was employed to analyze the structure and determine its ability to withstand the applied loads at different magnitudes.

Flood Vulnerability

In the context of designing a flood-resilient structure, the researchers prioritize certain parameters. One such parameter involves elevating the structure on stilts, typically ranging from one to two meters, depending on the location. By raising the interior of the structure above ground level, shelter residents are protected from flooding (Berkeley, 2021), while allowing water to flow freely underneath the structure (Kouhirostami, & Kibert, 2003). Considering this important parameter, the structure can be designed to be flood-resilient, mitigating the potential impacts of flood events.

4. Results and Discussion

Figure 1 The Disaster-Resistant Modern Bahay Kubo

The researchers utilized AutoCAD to design the frame system required to simulate various loads and its floor plan. SketchUp was another tool utilized by the researchers to create the 3D model of the structure, and it was rendered using V-Ray to depict its view in a real-world structure. The designed disaster-resistant Bahay Kubo is shown in Figure 1, along with its floor plan in Figure 2.
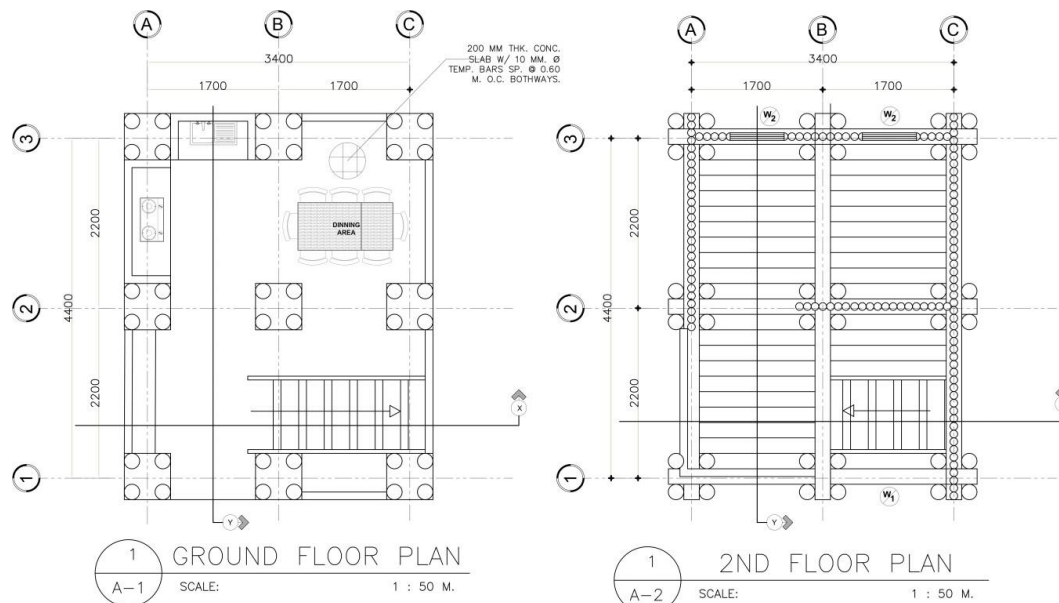
Figure 2 Floor Plan of the Structure

The Bahay Kubo is built utilizing data and criteria acquired from several literature sources to construct a bamboo house that can withstand the high winds caused by typhoons and its height from the ground in terms of floods. In assessing the structure's vulnerability in terms of flood, some studies (Berkeley, 2021; Kouhirostami, & Kibert, 2003) suggest raising the structure's floor from the ground as a mitigating measure that must be integrated into the design to ensure that the building will not drown. The designed modern

Bahay Kubo adopted this approach by elevating the structure by about 2 meters to ensure that the occupancy of the Bahay Kubo is safe from flooding.

Figure 3.1 Column and Beam Connection

Figure 3.2 Column and Roof Connection

Figure 3.3 Column and Foundation Connection

The joints for the bamboo construction should be carefully and effectively lashed to prevent future collapse or undesirable displacement in the structure. To further maintain the full strength of bamboo, the researchers utilized a lash for each connection rather than creating a hole to connect the bamboo, which may lead to an undesirable outcome. As shown in Figures 3.1 and 3.2, the cut connection between the column and the beam is revealed. In connecting the bamboo, the researchers needed a 3.5m nylon monoline (Tansi) to lash the column and beam of the structure. For the column and foundation of the structure, the column should be attached to the concrete floor, as shown in Figure 3.3.

The loadings gathered from the National Structural Code of the Philippines are applied to the structural bamboo frame and are validated by analyzing the frame using STAAD Pro. The frame dimension has been taken to be 4.31m in height and a span of 5 meters by 4 meters. The supports at the base of the column are pinned joints. The material specified for the analysis is the Bambusa blumeana. Figures 4.1, 4.2, and 4.3 show the simulation of STAAD Pro load in dead load, live load, and wind load, respectively.
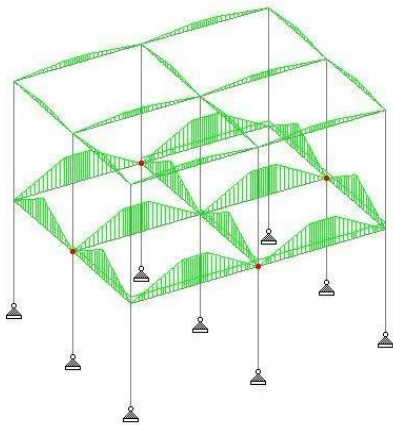
Figure 4.1 Dead Load Simulation
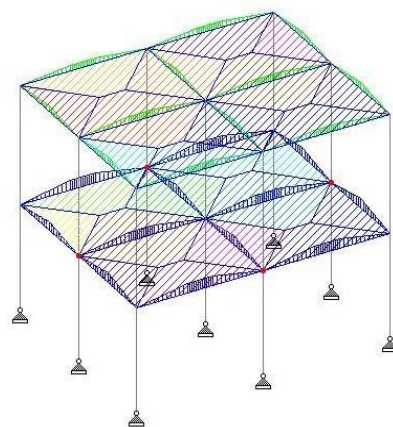
Figure 4.2 Live Load Simulation
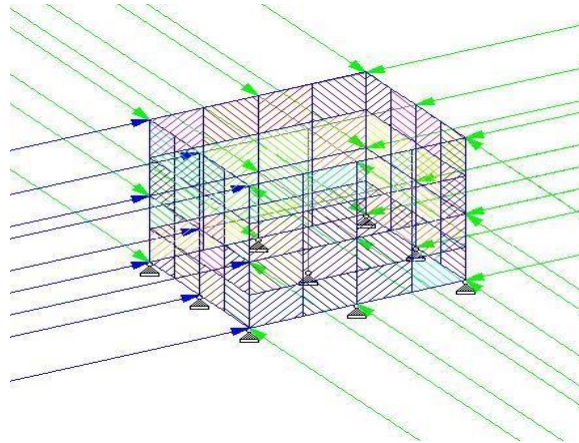
Figure 4.3 Wind Load Simulation

The results of the STAAD analysis show different values of maximum displacement from different loads and load combinations set by NSCP. In Table 3, the tabulated data is from 240 kph, 280 kph, and 320 kph wind velocity for the standard occupancy category. The maximum node displacement is 0.284 millimeters in all wind velocity ranges. The highest node displacement is load combination two, the factored load of dead load and live load, followed by 0.256 millimeters as the second-highest maximum node displacement at 280 kph, which is then factored load of dead load, live load, and wind load. While dead load alone has a node displacement of 0.142mm in all wind velocity ranges, the live load alone has a 0.074-millimeter node displacement in all wind velocity ranges. Concerning wind load simulation, the maximum displacement is at the windward of 320 kph, having node displacement of 0.099mm, while minimum node displacement is at leeward of 240 kph with 0.044mm node displacement.

Table 3 Nodes Displacement

Load	Wind Velocity (kph)		
	240	**280**	**320**
DL	0.142mm	0.142mm	0.142mm
LL	0.074mm	0.074mm	0.074mm
WL Windward	0.056mm	0.076mm	0.099mm
WL Leeward	0.044mm	0.060mm	0.049mm
WL Sidewall	0.052mm	0.071mm	0.058mm
Load Combination 1	0.198mm	0.198mm	0.198mm
Load Combination 2	0.284mm	0.284mm	0.284mm
Load Combination 3	0.284mm	0.256mm	0.284mm
Load Combination 4	0.284mm	0.256mm	0.284mm
Load Combination 5	0.284mm	0.256mm	0.284mm

When the structure induces dead load, live load, and load combinations, node number 24 exhibits the most significant displacement from its initial location, as tabulated in Table 4. Node number 24 is located in the middle of the roof, which carries the roofing structure of the Bahay Kubo. Node numbers 11, 13, 16, and 17 have the most significant node displacement in wind load. The tabulated displacement in all loads and load combinations is not enough to displace the nodes of the structure, as shown in Figure 5. Therefore, the modern Bahay Kubo design is sturdy and firm enough to withstand a 240, 280, and 320 kilometers per hour wind velocity.

Table 4 Number of Nodes Displaced

Load	Node Number with Maximum Displacement		
	240	280	320
DL	24	24	24
LL	24	24	24
WL Windward	11, 13, 16, 17	11, 13, 16, 17	11, 13, 16, 17
WL Leeward	11, 13, 16, 17	11, 13, 16, 17	11, 13, 16, 17
WL Sidewall	11, 13, 16, 17	11, 13, 16, 17	11, 13, 16, 17
Load Combination 1	24	24	24
Load Combination 2	24	24	24
Load Combination 3	24	24	24
Load Combination 4	24	24	24
Load Combination 5	24	24	24
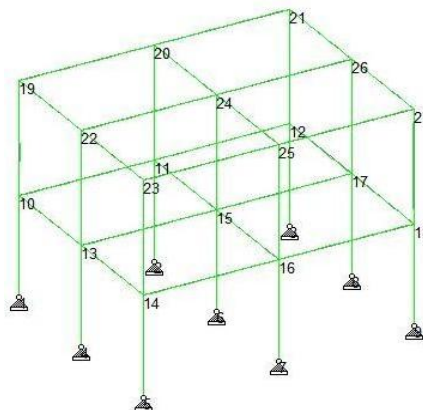
Figure 5 Maximum Displacement

Table 5 outlines the quantities and costs of various materials required for the construction of the project. It offers valuable insights into the cost breakdown, aiding in the overall project budgeting and procurement process. The majority of the expenses are allocated to essential construction materials such as CHB (Concrete Hollow Blocks), cement, gravel, and sand. These items are fundamental for creating a sturdy foundation and structural elements. Additionally, steel bars are included to reinforce the structure, ensuring its strength and stability. The utilization of bamboo for both the sidewall and flooring showcases the project's commitment to sustainable and locally available materials. Other materials, such as nipa for the roof, wood for the stairs, and nylon for various purposes, contribute to the aesthetic and functional aspects of the construction. By analyzing the quantities and rates provided in the table, it becomes evident that the estimated total cost of ₱40,000 aligns with the project's budget constraints. This affordability factor reinforces the feasibility and accessibility of the construction materials,

promoting cost-effective and sustainable building practices. In summary, this comprehensive materials table provides a valuable reference for project managers, contractors, and stakeholders, enabling effective cost estimation, procurement planning, and informed decision-making throughout the construction process.

Table 5 Cost Estimation of the Structyre

Name of Item	Quantity	Unit	Rate (P)	Amount
CHB	150	pcs	12	1800
Cement	51	bags	230	11730
Gravel	6	cu.m	715	4290
Sand	3	cu.m	572	1716
Steel Bar (10mm)	20	pcs	165	3300
Bamboo (Sidewall)	196	pcs	12	3144
Bamboo (Flooring)	262	pcs	12	2352
Nipa (Roof)	234	pcs	5	1170
Wood (Stairs)	43	m²	179	7697
Bamboo (0.25 m diameter)	36	pcs	12	432
Bamboo (0.10 diameter)	18	pcs	12	216
Nylon (0.1)	60	pcs	35	2100
			Total	40 000

5. Conclusion

In conclusion, this project has successfully conducted an analysis and conceptual design of a disaster-resistant modern Bahay Kubo, considering various loads and their combinations, with a specific focus on wind loads based on the provisions of Section 207 of NSCP 2015. The designed structure offers an environmentally friendly and resilient alternative for housing construction in disaster-prone areas. The computed forces, including wind loads, dead loads, live loads, and load combinations, have been satisfactorily addressed in the design. The structure exhibits robust connections between its components, showing minimal displacement when subjected to wind loads and various load combinations.

It is recommended to further enhance the disaster-resistant modern Bahay Kubo by conducting detailed calculations and designs specifically for its foundation. Strengthening the foundation will contribute to the overall sturdiness and load-bearing capacity of the structure, ensuring its resilience against different loadings. Since there is currently no specific code of practice available for bamboo construction, it is important to note that the steel code (NSCP 2015) has been utilized where necessary, which may have introduced some potential errors in the design. Therefore, future research and development efforts should focus on establishing comprehensive codes and guidelines specifically tailored for bamboo construction, ensuring accurate and reliable design practices for resilient structures.

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Eco-bricks with Animal Manures for Covered Walkways

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Abstract

This study aimed to create an eco-friendly brick using an environmentally friendly process to address transmission concerns. Animal manures, specifically horse manure, cow manure, and carabao manure, were sun-dried and pulverized for experimentation. Alluvial soil was partially replaced with animal manures at 10%, 20%, and 30% ratios, and the resulting bricks were tested for compressive strength and water absorption. The findings indicated that the addition of animal manure significantly improved water absorption. The combination of 10% carabao manure demonstrated the highest compressive strength at 0.38 MPa. Water absorption varied between 14% and 25% across different mixtures. Notably, the 10% cow manure mixture had the lowest water absorption capacity at 14.36%, while its compressive strength measured 0.35 MPa. The carabao manure mixture exhibited a water absorption capacity of 14.68% but had the highest compressive strength. Based on comprehensive analysis, the inclusion of a 10% carabao manure mixture yielded the most favorable results among all treatments.

Keywords : alluvial soil, bricks, horse manure, cow manure, carabao manure, compressive strength, water absorption

1. Introduction

Clay brick has been a widely utilized construction material for centuries. However, the depletion of suitable alluvial soil, commonly used for brick production due to its mineral-rich and moisture-retentive properties, is becoming a pressing issue (Wang, 2016). The brick industry, known for its significant consumption of raw materials and production of finished products, is a prime candidate for incorporating solid waste management practices (Andreola et al., 2005).

Researchers have explored various avenues in the development of eco-bricks to address the depletion of alluvial soil. One approach involves creating bricks from discarded plastic, effectively reducing waste and mitigating health risks associated with improper disposal. The enhanced binding capability of molten plastic has contributed to a sustainable solution for plastic waste management (Kagnole et al., 2019). Another study investigated the feasibility of using waste from paper mills, specifically lime mud waste, as a substitute for natural soil in brick production (Sarkar et al., 2017). Additionally, animal manures such as cow dung (Sruthy et al., 2017), horse manure (Sahu & Tiwari 2018), and carabao manure (Evasco, 2019) have been investigated as potential alternatives for eco-brick development. However, previous studies involved burning the manure, resulting in the release of harmful gases such as hydrogen sulfide, methane, ammonia, and carbon dioxide, posing risks to human health (Saxena et al., 2013).

To address these concerns, this study sought to determine if unburnt animal manure could meet brick production standards. While animal manures have been studied as partial replacements for brick materials, no previous study has explored their use without involving burning processes. The present study aimed to develop an eco-friendly brick using an environmentally friendly approach, considering the adverse impact of brick

Figure 4 Alluvial Soil

Table 1 Various proportions and percentages of bricks

Treatment No.	Animal Manure	Percentage	Clay Soil Percentage
1	None	0 %	100 %
2		10%	90%
3	Horse Manure	20%	80%
4		30%	70%
5		10%	90%
6	Cow Manure	20%	80%
7		30%	70%
8		10%	90%
9	Carabao Manure	20%	80%
10		30%	70%

The study utilized hand mixing as the method of choice to blend the different components. Alluvial soil was combined with varying proportions of cow manure, carabao manure, and horse manure. Table 1 provides an overview of the different mixture ratios employed in the study. Each treatment involved the production of three bricks to ensure accuracy and reliability in obtaining the average values for both compressive strength and water resistance.

Figure 5 Rectangular-shaped molds

The prepared alluvial soil was skillfully shaped into bricks using wooden rectangular molds, as depicted in Figure 5. These molds were specifically designed to create bricks with a uniform thickness of 3.5 inches and a cross-sectional area of 70000 mm^2. The mixture of the soil and other components was carefully poured into the molds. To ensure a smooth and even top surface, a plastic scraper was employed to level the mixture. Once the bricks were properly set, the molds were gently removed, allowing the bricks to be transported for the drying process.

After the molding process, the bricks were carefully collected and set aside for drying to mitigate the risk of fractures. To facilitate proper drying, the bricks were stacked in a manner that allowed for sufficient air circulation between them. Over three days, the bricks underwent a sun-drying process in a shaded area.

Following the drying phase, the bricks underwent an additional step to enhance their strength and durability. They were subjected to a controlled heating process in an oven, which further solidified their structure, enabling them to withstand various weather conditions effectively. This additional treatment aimed to optimize the overall quality and performance of the bricks.

To assess the quality of the manure bricks, a water absorption test was conducted. Water absorption measures the amount of water absorbed by the bricks under specific conditions. For this test, the researchers carefully dried the brick specimens in a vented oven at temperatures ranging from 105°C to 115°C until a substantially constant mass was achieved. Once cooled to room temperature, the specimens were weighed (M_1). It is important to note that excessively hot specimens should not be handled to ensure safety. Subsequently, the dried specimens were submerged in clean water at a temperature of 27±2°C for 24 hours. After removing the specimens from the water, any remaining water was gently wiped away using a wet towel, and the specimens were weighed again (M_2) (The Constructor, 2010). The water absorption was then calculated using Formula (1), which determines the percentage of water absorbed by mass after the 24-hour immersion in cold water. The accepted water absorption capacity for clay bricks falls within the range of 12% to 20% (The Clay Brick Association of Southern Africa, 2022).

$$W = \frac{M_2 - M_1}{M_1} \; x \; 100$$

(1)

Compressive strength tests are conducted on the bricks using compression testing equipment to assess their load-carrying capacity. Bricks are commonly employed in load-bearing masonry structures such as walls, columns, and footings, which primarily experience compressive loads. Therefore, understanding the compressive strength of bricks is crucial to determine their suitability for construction purposes. The procedure for the Compressive Strength Test on Bricks is as follows: The specimen is carefully positioned, and an axial load is applied at a constant rate of 14 N/mm^2 (140 kg/cm^2) per minute until failure occurs. The highest load recorded at the point of failure is noted. The load at failure represents the maximum load at which the specimen no longer exhibits any further increase in the indicator reading on the testing equipment. After conducting the test, the compressive strength of the brick is calculated. The formula used is as follows: Maximum Load at Failure (N) divided by the Average Bed Face Area (mm^2) equals the Brick Compressive Strength. The resulting value represents the average compressive strength of the bricks tested. The range selection for the test parameters, including maximum compressive strength, contact area, and maximum expected load, is determined accordingly (The Constructor, 2012).

4. Results and Discussion

Figure 6 Eco-bricks with animal manure

The compressive strength analysis was performed on the eco-bricks shown in Figure 6. The results, presented in Table 2, indicate that the eco-bricks treated with 10% manure exhibit significantly higher compressive strength. However, except for the carabao manure mixture, the compressive strength of the eco-bricks decreases as the percentage of manure increases. Notably, the control treatment of bricks without any manure mixture still exhibits slightly higher compressive strength than the 10% carabao mixture. Nevertheless, the 10% carabao manure mixture stands out as the most favorable among all the manure combinations tested. This finding contradicts previous studies, where a 10% mixture of cow manure is identified as the most advantageous. It is worth mentioning that exceeding a 10% content of cow manure has a detrimental effect on the strength characteristics of the specimens (Magudeaswaran, 2018).

Table 2 Compressive strength results

Manure	Sample Identification	Max load (KN)	MPa (N/mm2)
Control	100% clay	26.66	0.39
		26.02	0.38
Horse	10% manure	26.19	0.37
		14.61	0.22
	20% manure	15.84	0.24
		19.64	0.3
	30% manure	11.64	0.17
		10.40	0.15
Cow	10% manure	24.96	0.36
		23.51	0.34
	20% manure	20.39	0.29
		18.24	0.26
	30% manure	22.81	0.35
		12.69	0.19
Carabao	10% manure	25.18	0.36
		27.19	0.39
	20% manure	23.72	0.36
		22.46	0.33
	30% manure	19.26	0.28
		28.62	0.42

Water absorption is a crucial parameter for assessing the quality of bricks. Table 4 presents the water absorption values of bricks with varying percentages of animal manure. The findings reveal that as the percentage of animal manure increases, the water absorption of the bricks also increases. In a previous study, it was reported that the maximum water absorption reached 17% when using a mixture of 20% cow dung ash (Fernando et al., 2019). In comparison, our study demonstrates a higher maximum water absorption of 25.05% with a 30% cow manure mixture. The water absorption values obtained in this study range from 14% to 25%.

Notably, the bricks with a 10% cow manure mixture exhibit the lowest water absorption capacity of 14.36%. However, their compressive strength is 0.35 MPa. On the other hand, the carabao manure mixture exhibits a water absorption capacity of 14.68% but boasts the highest compressive strength. These findings indicate that the inclusion of animal manure has an impact on the water absorption characteristics of the bricks. The results demonstrate that the water absorption of the bricks falls within the acceptable range

of 12% to 20% (The Clay Brick Association of Southern Africa, 2022) Therefore, these eco-friendly bricks are suitable for various applications, including gardens, paths, and patios (Quadra, 2020).

Table 3 Water absorption results

Treatment No.	Ratio	Normal Weight (kg)	Wet Weight (kg)	Dry Weight (kg)	Moisture Content (%)	Water Absorption (%)
1	Control	1.120	1.326	1.118	18.60%	18.39%
2	10% Horse Manure	1.105	1.285	1.103	16.50%	15.83%
3	20% Horse Manure	1.100	1.289	1.098	17.40%	17.18%
4	30% Horse Manure	0.998	1.213	0.996	21.79%	21.54%
5	10% Cow Manure	1.086	1.242	1.087	14.30%	14.36%
6	20% Cow Manure	1.112	1.291	1.118	15.47%	16.10%
7	30% Cow Manure	1.038	1.298	1.037	25.17%	25.05%
8	10% Carabao Manure	1.090	1.250	1.094	14.26%	14.68%
9	20% Carabao Manure	1.057	1.223	1.056	15.81%	15.70%
10	30% Carabao Manure	1.022	1.199	1.021	17.43%	17.32%

5. Conclusion

Based on the three tests conducted with varying percentages of animal manure, it was determined that the combination of carabao manure with a 10% proportion exhibited the highest compressive strength among the three types of animal manure. Furthermore, its water absorption rate falls within the acceptable range of water absorption. On the other hand, the cow manure with a 10% combination displayed the lowest water absorption capacity. However, it still achieved a considerable compressive strength. Overall, the results suggest that adding a 10% carabao manure mixture yields the most favorable outcomes among the tested treatments.

The researchers recommend conducting additional tests, such as soundness tests, to assess the behavior of the bricks when subjected to sudden impacts, which is crucial for evaluating their quality. It is also advised to ensure uniform thickness of the eco-bricks during testing to obtain more accurate results. Based on the findings, the researchers propose the use of a 10% carabao manure mixture for high-strength external construction, internal wall barriers, and decorative applications. This approach can be implemented on-

site, resulting in cost savings, the creation of semi-skilled jobs, and contributing to overall economic growth.

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Assessment of Coastal Erosion: A Basis for a Salvage Zone Map

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Abstract

Coastal erosion has become a significant global problem, and this study focuses on analyzing the shoreline rate of change in Centro East and Centro West, two barangays in Ballesteros. Using the Last High Tide (LHT) data from the Sea Level Affecting Marshes Method (SLAMM) and the Shoreline Change Special Area Management Plan (SAMP), we assessed the coastal retreat over 14 years (2007-2021) and predicted potential landward movement of the shoreline over the next 15 years (2021-2036). The findings highlight a worrisome average shoreline rate of change of 2.236 meters per year, indicating the rapid erosion of coastal areas. In the examined 14-year period, approximately 4.8 hectares of coastal land experienced retreat, underscoring the tangible impact of coastal erosion in the region. Looking ahead, without human intervention, projections suggest that an additional 5.1 hectares of coastal land will face retreat within the next 15 years. Considering the Philippines' susceptibility to natural disasters like typhoons, landslides, and the exacerbating effects of climate change, which contribute to coastal erosion, immediate actions are crucial. The government must prioritize proactive measures to mitigate this coastal problem and protect affected communities. Implementing strategies such as reforestation efforts to restore natural protective barriers and constructing resilient seawalls are vital steps toward combatting further degradation and potential hazards. By undertaking these adaptive measures, the government can enhance the resilience of coastal areas, safeguard the environment, and secure the livelihoods of coastal communities for future generations.

Keywords : coastal erosion, shoreline, salvage zone, coastal retreat, natural disasters

1. Introduction

Coastal erosion poses a significant threat to the coastal areas of the Philippines, which are not only rich in natural resources but also economically and socially important. As the country experiences constant development and rapid land conversion, the coastline, with its diverse characteristics and beauty, is constantly changing over time. Factors such as human activities and natural environmental changes contribute to the imbalance in coastal processes, leading to the destructive process of coastline retreat and beach erosion. This problem has been observed in various studies conducted in both local and international contexts (Rose et al., 2021; Makar, 2018; Vrinda & Mohammed-Aslam, 2021).

Despite the existence of regulations, such as the Salvage Zone defined by the Water Code of the Philippines, which prohibits residing or building structures within the designated zone, it has been discovered that some residents and businesses have encroached upon these critical coastal areas (Valencia, 2014). This not only violates the law but also exposes these individuals to significant risks posed by potential calamities. Moreover, improper septic vaults and waste disposal practices by residents within the salvage zone can also have detrimental effects on the environment.

In light of these problems, coastal studies have been conducted to assess the impact of climate change and identify adaptive responses to these threats. Evaluations have been

made regarding the possible consequences of accelerated sea-level rise, particularly in coastal barangays of Metro Manila, Bulacan, and Cavite, should a 1-meter sea-level rise occur (Jose & Cruz, 1999). Similar studies conducted in Rhode Island using the Sea Level Affecting Marshes Method (SLAMM) have examined the effects of coastal storms, sea-level rise, and coastal retreat, revealing increased erosion and shoreline changes due to rising sea levels (Olsen, McCann, & Fugate, 2014).

The municipality of Ballesteros, Cagayan, situated adjacent to the Babuyan Channel, is also facing the challenges of coastal erosion and recurring typhoons. Residents in the Poblacion area have witnessed alarming and drastic coastal erosion, with notable damage observed during typhoon Ulysses in 2020, including the washing away of the Ballesteros beach and the destruction of small hut houses. To address these concerns, this study aims to assess the physical changes of the coast and predict potential coastal damage in the Poblacion Area of Ballesteros, Cagayan. The Sea Level Affecting Marshes Method (SLAMM), Last High Tide Swash, and QGIS will be utilized to generate historical and prediction maps of the coastline, offering valuable insights into the extent and impact of coastal erosion in the area.

2. Objectives

This study aims to investigate the coastal erosion in the Poblacion area in Ballesteros, Cagayan through the use of GIS. Specifically, it aims to achieve the following objectives:

1. Determine the area of the coastal retreat for the past 14 years.
2. Identify the possible area of the coastal retreat for the next 15 years.
3. Delineate the salvage zone.

3. Materials and methods

Ballesteros, a coastal municipality situated adjacent to the Babuyan Channel, encompasses an approximate total area of 120 square kilometers and is composed of nineteen barangays. Among these coastal barangays, Centro East and Centro West stand out as the most populated. According to the 2020 census, Centro East has a population of 4,174, while Centro West is home to 2,046 residents. Figure 1 provides an overview of the study area's location within Ballesteros. To the north lies the Babuyan Channel, a significant fishing ground catering to the daily needs of many local fishermen. The neighboring barangays of Sta. Cruz, Mabuttal, and Cabuluan East are situated to the east, south, and west, respectively.
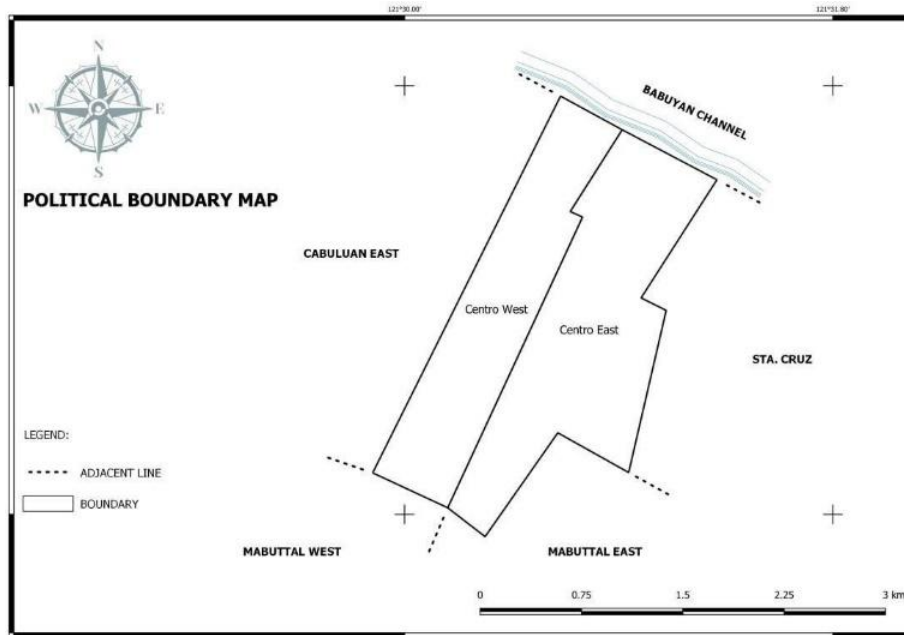
Figure 1 Political Boundary Map of the Study Area

Satellite images play a crucial role as the primary framework for this study, providing valuable historical data. To acquire these essential images, the researchers reached out to various government agencies, including the Philippine Satellite Agency (PhilSA). Through collaboration with the PhilSA, the researchers were able to obtain satellite images depicting the Poblacion area for the years 2007 and 2021. Additionally, Elshayal Smart GIS software, in conjunction with Google Earth, was utilized to download georeferenced high-definition satellite images, further enhancing the study's data collection process.

$$\Delta\square h\square\square\square\square\square\square\square = \frac{\square\square\square\square\square\square\square\square\square\square\square}{\square\square.\square\square\ \square\square\square\square\square}$$

(1)

The researchers employed the Last High Tide Swash (LHTS) method, which utilizes the wet/dry land as baselines, to accurately measure displacements along assigned transects. These transects were specifically chosen in areas where notable changes were observed. By collecting data on these transects, the Shoreline Rate of Change (SRC) per year was calculated using the following formula (1). The computation took into account the 14 years from 2007 to 2021, with displacement measurements taken for each transect.

$$\square\square\square\square\square\square\square\square\ \square h\square\square\square\square = \Delta\square h\square\square\square\square\square\square\square * \square\square.\square\square\ \square\square\square\square\square$$

(2)

The researchers utilized the Shoreline Rate of Change to estimate the predicted shoreline displacement on each transect after a 15-year period (2021 to 2036) using formula (2).

In accordance with Section 51 of the Water Code of the Philippines, the Salvage zone refers to the land measuring twenty (20) meters landward from the interior limit of the shoreline. This easement is applicable to all foreshore lands, including marshy lands or those covered with water that border shores or banks of navigable lakes or rivers. To identify residential houses within the salvage zone, the researchers delineated the area using satellite images from 2021 obtained from the Philippine Space Agency (PhilSA) and Google Earth.

The analysis of the study area's available images and the creation of maps were carried out using QGIS software. Transect lines were assigned to prominent eroded points to determine the shoreline rate of displacement per year. Furthermore, QGIS was instrumental in visualizing the projected coastal retreat of the shoreline. The Last High-Tide Swash (LHTS) served as the reference point for measuring shoreline changes throughout the study.

4. Results and Discussion

Figure 2 incorporates a satellite image from 2007, highlighting the shoreline's initial position and its subsequent landward movement over the years. The shoreline is depicted by a yellow line, while the light blue line represents the updated shoreline as of 2021. The figure showcases diverse displacements observed at each transect line, reflecting the shoreline rate of change per year.

Figure 2 Shoreline Retreat for the past 14 years

Table 1 presents the displacement distance and rate of change of the shoreline from 2007 to 2021. Figure 3 visually illustrates this data, highlighting that the largest displacement of 47.569 meters occurs at transect 9, while the smallest displacement of 18.564 meters is observed at transect 2. Notably, all displacements measured from the 2007 shoreline display negative values, indicating a landward movement of the shoreline until 2021, with an average displacement of 32.631 meters. The average rate of change is calculated to be 2.326 meters per year.

Table 1 Shoreline Retreat for The Past 14 Years (2007-2021)

Transect Number	Shoreline Displacement (M)	Shoreline Rate of Change (M/Yr)
1	-22.576	-1.614
2	-18.564	-1.326
3	-33.079	-2.300
4	-39.942	-2.850
5	-31.975	-2.280
6	-27.207	-1.943
7	-29.632	-2.120
8	-21.442	-1.530
9	-47.569	-3.400
10	-42.433	-3.030
11	-42.404	-3.030
12	-47.045	-3.360
13	-20.330	-1.450
Average	-32.631	-2.326

Coastal erosion is an inevitable process, particularly in areas lacking protective features like mangrove forests or sea walls. Storm surges, caused by the rise of water during storms, are one of the contributing factors to coastal erosion. These surges exceed the normal high tide and, when combined with sea level rise resulting from climate change, pose an increased threat to the lives of people residing in coastal areas. Sea level rise is a global issue, driven by the thermal expansion of seawater due to high sea surface temperatures, including those found in the Philippines.

According to a report by Villarin et al. (2016), sea level rise in the country surpasses the global average, ranging from 5.7 mm to 7.0 mm per year. In recent years, the study area of Poblacion in Ballesteros, Cagayan, has experienced coastal erosion. A study on remote sensing of the ocean and coastal environment has quantified the average annual shrinkage of the coastline in the absence of human intervention, which ranges from 0.5 meters to 2.0 meters (Climate Change Commission, 2018).

This study reveals an average displacement per year of 2.236 meters toward the residents, indicating the presence of human intervention in the study area. Residents are cutting down and removing the abundant male Pandan trees without undertaking any replanting efforts. This clearing of the coastal vegetation leaves the area vulnerable to further coastal erosion, as the soil becomes more susceptible due to the absence of tree cover.

The findings demonstrate that approximately 48,584 square meters, or roughly 5 hectares, of land resources have been lost in the barangays of Centro East and Centro West in Ballesteros. This significant loss emphasizes the need to inform the local government unit (LGU) of Ballesteros about the issue and prompt them to take appropriate actions to address coastal erosion in the area.

Figure 3 Predicted Shoreline in 15 years

Figure 3 illustrates the projected shoreline retreat displacement over 15 years starting from 2021, based on the observed trend of the past 14 years. The 2021 shoreline is depicted by a light blue line, while the predicted shoreline is represented by a red line. The figure provides a visual representation of the potential landward movement of the shoreline. Additionally, Figure 4 highlights the specific transects, namely 9-12, where residential areas are significantly impacted by coastal erosion. These transects indicate the locations along the coastline where the erosion has particularly affected the residential communities. The figure serves to emphasize the vulnerability of these areas to coastal erosion and the urgent need for appropriate measures to mitigate the impacts on the affected residents.

Table 2 Projected Shoreline Displacement in 15 Years

Transect Number	Shoreline rate of change (m/yr)	Shoreline displacement (m)
1	-1.614	-24.195
2	-1.326	-19.890
3	-2.30	-35.445
4	-2.850	-42.795
5	-2.280	-34.260
6	-1.943	-29.145
7	-2.120	-31.755
8	-1.530	-22.980
9	-3.400	-50.970
10	-3.030	-45.465
11	-3.030	-45.435
12	-3.360	-50.400
13	-1.450	-21.780
Average	-2.236	-34.963

Table 2 provides the approximate distances of the shoreline from 2021 to 2036, highlighting the projected changes in the subject area. Figure 4 visually represents the projected shoreline retreat in the study area. Notably, transect 9 exhibited the greatest displacement, with a distance of 50.4 meters, while transect 2 had the least displacement, measuring 19.890 meters. The average change in the shoreline after 15 years was found to be approximately 34.963 meters.

The unpredictability of Sea Level Rise (SLR) poses significant challenges as it is a consequence of climate change. The current global SLR is estimated to range from 50 centimeters to 3 meters, making it crucial to address this issue effectively. Failure to do so will particularly impact coastal communities, which are the most vulnerable to the effects of SLR and frequent cyclones. The study highlights the increasing severity of flooding and predicts that informal settlers, especially those within the salvage zone of the Poblacion Area of Ballesteros, Cagayan, will face critical challenges by 2035.

Furthermore, the study revealed that without human intervention and with a sustained rate of change, an estimated area of fifty-one thousand five hundred seventy (51,570) square meters will be lost from the Poblacion Area. This finding emphasizes the urgent need for proactive measures and interventions to mitigate the adverse impacts of coastal erosion and SLR on the affected region.
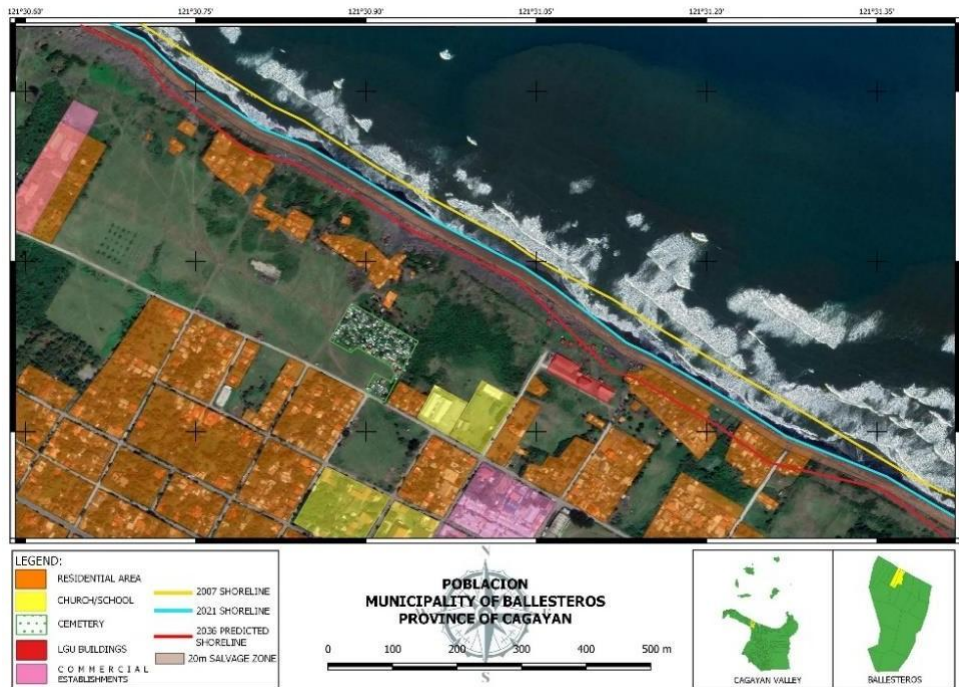
Figure 4 Predicted Shoreline in 15 years

Figure 4 provides a visual representation of the actual salvage zone in the Poblacion area. The study determined that the approximate area of the salvage zone is twenty-eight thousand seven hundred nine square meters (28,709), highlighting its boundaries. Notably, the figure reveals the presence of privately owned land parcels and residences within the designated salvage zone. This finding underscores the fact that residents of Ballesteros, Cagayan have already been affected by the adverse shoreline changes.

It is imperative to inform the local government unit (LGU) of Ballesteros about the situation, particularly the need to consider relocating or prioritizing the affected residents in the application for Alienable and Disposable areas of Ballesteros. While living and conducting businesses near the ocean may have its allure, it is crucial to respect and adhere to easement regulations. The Philippine Coastal Adaptation study emphasized the inherent dangers of residing in such areas due to the impact of climate change and the inevitable occurrence of catastrophic events (Ye, 2017). The presence of residential areas along the salvage zone of the study area confirms that as the shoreline moves inward, it encroaches upon the homes of the residents. This highlights the vulnerability of those living within and beyond the salvage zone, particularly in the face of uncontrollable natural disasters that pose a threat to their lives.

5. Conclusion

This study focused on the coastal projection of the Poblacion Area in Ballesteros and employed the SLAMM model to determine the current shoreline position and project future shoreline retreats. The findings revealed significant coastal erosion over the past 14 years, with a substantial landward movement of the shoreline. Settlements and privately-owned land within the salvage zone were identified as vulnerable to sea-level rise and other coastal hazards. The study highlighted the importance of implementing mitigation

measures such as reforestation, seawalls, and mangrove restoration to protect the area from further erosion and enhance coastal resilience.

In conclusion, coastal erosion in the Poblacion Area poses risks to the densely populated community, particularly fishermen residing in vulnerable sections. The study emphasized the need for awareness programs on reforestation and the construction of seawalls, along with the establishment of mangrove forests to mitigate ecological degradation and promote sustainable development. Future research should consider utilizing topographic maps, assessing the economic impact of coastal erosion, and exploring the effects of different mitigation strategies. These efforts are vital for effective coastal management and safeguarding the community's well-being in the face of ongoing climate change and coastal hazards.

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Caffeine removal from aqueous solution by amine-functionalized rice husk ash

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Abstract

This study's purpose is to evaluate the adsorption capacity of RHA-NH$_2$ as an adsorbent for removing the caffeine (CAF) from an aqueous solution. The RHA–NH$_2$ were synthesized successfully via post grafting method using (3-Aminopropyl)-triethoxysilane (APTES), [3-(2-Aminoethylamino) propyl]-trimethoxysilane (AEA) and 3-[2-(2-Amino ethylamino)ethylamino] propyl-trimethoxysilane (AEEA) as amine group precursors. Surface and structural characteristics of RHA–NH$_2$ were examined using X-ray diffraction, N$_2$ adsorption–desorption analysis and Fourier transform infrared spectroscopy. In addition, the effects of type of RHA–NH$_2$ adsorbents, adsorbent dose (M/V(g/L)), CAF concentration, adsorption time, and shaking speed on the CAF removal efficiency (%) of RHA–NH$_2$ were also analyzed. The RHA–NH$_2$ functionalized with AEEA exhibited an effective for CAF removal when compared with other adsorbents. Moreover, the maximum adsorption capacity of this RHA–NH$_2$ for CAF was 82.25 mg/g and it could be reused in the adsorption of CAF for at least 4 times.

Keywords : Rice husk ash, Amine, Functionalize, Caffeine, Adsorption

1. Introduction

Caffeine (CAF) is one of the most consumed psychotropic substances in the world and can be used as ingredient in a wide variety of foods, drinks and medicines [(Li et al., 2020, pp. 125343),(Bachmann et al., 2021, pp. 144229)]. It is a purine alkaloid. Due to its low metabolization rates allied with high consumption worldwide, CAF is frequently found in environmental matrices, making it an important anthropogenic pollutant. According to the Environmental Protection Agency (EPA), CAF has been considered a potential tracer for sanitary wastewater, serving as and indicator to evaluate the efficiency of treatment systems of sewages and waters [(Santos-Silva et al., 2018, pp. 237-242),(Ondarza et al., 2019, pp. 1029-1037)]. In front of the environmental and public health problems that CAF can cause, researchers are focusing the attention to the development of new strategies to remove these compound and other contaminants from environmental matrices. According to literature data, caffeine can be removed from aqueous with the use of advanced technologies such as ozonation [(Ternes et al., 2003, pp. 1976-1982)], advanced oxidation processes [(Afonso-Olivares et al., 2016, pp. 130-138)], membrane filtration [(Mahlangu et al., 2014, pp. 28-34)] and adsorption [(Ptaszkowska-Koniarz et al., 2018, pp. 13-21)].

The adsorption method is a potential application for the removal of CAF since it exhibits many advantages such as low initial cost, simple and flexible design, easy operation, the possibility of effluent reuse, and insensitivity to toxic pollutants. In addition, intermediate by-products are not generated during this process [(Li et al., 2020, pp. 125343)]. Over the past years, several adsorbents have been employed for antibiotics adsorption such as activated carbon, zeolite, metal-organic frameworks (MOFs), and

mesoporous silica [(Li et al., 2020, pp. 125343)-(Santos-Silva et al., 2018, pp. 237-242)]. However, those adsorbents are expensive, which resulted in high operating costs.

Recently, the low-cost adsorbent is interesting for use in the adsorption process and has a higher usage trend. Rice husk (RH) is an agricultural waste that produced about one-fifth of the annual rice production of the world, or around 550 million metric tons [(Imyim & Prapalimrungsi, 2010, pp. 775-781)]. It can be applied for several uses such as energy production and as an adsorbent. RH has the potential to be accounted as an adsorbent because its main components are carbon and silica. In addition, rice husk ash (RHA) produced by heating rice husk at 700 °C possesses a higher amount of silica content (~84.3%) and has been used as an adsorbent for the removal of pollutants in the wastewater such as heavy metals ions [(Feng et al., 2004, pp. 1-8)], and dye [(Chou et al., 2001, pp. 217-219)]. However, there has not been reported using rice husk applied as adsorbent to remove caffeine in aqueous.

To enhance the adsorption capacity and selectivity of silica adsorbents for particular substances, surface modification is useful by utilizing interactions between adsorbents and adsorbates. Therefore, the modified silica surface has been regarded as an effective adsorbent due to its high surface area which allows the binding of a large number of surface groups. The amine-functionalized silica (SiO_2-NH_2) has received substantial attention because the amine group has a positive impact on the performance of the adsorption systems of heavy metals, dyes, and other organic compounds [(Abu Rumman et al., 2021, pp. 100536)]. In addition there has been reported using carbon xerogels modified with amine groups applied as adsorbent to remove caffeine in aqueous [(Ptaszkowska-Koniarz et al., 2018, pp. 13-21)]. Therefore, the rice husk ash with high amount of silica content is interesting to modify its surface with amine groups to enhance its adsorption performance.

This work aimed to study the feasibility of using amine-functionalized rice husk ash (RHA-NH_2) as adsorbents for the removal of CAF from wastewater. The textural and structural properties of RHA-NH_2 with respect to adsorption were examined by advanced analyses. The adsorption performance of RHA–NH_2 for removal of CAF was evaluated by studying the effects of types of RHA-NH_2 adsorbents, pH, adsorbent dose (M/V(g/l)), CAF concentration, adsorption time, shaking speed, and reusability.

2. Materials and methods

2.1 Preparation of adsorbents

2.1.1 Rice husk ash (RHA)

The rice husk ash (RHA) is the byproduct of utilizing rice husk (RH) as fuel, and it can be prepared by the following methods. Initially, 40 g of rice husks were washed multiple times with de-ionized (DI) water and dried at 110 ºC for 2 days. For the preparation of rice husk ash, the burned residue was crushed and calcined at 700 ºC for 6 h in a muffle furnace (Carbolite ELF11).

2.1.2 Amine-functionalized rice husk ash (RHA-NH_2)

The preparation of amine-functionalized rice husk ash was applied synthesis method reported by Imyim et al. [(Imyim & Prapalimrungsi, 2010, pp. 775-781)]. First, 40 g of rice husk was submerged for 4 h in 1M HCl. The solid was rinsed multiple times with DI water and dried in a 110 ºC oven for 2 days. The material was generated into rice husk

ash by heat-treating in a muffle furnace for 6 h at 700 ℃ using ceramic crucibles. The rice hush treated with acid was designated as A-RHA.

A-RHA is categorized into 3 types, each amounting to 5 g. They were refluxed in toluene (100 mL) at 70 ℃ for 2 h, and then slowly added amino silanes by a dropper into each portion such as 4 g of (3-Aminopropyl)-triethoxysilane(APTES),4.03 g of [3-(2-Aminoethylamino)propyl]-trimethoxysilane (AEA) and 4.80 g of 3-[2-(2-Amino ethylamino)ethylamino]propyl-trimethoxysilane (AEEA). The mixture were continually refluxed for 24 hours. The solids were then filtered, washed three times with ethanol and dichloromethane, and left to dry at room temperature. The obtained samples were designed as RHA-NH$_2$-nN, where n was 1, 2, and 3, respectively representing APTES, AEA, and AEEA. The synthetic route for the modification of RHA with amino silanes is shown in Fig 1.
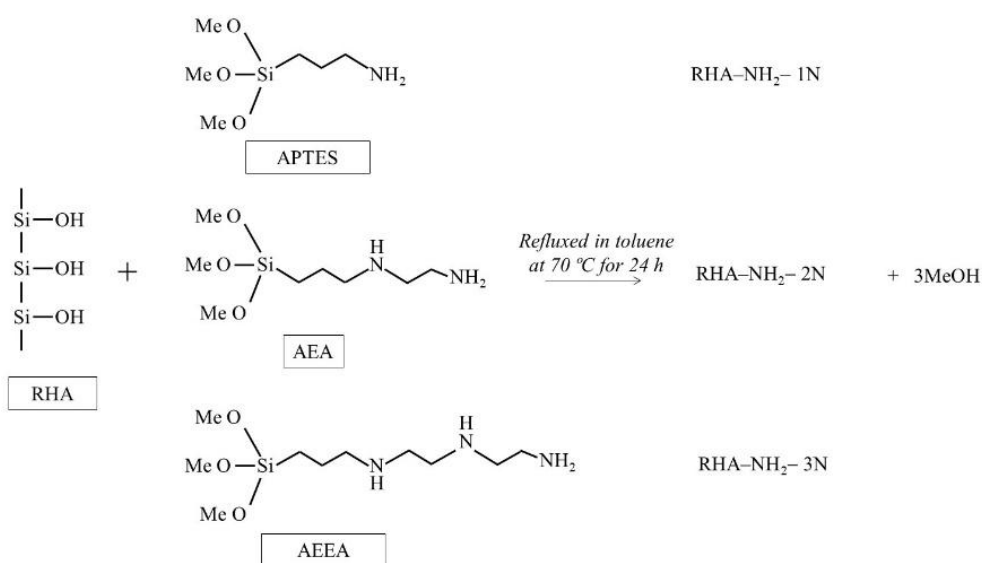
Fig. 1 Synthetic route for the modification of RHA with amino silanes.

2.2 Physical Measurements of adsorbents

The physical measurements of the synthesized adsorbents were analyzed using multiple techniques according to the report of Imyim et al. [(Imyim & Prapalimrungsi, 2010, pp. 775-781)] Standard procedures were used to characterize the prepared physical and chemical properties of the adsorbents. X-ray powder diffraction (XRD) patterns were obtained on a PAN analytical Empyrean III X-ray diffractometer employing CuKα radiation and an X-ray power of 40 kV and 40 mA. N$_2$ adsorption-desorption measurements were carried out at 196 °C using a BEL Japan BELSORP-mini II instrument to determine the material's textural characteristics. All samples were pretreated at 150 °C for 2 h and then measured for exact weight prior to the adsorption. The presence of functional groups was determined using Fourier-transform infrared (FTIR) spectra (Perkin Elmer spectrum two: 900–4000 cm^{-1} in transmittance mode by KBr pellet technique). The number of organic contents in the silica structure was evaluated using an Elementar Vario Micro Cube CHNS elemental analyzer.

2.3 Adsorption study

The adsorption experiments studied the parameters according to the report of Ptaszkowska-Koniarz et al. [(Ptaszkowska-Koniarz et al., 2018, pp. 13-21)]. In a batch system, the adsorption studies of CAF on RHA-NH$_2$ were performed using 50-mL Erlenmeyer flasks containing CAF solution and dried absorbents. The adsorption experiments were conducted by shaking the flasks in a shaker at desired conditions. Subsequently, the adsorption performance of RHA-NH$_2$ for CAF removal was examined under varying physicochemical conditions: time: 0 – 100 min; pH: 3–9; M/V: 1–10 g/L; initial CAF concentration (C_o (mg/L)): 100–150 mg/L; shaking speed: 100–150 rpm.

The concentration of CAF solution after adsorption was measured using a UV–vis spectro photometer (Jasco V-730) at 273.5 nm. The collected samples were measured three times to further UV-vis analysis. The following formula (Eq. (1)) was used to calculate the adsorption capacity (q_e). Six experimental points were used to plot a calibration curve. The regression equations for CAF were y = 0.1578x - 0.1745 (R^2 = 0.9987), where x is the concentration (mg/L), y is the absorbance values.

Adsorption capacity:
$$q_e = \frac{(C_0 - C_e)V_i}{W}$$
(1)

where q_e is adsorption capacity at adsorption equilibrium (mg/g, dried adsorbent); C_o and C_e are the initial and equilibrium concentrations of CAF in the solutions (mg/L), respectively; V_i is the volume of initial solution (mL); W is the weight of dried adsorbent (g).

3. Results and discussion

3.1 Characterization of RHA-NH$_2$ adsorbents

FTIR spectra of A-RHA and RHA-NH$_2$ adsorbents in the wavenumber range of 900–4000 cm^{-1} are shown in Fig. 2. The FTIR spectrum of these materials exhibited a broad band between 2800 and 3700 cm^{-1} which indicated the presence of both OH groups and the Si-OH group. In addition, the band at 1100 cm^{-1} is attributed to the stretching of Si–O–Si. However, the small peaks of RHA-NH$_2$ materials found at 2940 and 2866 cm^{-1} were assigned to the C–H stretching of methylene groups. In addition, the FTIR spectrum of RHA-NH$_2$ observed in the range of 1465–1642 cm^{-1} is attributed to the bending vibration of the N–H group. The appearance of these bands confirmed the successful functionalization of amino silanes onto the RHA surface.
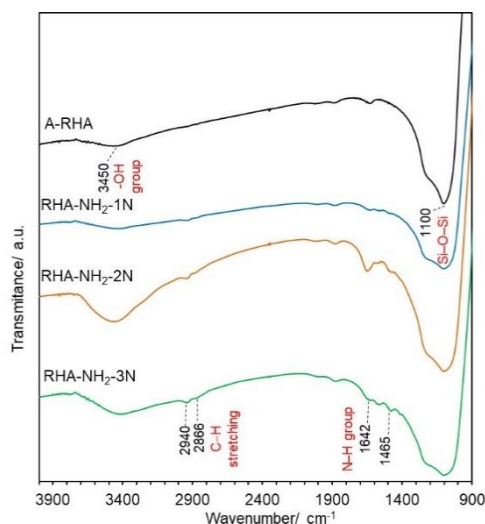
Fig. 2 FTIR spectra of A-RHA and RHA-NH$_2$ adsorbents.

The RHA consists mainly of silica (>90%) and some metallic impurities such as Fe^{3+}, Ca^{2+}, Na$^+$, K$^+$, and Mg^{2+} which influence the purity and color of silica [(Xu et al., 2018, pp. 1697)]. The minor metallic impurities could be eliminated by H$_2$SO$_4$ acid leaching treatments before the combustion process and designated as A-RHA [(Rafiee et al., 2012, pp. 29)]. After that, the A-RHA was functionalized with various aminosilane to modify its surface, and designated as RHA-NH$_2$. The obtained materials were characterized by the XRD technique to investigate the structural properties shown in Fig. 3. XRD patterns of A-RHA and RHA-NH$_2$ materials were similar. The broad diffused peak between 15°−35° 2θ diffraction angle indicated that amorphous silica was formed. However, the heating A-RHA at 700 °C exhibited some structure change of amorphous silicon dioxide to a crystalline structure (observed at 2θ around 22° and 26°), such as quartz, cristobalite, or tridymite [(Imyim & Prapalimrungsi, 2010, pp. 775-781)].
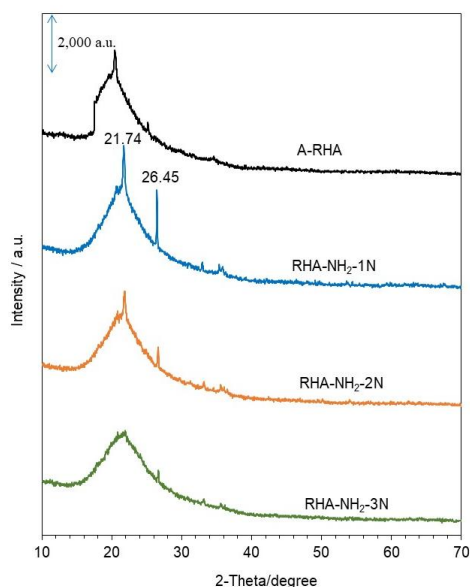
Fig. 3 XRD patterns of A-RHA and RHA-NH$_2$ adsorbents.

Textural properties of synthesized materials were determined by N$_2$ adsorption–desorption analysis as shown in Table 1. Based on its textural properties, A-RHA is suitable for use as an adsorbent due to its high specific surface area, pore diameter, and pore volume. After the surface of A-RHA with various amino silanes was modified, the

surface area, pore diameter, and pore volume were reduced in comparison to pristine A-RHA. Additionally, the RHA-NH$_2$ materials exhibited an increase in CHN contents (Table 1). These results suggested that the aminosilanes had been incorporated into the pore structure of A-RHA.

Table 1 Physicochemical properties of the adsorbents

Sample[a]	S_{BET}[b] (m^2 g^{-1})	D_p[c] (nm)	Vt[d] (cm^3 g^{-1})	CHN contents[e]		
				% C	% H	% N
A-RHA	136	3.71	0.34	0.22	0.22	0.08
RHA-NH$_2$-1N	44	3.28	0.20	1.63	0.42	0.55
RHA-NH$_2$-2N	45	3.28	0.19	3.34	0.76	1.28
RHA-NH$_2$-3N	45	3.28	0.19	4.36	1.03	1.86

[a] Dried samples

[b] BET surface area

[c] Pore diameter calculated using BJH method

[d] Total pore volume

[e] Determined by CHNS analyzer

3.2 Adsorption study

All A-RHA and RHA-NH$_2$ materials obtained were tested as adsorbents of caffeine from water solutions. The adsorption capacity and removal efficiency (%) of CAF of these samples are presented in Fig. 4. The RHA-NH$_2$ adsorbents exhibited a greater adsorption capacity and removal efficiency (%) than pristine A-RHA, suggesting that CAF was strongly adsorbed onto the RHA-NH$_2$ surface, resulting in an increase in adsorption capacity. Moreover, RHA-NH$_2$-3N with a high amount of amine group exhibited the highest adsorption capacity of CAF at 42.38 mg/g. Since the amount of amine group could enhance the H-bond interaction between CAF and surface of adsorbent, resulted in an increasing of CAF removal. Therefore, RHA-NH$_2$-3N was a suitable adsorbent for use in further studies.
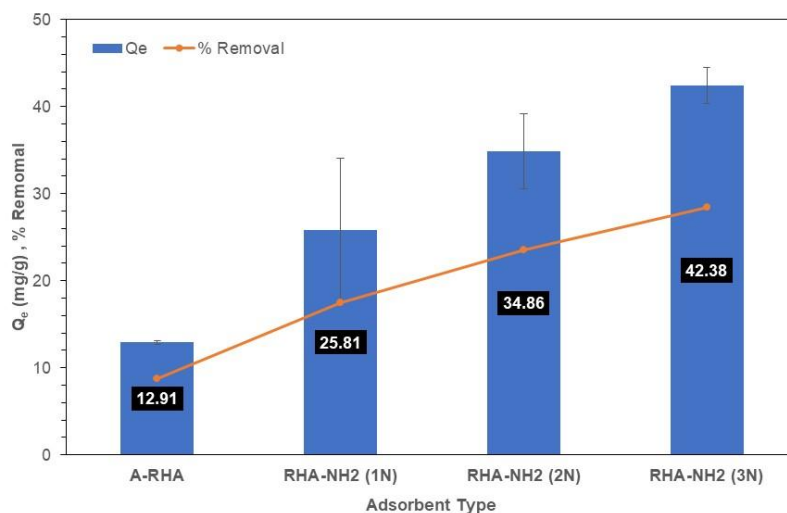
Fig. 4 Effect of type of adsorbents on CAF removal

The adsorption performance of RHA-NH$_2$-3N for removal of CAF was evaluated by studying the effects of adsorption time, CAF concentration, adsorbent dose (M/V(g/l)) and shaking speed as shown in Fig. 5. The RHA-NH$_2$-3N was used to study contact time for CAF removal as shown in Fig. 5A. It was found that high amount of CAF was absorbed on the adsorbent in the first 60 minutes. After that, the contact time required for reaching adsorption equilibrium was around 80 min.

Effects of initial concentration on the CAF removal of RHA-NH$_2$-3N were studied (Fig. 5B). The adsorption capacities were reduced from 44.69 to 27.88 mg/g when C_0 was enhanced from 100 mg/L to 150 mg/L. Since M/V in the aqueous solution remained constant, these results implied that the active site ($-NH_2$ group) of this adsorbent had a limited quantity. Therefore, an increase in initial concentration resulted in the competition between CAF molecules to occupy the available active sites increased.

The effect of mass of adsorbent per volume of CAF solution (M/V) on the CAF adsorption capacity of RHA-NH$_2$-3N are shown in Fig. 5C. When M/V was increased from 1 g/L to 10 g/L, the adsorption capacity of CAF increased from 42.90 to 82.25 mg/g. This was because with an increase in M/V at a fixed CAF concentration according to the concentration of CAF in the aqueous solution, the number of active sites also increased. Based on these results, 10 g/L was considered the optimum M/V for the treatment of 1 L CAF solution with a CAF concentration of 100 mg/L.

Figure 5D shows the effect of an increase in shaking speed from 100 rpm to 150 rpm on the adsorption capacities of CAF of RHA-NH$_2$-3N. The increase in shaking speed improved the adsorption capacities of RHA-NH$_2$-3N along with an increase in the shaking speed and the mixing rate of adsorbent particles in the aqueous solution. Due to the increasing adsorption rate, this enhanced the collision and contact rate between CAF molecules and adsorbent particles.
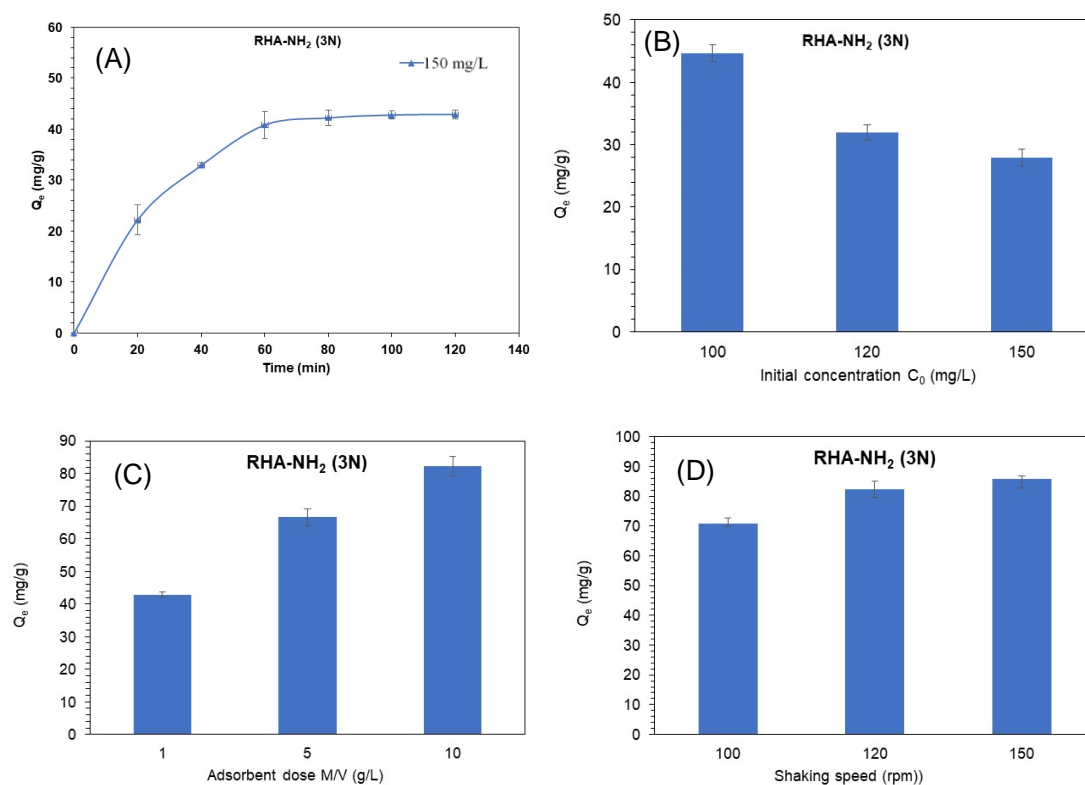
Fig.5 Effect of (A) contact time, (B) innitial concentration, (C) adsorbent dose and (D) shaking speed on CAF removal

3.3 Reusability

In the field of wastewater treatment using adsorption systems, one of the most important economic parameters is the reusability of the employed adsorbent. Therefore, in the present study, the recyclability of RHA-NH$_2$-3N was examined for five consecutive CAF adsorption–desorption cycles under the following optimal conditions: M/V = 10 g/L; CAF concentration = 100 mg/L; t = 80 min; shaking speed = 150 rpm; and room temperature. At the end of each CAF adsorption cycle, RHA-NH$_2$-3N was separated from the aqueous solution via vacuum filtration, then, rinsed with deionized water and ethanol to desorb the adsorbed CAF molecules, dried at 110 °C, and then reused in the next adsorption cycle. This adsorbent could be repeatedly used in the adsorption at least 4 times and then the adsorption capacity loss was found in the 5th repetition. It might be due to the strong adsorption of CAF on the RHA-NH$_2$ surface.
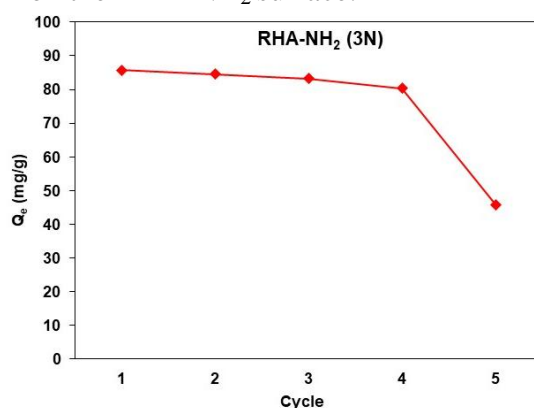
Fig. 6 Reusability study of RHA-NH$_2$ adsorbent for the removal of CAF from aqueous solutions.

4. Conclusion

Rice husk ash was pre-treated by HCl and thermally treated at 700 °C and chemically modified it surface with 3 types of amino silanes. It was found to be a suitable adsorbent for adsorption of CAF from water compared to pristine rice husk ash. Characterization analysis revealed that RHA-NH$_2$ possessed an amorphous silica structure with an amine group incorporated into their surface. Moreover, they possessed a high surface area and pore volume, making them an efficient adsorbent. According to the adsorption results, the RHA–NH$_2$-3N functionalized with AEEA exhibited effectiveness for CAF removal. The maximum adsorption capacity of this RHA–NH$_2$ for CAF was 82.25 mg/g. Moreover, the optimum environmental conditions for achieving the maximum CAF removal were as follows: M/V = 10 g/L; CAF concentration = 100 mg/L; t = 80 min; and shaking speed = 150 rpm. In addition, RHA–NH$_2$-3N adsorbent could be reused 4 times.

Although literature does not provide many reports on caffeine adsorption on rice husk ash, the results we obtained seem satisfactory. However, this study was necessary to study additional factors such as the effect of pH, the effect of temperature and isotherm to obtain the optimum condition for removal CAF from wastewater.

5. Acknowledgements

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Adsorption of ciprofloxacin from aqueous solution by biochar prepared from longan peel

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Abstract

Due to ineffective pharmaceutical wastewater treatment, the aquatic environment is exposed to antibiotic contaminants released by the pharmaceutical industries. These substances are harmful to both humans and aquatic life. This study's purpose is to evaluate the adsorption capacity of biochar from longan peel prepared in difference pyrolysis temperature (BCL) as an adsorbent for removing the antibiotic ciprofloxacin (CIP) from an aqueous solution. The BCL adsorbents were prepared with pyrolysis temperature at 300, 500 and 700 °C. Surface and structural characteristics of BCL adsorbents were examined using X-ray diffraction, N_2 adsorption–desorption analysis and Fourier transform infrared spectroscopy. In addition, the effects of type of BCL adsorbents, pH, adsorbent dose (M/V(g/L)), CIP concentration, adsorption time, and shaking speed on the CIP removal efficiency of them were also analyzed. The biochar from longan peel pyrolyzed at 700°C (BCL-700) exhibited an effective for CIP removal when compared with other adsorbents. Moreover, the maximum adsorption capacity of this BCL-700 for CIP was 120 mg/g and it could be reused in the adsorption of CIP for at least 3 times.

Keywords : Biochar, Longan peel, Pyrolysis, Ciprofloxacin, Adsorption.

1. Introduction

Antibiotic contaminated pollutants in pharmaceutical wastewater are one of the most harmful and widespread pollutants in the environment. Currently, the pharmaceutical industries have an increased antibiotic production of about 100 thousand tons/year [(Zhao et al., 2014, pp. 19-25),(Serwecińska, 2020, pp. 3313)]. Ciprofloxacin (CIP) is a fluoroquinolone antibiotic and its chemical structure is 1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinoline carboxylic acid as shown in Fig.1. It is used to treat different types of bacterial infections; for example, urinary tract, and gastrointestinal infections. Whereas, antibiotics and also their by-products cause pollution that is hazardous to human health. Hence, it is important to investigate methods to remove CIP from pharmaceutical wastewater for consumption afterward [(Abu Rumman et al., 2021, pp. 100536),(Peng et al., 2016, pp. 472-481)].

The adsorption method is a potential application for the removal of pharmaceuticals since it exhibits many advantages such as low initial cost, simple and flexible design, easy operation, the possibility of effluent reuse, and insensitivity to toxic pollutants. In addition, intermediate by-products are not generated during this process [(Zhao et al., 2014, pp. 19-25)]. Over the past years, several adsorbents have been employed for antibiotics adsorption such as activated carbon, zeolite, metal-organic frameworks (MOFs), and mesoporous silica [(Zhao et al., 2014)-(Abu Rumman et al., 2021, pp. 100536)]. However, those adsorbents are expensive, which resulted in high operating costs.

Biochar is a carbonaceous compound produced under oxygen deficient condition through the process of slow and fast pyrolysis. It is produced from various carbon-based biowastes such as woody biomass, crop residues, animal carcasses, and biosolids. Biochar approaches potentially an innovative technology for as removal from the water or aqueous solution having some unique properties like porosity, large surface area and negative surface charge that makes it an efficient

means for decontaminating water (organic and inorganic pollutants) [(Mukherjee et al., 2021, pp. 111814),(Verma & Singh, 2019, pp. 109235)]. However, most of the commercial biochar is usually expensive due to their high-cost sources, regeneration, and reactivation procedures, which restricts their extensive application. Longan is an important fruit of Thailand that is produced and exported in large numbers. The longan processing for export produces a large amount of residue from it, whereas longan peel is often discarded or burned as a waste material up to hundreds of tons per year because of the lack of a comprehensive utilization. Longan peel, a high content of C, O and H, is a good precursor to produce an effective biochar due to its abundance and availability [(Vu & Do, 2021, pp. 569-588)].

This work aimed to study the feasibility of using biochar from longan peel (BCL) as adsorbents for the removal of CIP from wastewater. The textural and structural properties of BCL with respect to adsorption were examined by advanced analyses. The adsorption performance of BCL for removal of CIP was evaluated by studying the effects of types of BCL adsorbents, pH, adsorbent dose (M/V(g/l)), CIP concentration, adsorption time, shaking speed, and reusability.
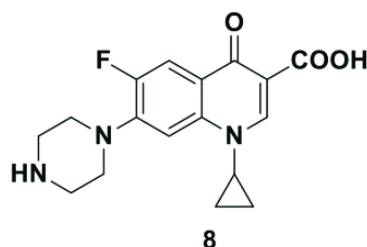
Fig.1 Chemical structures of Ciprofloxacin (CIP)

2. Materials and methods

2.1 Preparation of biochar

In this experiment, the raw materials used to produce biochar were longan residue from peel. Initially, the longan residue was washed multiple times with de-ionized (DI) water and dried at 110 ℃ for 2 days. The dried samples were ground and sieved to obtain the particle size less than 10 mm. After that, this material was subjected to pyrolysis in various temperature at 300, 500 and 700 °C for 4 h with a heating rate of 5°C/min, using tube furnace (Sante STG-100). The resulting biochar from longan residues were labeled BCL-300, BCL-500 and BCL-700, respectively. They were then dried in a hot air oven at 105℃ for 24 h and kept in the desiccator.

2.2 Biochar characterization

Standard procedures were used to characterize the prepared physical and chemical properties of the adsorbents. X-ray powder diffraction (XRD) patterns were obtained on a PAN analytical Empyrean III X-ray diffractometer employing CuKα radiation and an X-ray power of 40 kV and 40 mA. N_2 adsorption-desorption measurements were carried out at 196 °C using a BEL Japan BELSORP-mini II instrument to determine the material's textural characteristics. All samples were pre-treated at 150 °C for 2 h and then measured for exact weight prior to the adsorption. The presence of functional groups was determined using Fourier-transform infrared (FTIR) spectra (Perkin Elmer spectrum two: 900–4000 cm^{-1} in transmittance mode by KBr pellet technique).

2.3 Adsorption study

In a batch system, the adsorption studies of CIP on BCL samples were performed using 50-mL Erlenmeyer flasks containing CIP solution and dried absorbents. The adsorption experiments were conducted by shaking the flasks in a shaker at desired conditions. Subsequently, the adsorption performance of BCL adsorbents for CIP removal was examined under varying physicochemical conditions: time: 0 – 100 min; pH: 3–9; M/V: 1–10 g/L; initial CIP concentration (C_o (mg/L)): 80–120 mg/L; shaking speed: 100–150 rpm.

The concentration of CIP solution after adsorption was measured using a UV−vis spectro photometer (Jasco V-730) at 276.5 nm. The collected samples were measured three times to further UV-vis analysis. The following formula (Eq. (1)) was used to calculate the adsorption capacity (q_e). Six experimental points were used to plot a calibration curve. The regression equations for CIP were y = 0.0078x + 0.0132 (R^2 = 0.9981), where x is the concentration (mg/L), y is the absorbance values.

$$\text{Adsorption capacity:} \qquad q_e = \frac{(C_o\text{-}C_e)V_i}{W} \tag{1}$$

Where q_e is adsorption capacity at adsorption equilibrium (mg/g, dried adsorbent); C_o and C_e are the initial and equilibrium concentrations of CIP in the solutions (mg/L), respectively; V_i is the volume of initial solution (mL); W is the weight of dried adsorbent (g).

3. Results and discussion

3.1 Characterization of biochar from longan peel

The FTIR spectrums of biochar from longan peel BCL-300, BCL-500 and BCL-700 are shown in Fig. 2. In general, the FTIR analysis shows that the functional groups of biochar samples decrease with increased pyrolysis temperature. This is due to the rapid removal of volatile compounds as a result of the accelerated and intensified degree of carbonization at higher pyrolysis temperatures [(Shaikh, 2018, pp. 545-553),(Zhao et al., 2018, pp. 977-987)]. The FTIR spectra of biochar samples exhibited a broad peak at 3394 cm^{-1} which corresponds to the O−H bond stretching of the alcoholic and phenolic hydroxyl groups. The intensity of this peak was found to be very strong at lower pyrolysis temperature; however, it become disappear at higher temperature. The characteristic C–H stretching vibration of alkyl structure of aliphatic group can be seen at 2927 cm^{-1}. The peak at 1693 cm^{-1} represents the stretching of carbonyl bonds (C=O) of the carboxylic groups or conjugated ketone. The stretching vibrations of the aliphatic –C=C– appears at 1597 cm^{-1} [(Zhao et al., 2018, pp. 977-987),(Elnour et al., 2019, pp. 1149)]. It can be seen from Figure 2 that the intensity of all these peaks decreased with increasing pyrolysis temperature. At higher temperatures, i.e., more than 600 °C, almost no aliphatic functional groups would be present in the biochar. These aliphatic structures were known to reform into aromatic structures, resulting in the increased presence of phenolic and ether groups. Moreover, at high temperatures many C=C bond breakages take place due to availability of adequate energy. Therefore, at higher temperature, due to extensive carbonization, formation of graphite-like structures of the biochar occurred which shows less intense peaks [(Elnour et al., 2019, pp. 1149)].
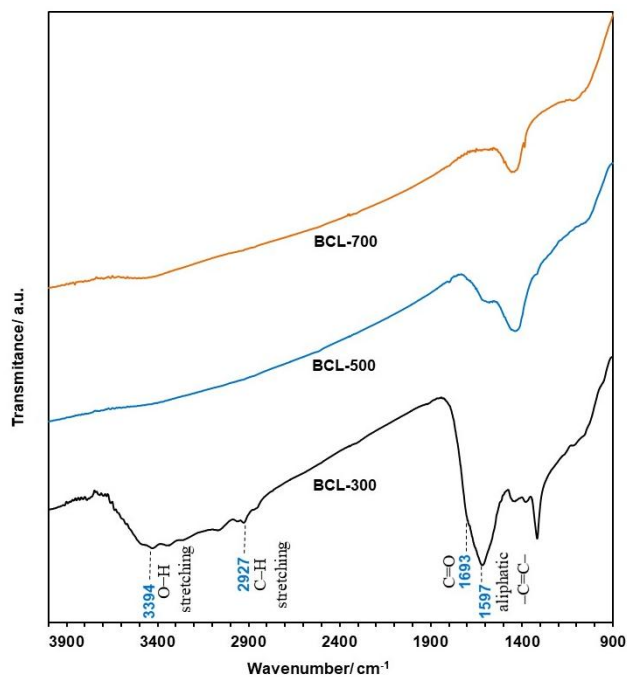
Fig. 2 FTIR spectra of biochar from longan peel BCL-300, BCL-500 and BCL-700 adsorbents.

XRD analysis was done for the determination of crystalline and amorphous structure of the prepared biochar materials. Although the major component of biochar is carbonaceous compound, various inorganic minerals can be found in their structure. From the XRD spectra of BCL materials (Fig. 3) showed an amorphous peak at 2θ values of ~10–25° but disappeared in BCL-700. In addition, the heating BCL at 500 and 700 °C exhibited some structure change of amorphous silicon dioxide to a crystalline structure (observed at 2θ around 22° 23° and 27°), such as quartz, cristobalite, or tridymite [(Mukherjee et al., 2021, pp. 111814),(Verma & Singh, 2019, pp. 109235)]. This result was probably from Si content as a minor component of the initial longan peel. Moreover, the other inorganic minerals were found in these biochars. A peak at 2θ ~ 29° was identified as sylvite (KCl), which was much prominent in BCL-700 compared to BCL-300 [(Verma & Singh, 2019, pp. 109235)]. Calcite ($CaCO_3$) was also found at 2θ = 32.2 in BCL-300 and BCL-500, but disappeared in BCL-700. In addition, the diffraction peaks present at 38.9°, 39.45°, 42.96° and 43.39° corresponds to calcium silicate (Ca_2SiO_4).
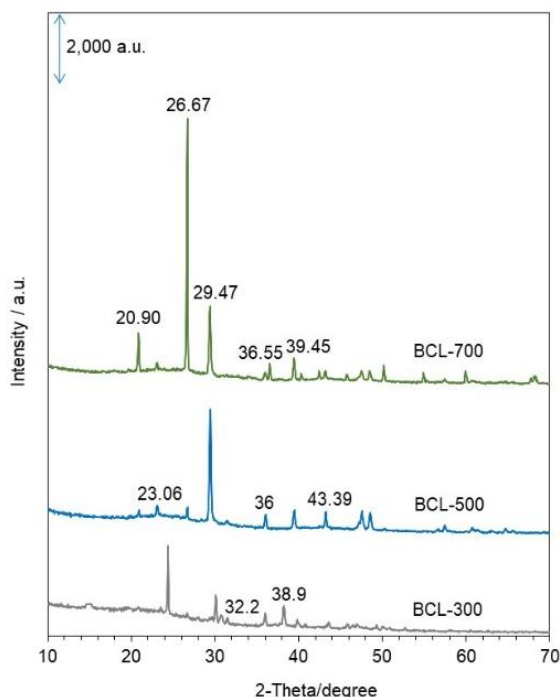
Fig.3 XRD analysis of biochar from longan peel BCL-300, BCL-500 and BCL-700

The surface area and pore volume of biochar were very important factors for adsorption to remove CIP from wastewater. The BET surface area and pore volume of biochar samples are showed in Table 1. It can be seen that both the BET surface areas and pore volumes of biochars were significantly increased with pyrolytic temperature. The surface area and pore volume of biochar produced at 700 °C was found to 20.58 m^2/g and 0.0408 cm^3/g, respectively. On the other hand, biochar made at 300 °C exhibited a surface area of 18.81 m^2/g and pore volume of 0.0337 cm^3/g. This increase of surface area is due to the removal of carbon mass as volatile matters from the biomass surface which creates pores in the resulting biochars structure.

Table 1 Physicochemical properties of the adsorbents

Sample[a]	S_{BET}[b]	Vt[c]
	$(m^2\ g^{-1})$	$(cm^3\ g^{-1})$
BCL-300	18.81	0.0337
BCL-500	19.01	0.0371
BCL-700	20.58	0.0408

[a] Dried samples

[b] BET surface area

[c] Total pore volume

3.2 Adsorption study

In the present study, the effects of the physicochemical parameters on the CIP adsorption process were studied. The biochar from longan peel BCL-300, BCL-500 and BCL-700 were examined as adsorbents in the removal of CIP from an aqueous solution. The adsorption efficiencies by function of adsorbent type are shown in Fig. 4 (conditions: M/V = 10 g/L; CIP

concentration = 120 mg/L; t = 120 min; shaking speed = 120 rpm; and room temperature). It was found that the biochar prepared with increasing pyrolysis temperature exhibited an enhance of adsorption capacity for CIP removal (BCL-300 < BCL-500 < BCL-700), corresponded to the BET surface area and pore volume as shown in Table 1. These results suggested that the highest adsorption capacity for CIP removal upon to the textural properties of the adsorbent. Therefore, BCL-700 was a suitable adsorbent for use in further studies.
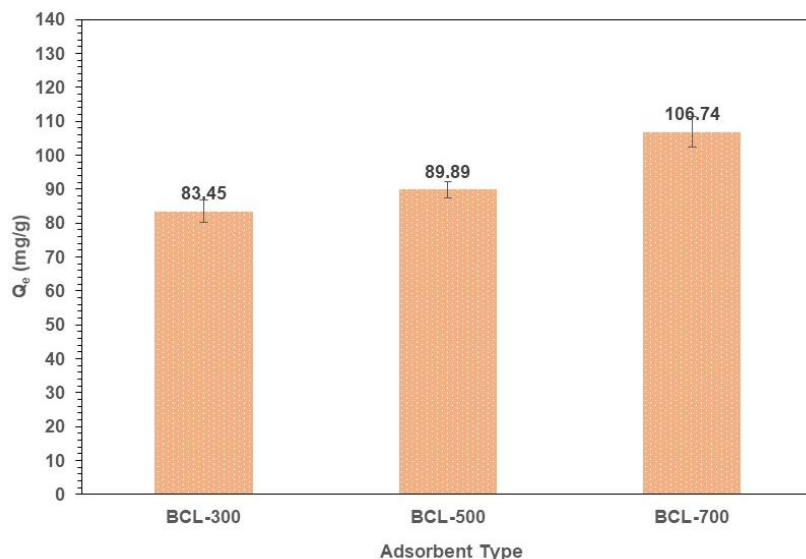
Fig. 4 Effect of type of adsorbents on CIP removal

The BCL-700 adsorbent was used to study the contact time and initial concentration on CIP removal as illustrated in Fig. 5 (conditions: pH = 7; M/V = 1 g/L; CIP concentration = 80-120 mg/L; t = 120 min; shaking speed = 120 rpm; and room temperature). The results revealed that the contact time required for reaching adsorption equilibrium was around 60 min in each concentration. In addition, the adsorption capacities were increased from ~ 32 to 40 mg/g when C_0 was enhanced from 80 mg/L to 120 mg/L. These results suggested that the capacity limit of BCL-700 was not reached in this condition. Therefore, an increasing CIP concentration, the adsorption capacity was enhanced.
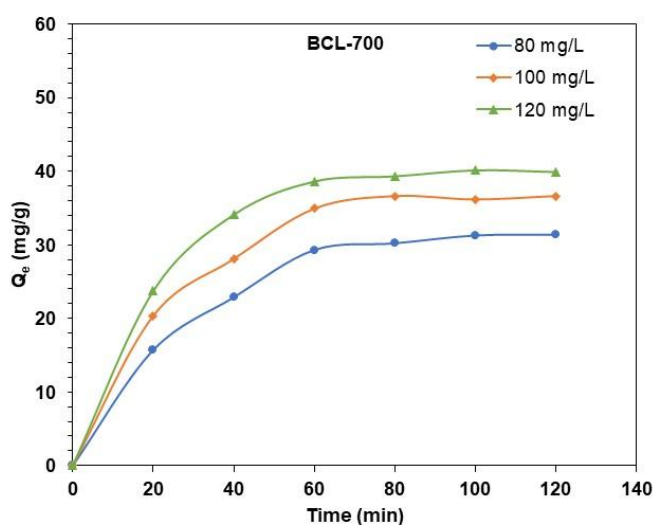
Fig. 5 Effect of contact time and initial concentration on CIP removal

The effect of mass of adsorbent per volume of CIP solution (M/V) on the CIP adsorption capacity of BCL-700 are shown in Fig. 6 (conditions: M/V = 1–10 g/L; CIP concentration = 120 mg/L; t = 60 min; shaking speed = 120 rpm; and room temperature). When M/V was increased from 1 g/L to 10 g/L, the adsorption capacity of CIP increased from 41 to 120 mg/g. This was because with an increase in M/V resulted in the amount of pore volume and functional groups (–COOH, -OH and aliphatic –C=C–) of this material were also increased. Therefore, the physicochemical adsorption capacities of this adsorbent for removal CIP was better. Based on these results, 10 g/L was considered the optimum M/V for the treatment of 1 L CIP solution with a CIP concentration of 120 mg/L.
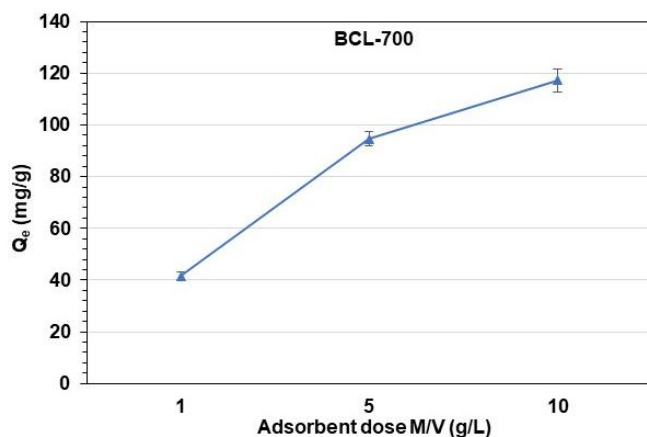
Fig. 6 Effect of adsorbent dose on CIP removal

The effect of pH on the CIP adsorption capacity of BCL-700 are shown in Fig. 7 (conditions: pH = 3–9; M/V = 10 g/L; CIP concentration = 120 mg/L; t = 60 min; shaking speed = 120 rpm; and room temperature). The adsorption capacity was enhanced as the pH increased from 3 to 7, and the maximum adsorption capacity achieved herein was 102.5 mg/g. In addition, the adsorption capacity of BCL-700 reduced when pH was greater than 7. These results suggested that at a higher pH, the repulsive forces occurred between the BCL-700 surface and CIP molecule which is due to the same positive charges, resulting in hampered the adsorption of CIP molecules on BCL-700. This phenomenon was similar to the case of CIP adsorbed on amine-functionalized MCM–41 mesoporous silica reported by Rumman et al. [(Abu Rumman et al., 2021, pp. 100536)].
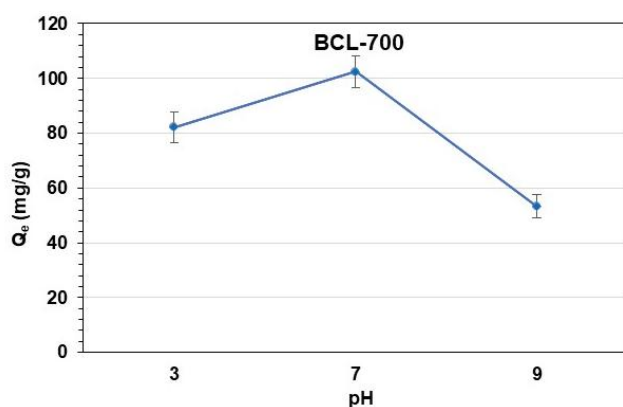
Fig. 7 Effect of pH on CIP removal

Figure 8 shows the effect of an increase in shaking speed from 100 rpm to 150 rpm on the adsorption capacities of CIP of BCL-700 (conditions: pH = 7; M/V = 10 g/L; CIP

concentration = 120 mg/L; t = 60 min; shaking speed = 100–150 rpm; and room temperature). The increase in shaking speed improved the adsorption capacities of BCL-700 along with an increase in the shaking speed and the mixing rate of adsorbent particles in the aqueous solution. Due to the increasing adsorption rate, this enhanced the collision and contact rate between CIP molecules and adsorbent particles. Therefore, the diffusion of CIP to the porous of biochar was improved, resulting in more adsorption at its surface.
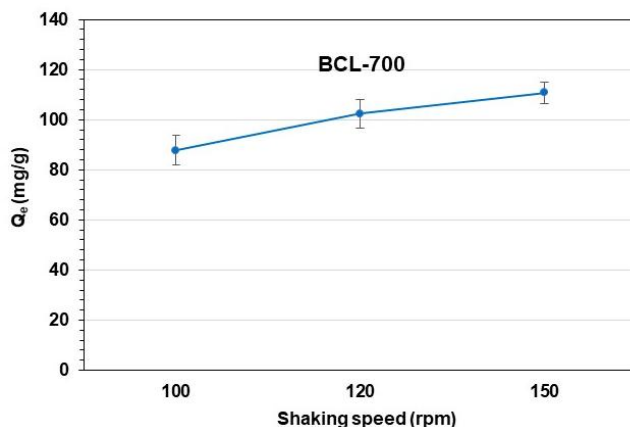
Fig. 8 Effect of shaking speed on CIP removal

3.3 Reusability

The reusability of BCL-700 adsorbent was preliminarily evaluated under the same adsorption conditions, as shown in Fig. 9. The BCL-700 adsorbent was examined for five consecutive CIP adsorption–desorption cycles under the following optimal conditions: pH = 7; M/V = 10 g/L; CIP concentration = 120 mg/L; t = 60 min; shaking speed = 150 rpm; and room temperature. At the end of each CIP adsorption cycle, BCL-700 adsorbent was separated from the mixture via filtration, then, rinsed with deionized water and ethanol to desorb the adsorbed CIP molecules, dried in an oven at 110 °C for 2 h, and then reused in the next adsorption cycle. The amount of CIP adsorbed in the 2-3 cycle were slightly smaller. This adsorbent could be repeatedly used in the adsorption at least 3 times and then the adsorption capacity loss was found in the 4-5 repetition. It might be due to the strong adsorption of CIP on the BCL-700 surface. Moreover, the spent biochar could be carbonized for further application as an adsorbent or solid fuel.
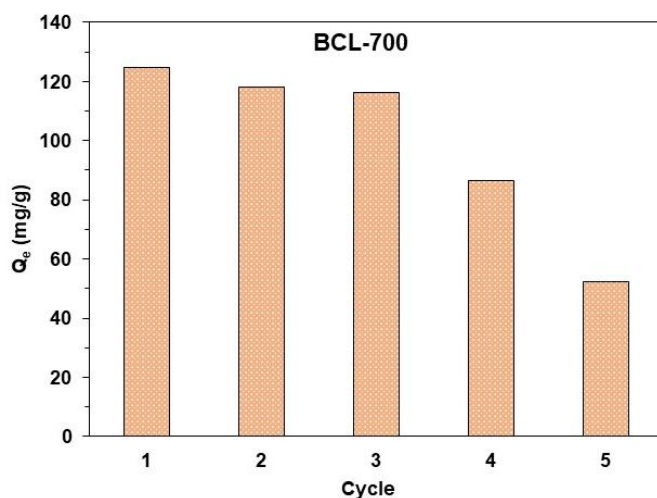
Fig. 9 Reusability study of BCL-700 adsorbent for the removal of CIP from aqueous solutions

4. Conclusion

In this study, biochar from longan peel were prepared in difference pyrolysis temperature and used as the adsorbents to remove CIP from contaminated solutions. The pyrolysis conditions were found to have significant impact on biochar structure. The inorganic minerals were found in these biochars such as KCl, $CaCO_3$ and Ca_2SiO_4. An increasing pyrolysis temperature to produce biochar resulted in almost no aliphatic functional groups would be present in the biochar, but enhanced the BET specific surface area and pore volume. According to the adsorption results, the biochar from longan peel pyrolyzed at 700°C (BCL-700) exhibited effectiveness for CIP removal. The maximum adsorption capacity of this adsorbent for CIP was 120 mg/g. Moreover, the optimum environmental conditions for achieving the maximum CIP removal were as follows: pH = 7; M/V = 10 g/L; CIP concentration = 120 mg/L; t = 60 min; and shaking speed = 150 rpm. In addition, BCL-700 adsorbent could be reused 3 times. However, this material could be further studied in a continuous fixed bed for application in the real wastewater to remove CIP.

5. Acknowledgements

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Effect of carboxyl methylcellulose, carrageenan, and locust bean gum on the properties of emulsion in meat analogue patties

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Abstract

The effect of carboxyl methylcellulose, carrageenan, and locust bean gum on the physicochemical properties and sensory evaluation of emulsion in meat analogue patties was investigated. The all of emulsion samples appeared in pink with a pigment of beetroot addition. The syneresis after the 5th of the freeze-thaw cycle was shown that the carrageenan mixed emulsion was the highest syneresis while the CMC mixed emulsion was the lowest syneresis. The mixing of CMC showed a high level of WHC in every sample of the CMC addition to emulsion while the addition of LBG led the emulsion to lower WHC than other hydrocolloids addition. The result of cooking yield showed as 80.69-84.90% but the results could not significant difference between hydrocolloids addition. The addition of carrageenan had the highest hardness, gumminess, and chewiness while the addition of CMC could increase adhesiveness and cohesiveness when mixed with LBG and carrageenan. The percent acceptability of CMC mixed emulsion in meat analogue patties had lower than in others treatments while the carrageenan mixed emulsion in meat analogue patties had the highest percent acceptability. Thus, the carrageenan mixed emulsion in meat analogue patties was suitable for this experiment.

Keywords : Hydrocolloids, Emulsion, Meat analogue

1. Introduction

Plant-based Food (especially, vegetable meat) was considered as an alternative protein food or future food due to healthy food trends and climate change (van Vliet et al., 2020). The growth of the plant-based meat market was expected to be $30 billion by 2026 according to their ecological and health benefits compared with real meat (van Vliet et al., 2020). Textured vegetable proteins (TVP) were transformed from a flour-type material mixed with other ingredients into a structure of meat-like texture by using the extrusion technique. Extrusion is normally used to produce TVP by a mixture of ingredients forced through an opening in a die and finally cut to a specific size or shape (MacDonald & Reitmeier, 2017).

A part of the meat analogue was emulsion, especially in patties preparation. The emulsion would act as linking the matrix component in patties. Thus, the stability of the emulsion was important for the application products. Hydrocolloid was a polysaccharide used in the food industry as a thickening agent, stabilizer, and emulsifier. Hydrocolloids might be acting as cross-linkers and binding protein filaments together which could improve the textural properties (Taghian Dinani et al., 2023). Carboxymethyl cellulose (CMC), cellulose derivatives, could be used in foods as fiber additives in various dairy products, ice cream, and also fat replacer in sausages and patties (Guedes-Oliveira et al., 2019; Schuh et al., 2013). Locust bean gum (LBG), a high molecular weight non-ionic galactomannan polysaccharide, was used as an additive (E410) as a thickening, stabilizing, and gelling agent, or emulsifier in the food and beverage industry (Petitjean & Isasi, 2022). LBG was studied as an additive to reduce the syneresis of starch gel during the freeze-thaw cycle (Xu et al., 2022). Carrageenan was a high molecular weight linear polysaccharide

that could increase yield and enhance product texture, and cohesiveness while decreasing drip loss of low-fat and low-salt sausages (Majzoobi et al., 2017). Moreover, carrageenan was studied to use in plant-based patty (Tunnarut et al., 2022). Moreover, the mixing of hydrocolloids was commonly combined to achieve increased viscosity or preferable properties of food gels which depended on the blending of different polysaccharides to an alternative way to develop a new texture. (Saha & Bhattacharya, 2010). For example, the mixing of carrageenan and LBG could be got an elastic cohesive gel texture like gelatin and could apply to use for cake glazing. (Saha & Bhattacharya, 2010). However, the concentration and mixing ratio of hydrocolloids in meat patties emulsion was still restricted.

2. Objectives

The objective of this research was to study the effect of carboxyl methylcellulose, carrageenan, and locust bean gum on the physicochemical properties and sensory evaluation of emulsion in meat analogue patties.

3. Materials and methods

3.1 Materials

Texture vegetable protein (TVP) was purchased (Khun yuy, Thailand). Maltodextrin, carboxy methyl cellulose (CMC), carrageenan, and locust bean gum (LBG) (Krungthepchemi Co., Ltd., Thailand) were used in this study.

3.2 Sample preparation

Emulsion preparation of the experimental was designed by using a Mixture design (Fig. 1 and Table 1). The hydrocolloids 4% (w/w) such as CMC, carrageenan, and LBG were mixed with other ingredients such as water, canola oil, coconut oil, beetroot powder, salt, SPI, maltodextrin, and yeast extract to form an emulsion. All of the ingredients were mixed by blender for 5 min until homogeneous. The emulsion samples were kept at 4°C for 24 h before measurement.
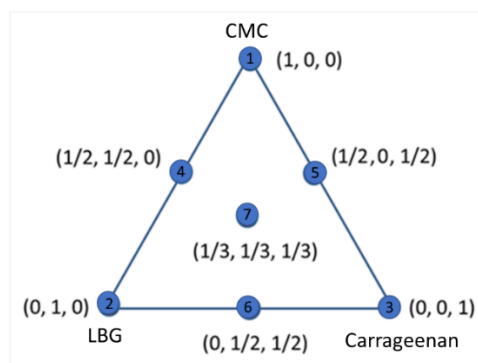
Figure 1 The mixture design of CMC, carrageenan, and LBG

Table 1 The ratio of CMC, carrageenan, and LBG for emulsion preparation

Treatment	Hydrocolloids		
	CMC	LBG	Carrageenan
Trt1(CMC)	4.00	-	-
Trt2(LBG)	-	4.00	-
Trt3(Carra)	-	-	4.00
Trt4(CMC+LBG)	2.00	2.00	-
Trt5(CMC+Carra)	2.00	-	2.00
Trt6(LBG+Carra)	-	2.00	2.00
Trt7(CMC+LBG+Carra)	1.35	1.35	1.35

3.3 Color

The color of the emulsion sample was measured with a Minolta colorimeter (CR-400/CR-410, Japan). Color in terms of luminosity, light versus dark (L*), red versus green (a*), and yellow versus blue (b*) were measured.

3.4 Syneresis after freeze-thaw cycles

The syneresis was measured with a modified from Serdaroğlu et al. (2016). The weight of 7 g emulsion samples in the plastic cup was determined and the tube was sealed again. The sample cup was stored in different temperatures cycle for 20 h at -20°C and 4 h at 25°C, repeated in 5 cycles. Then all fluid was removed from the cup by decanting of fluid and dabbing the sample with a tissue. Afterward, the weight of the cup was determined again. Finally, the sample was removed from the tube, and the empty tube was weighed. Syneresis was calculated from the equations as follows:

$$\text{Syneresis (\%)} = \frac{(\text{sample weight- sample weight after removed fluid}) \times 100}{\text{sample weight}} \quad (1)$$

3.5. Water holding capacity

Water holding capacity (WHC) were measuring modified from Panyathitipong & Puechkamut (2010). The emulsion sample was weight into a 15 ml centrifuge tube for 10 g. Then, the samples were centrifuged at 5000 rpm using Hettich MIKRO 220R (Andreas Hettich GmbH & Co. KG, Germany) for 20 min at 25°C. After that, the samples were taken in water bath (Memmert GmbH + Co. KG, Germany) at 90°C for 15 min. The supernatant was poured out and weighted the sample again. WHC was calculated from the equations as follows:

$$\text{WHC (\%)} = (1 - (\frac{\text{sample weight-sample weight after centrifuge}}{\text{water in the sample}})) \times 100 \quad (2)$$

3.6. Cooking loss

Cooking loss of meat analogue patties was investigated during meat analogue patties cooking. The meat analogue patties 10 g were placed in a circular mold of 36 mm height 7 mm. Then the samples were heated at 120°C for 3 min on each side until the center of the samples were 70 °C. After that, the samples were set at room temperature for 10 min until cooled down at room temperature. The samples were weight before cooking and after cooking (Serdaroğlu et al., 2016). The cooking yield of samples was calculated from the equations as follows:

$$\text{cooking yield (\%)} = \frac{\text{sample weight after cooking}}{\text{sample weight before cooking}} \times 100 \quad (3)$$

.3.7 Texture profile analysis of meat analogue patties

The soaking TVP 60 g was mixed with a blended emulsion of 40 g to forming mincemeat patties. The patties were kept at −20°C until cooked. The frozen patties were thawed at 4°C for 24 h and then were cooked to an internal temperature of 70°C. The patties were allowed to cool to room temperature, and a 13X25 mm core sample was taken from the center of each patty for textural analysis. Texture analysis of cooked TVP- minced meat. Texture profile analysis was performed using a LLOYD TA plus Material Tester (Lloyds, England). A 45 mm anvil was used to determine 70% compression at a rate of 1mm/s. Samples were evaluated for hardness, springiness, adhesiveness, cohesiveness, gumminess, and chewiness. Eight texture analyses were repeated on each sample (Crowe & Johnson, 2001).

.3.8 Sensory evaluation

Meat analogue patties samples were cooked and served to thirty semi-trained member panelists aged between 23 − 55 years old for sensory evaluation in terms of appearance, glossy, taste, texture, and like using a 9-point hedonic scale, and percent of overall acceptability. The scores were assigned from liked extremely (9) to disliked extremely (1). The samples were served to the panelists after coding with three digits of randomly selected numbers.

.3.9 Statistical analysis

All the samples were analyzed statistically using SPSS version 22. Different means were investigated by ANOVA and Duncan's multiple range tests at a level of significance of 0.05.

4. Results

4.1. Color of emulsion

The color of emulsion samples was identified using CIE L*a*b* coordinates. The color parameters were defined in the terms of light versus dark (L*), red versus green (a*), and yellow versus blue (b*). The color of the emulsion sample was shown in Table 2. The emulsion samples appeared pink with a pigment of beetroot addition. The mixture of hydrocolloids showed different effects on color as the L* value of CMC mixed emulsion

was higher than that of other mixed emulsions while carrageenan mixed emulsion showed the highest of a*.

Table 2 Color of emulsion samples

Treatment	L*	a*	b*
Trt1(CMC)	69.30±0.33[e]	22.38±0.41[a]	9.44±0.48[d]
Trt2(LBG)	53.91±3.26[ab]	23.00±0.40[b]	8.42±0.25[b]
Trt3(Carra)	52.65±1.37[a]	25.14±0.34[d]	9.07±0.52[cd]
Trt4(CMC+LBG)	62.06±0.80[c]	23.59±0.25[b]	7.93±0.26[a]
Trt5(CMC+Carra)	64.31±0.35[d]	24.43±0.35[c]	8.73±0.36[bc]
Trt6(LBG+Carra)	54.85±1.14[b]	23.03±1.28[b]	8.53±0.60[b]
Trt7(CMC+LBG+Carra)	64.39±1.23[d]	22.12±0.84[a]	7.80±0.40[a]

*Different letters significant difference at p.0.05 $\geq$

4.2. Syneresis and water holding capacity (WHC) of emulsion

Syneresis was an important parameter for emulsions and affected other characteristics of product such as stability and cooking yield (Serdaroğlu et al., 2017). Freeze–thaw stability was an important property to evaluate the ability of a product that resist unsatisfied physical changes occurring during freezing and thawing (Muadklay & Charoenrein, 2008). Thus, the syneresis during freezing and thawing was an interesting parameter that would affect frozen meat analogue patties. The emulsion after preparation was investigated syneresis after 5 cycles of the freeze-thaw cycle, the results were shown in Table 3. The carrageenan mixed emulsion was the highest syneresis while the CMC mixed emulsion was the lowest syneresis. The mixing of CMC showed high WHC in every sample of the CMC addition to emulsion while the addition of LBG led the emulsion to lower WHC than other hydrocolloids addition.

Table 3 Syneresis and water holding capacity

Treatment	Syneresis (%)	WHC (%)
Trt1(CMC)	3.36±0.38[a]	98.98±0.61[c]
Trt2(LBG)	19.55±0.81[c]	74.85±2.07[a]
Trt3(Carra)	27.23±1.47[e]	84.96±2.87[b]
Trt4(CMC+LBG)	3.99±0.28[ab]	99.45±0.11[c]
Trt5(CMC+Carra)	3.56±0.45[a]	99.36±0.1[c]
Trt6(LBG+Carra)	22.46±1.08[d]	74.97±1.94[a]
Trt7(CMC+LBG+Carra)	5.12±0.56[b]	99.33±0.06[c]

*Different letters significant difference at p.0.05 $\geq$

4.3. Cooking loss of meat analogue patties

The prepared emulsion was mixed with TVP to produce meat analogue patties. The meat analogue patties before and after cooking were shown in Fig.2. The meat analogue patties using CMC mixed emulsion tended to have higher cooking yield than those using LBG and carrageenan mixed emulsion. However, the result of cooking yield could not significantly difference between hydrocolloids addition (Table 4).
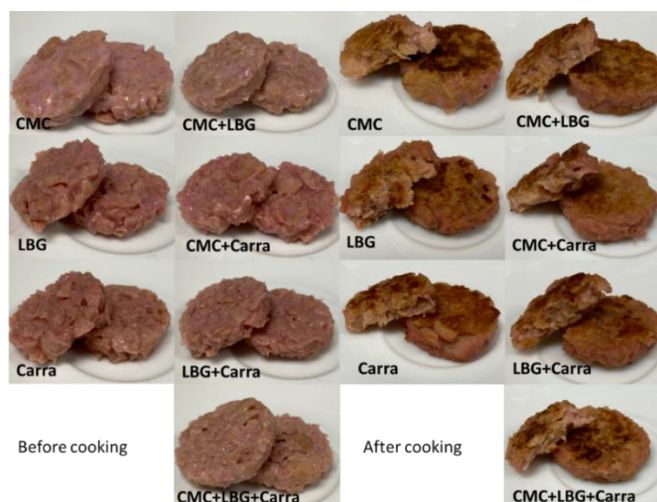
Figure 2 The meat analogue patties before and after cooking

Table 4 Cooking yield of meat analogue patties

Treatment	Cooking Yield
Trt1(CMC)	84.90±1.24[a]
Trt2(LBG)	81.53±1.40[a]
Trt3(Carra)	81.20±6.14[a]
Trt4(CMC+LBG)	82.83±2.26[a]
Trt5(CMC+Carra)	84.41±2.41[a]
Trt6(LBG+Carra)	81.13±3.51[a]
Trt7(CMC+LBG+Carra)	80.69±2.58[a]

*Different letters significant difference at p.0.05 ≥

4.4. The texture analysis of meat analogue patties

The texture profile analysis (TPA) of meat analogue patties was shown in Table 6. The addition of carrageenan had the highest hardness at 76.46±8.76 N. The results were similar trends with a springiness that the carrageenan, and carrageenan and LBG addition had the highest springiness. However, the addition of CMC could increase adhesiveness and cohesiveness when mixed with LBG and carrageenan (CMC+LBG+Carra).

Table 5 Texture properties of meat analogue patties

Treatment	Hardness (N)	Adhesiveness (Nmm)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (N)
Trt1(CMC)	47.55±9.52[ab]	4.80±0.54[cd]	5.87±1.13[bc]	0.46±0.04[ab]	8.32±2.10[ab]	3.81±1.06[ab]
Trt2(LBG)	67.17±16.20[c]	2.73±0.91[abc]	6.22±0.78[c]	0.46±0.05[ab]	11.71±2.19[cd]	5.02±1.33[bc]
Trt3(Carra)	76.46±8.76[c]	2.57±0.54[ab]	3.79±0.35[a]	0.48±0.04[b]	20.80±3.86[e]	10.10±2.30[d]
Trt4(CMC+LBG)	64.09±6.30[c]	1.24±0.56[a]	6.52±1.34[c]	0.45±0.05[ab]	10.14±1.76[bcd]	4.60±1.24[bc]
Trt5(CMC+Carra)	61.62±18.78[bc]	5.41±1.83[de]	6.73±0.76[c]	0.43±0.01[ab]	9.05±2.10[bc]	3.89±0.93[ab]
Trt6(LBG+Carra)	64.00±18.52[c]	3.51±1.03[bcd]	4.98±0.63[b]	0.48±0.07[b]	12.96±3.70[d]	6.25±182.[c]
Trt7(CMC+LBG+Carra)	40.21±10.53[a]	6.97±1.13[e]	6.34±1.01[c]	0.42±0.01[a]	5.89±1.38[a]	2.33±0.64[a]

*Different letters significant difference at $p.0.05 \geq$

4.5. The sensory test of meat analogue patties

The sensory score of meat analogue patties was shown in Fig 3. The CMC mixed emulsion in meat analogue patties would be less sensory score than others treatments. The percent acceptability of CMC mixed emulsion in meat analogue patties also had lower than in others treatments while the carrageenan mixed emulsion in meat analogue patties had the highest percent acceptability (75%). However, only the carrageenan mixed emulsion, and LBC and carrageenan mixed emulsion had a percent acceptability of more than 70%.
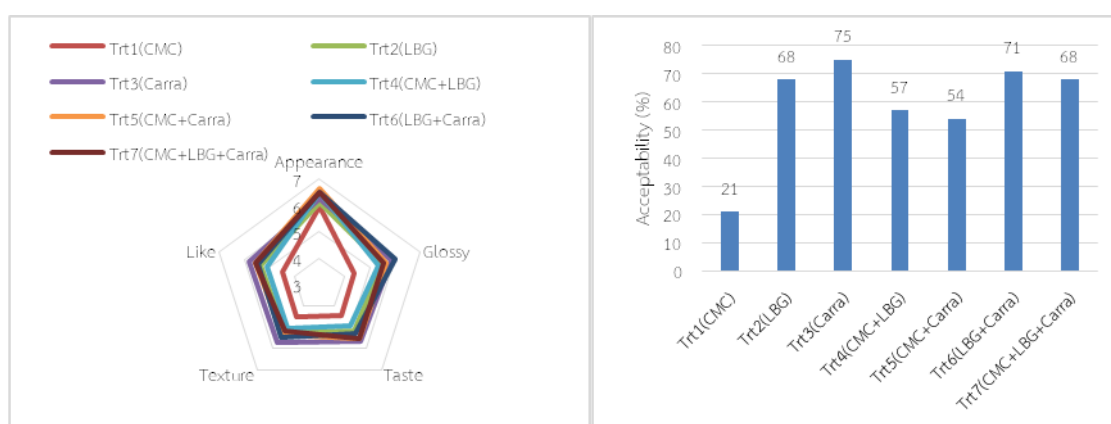
Figure 3 The sensory test of meat analogue patties

The CMC addition to emulsion could show better properties in syneresis, WHC, and cooking loss while the sensory evaluation showed the lowest score, especially the liked glossy test. The good emulsion stability of CMC might retain oil in composition when cooking, and be affected as greasy after eating.

5. Discussions

The color of the emulsion samples appeared pink with a pigment of beetroot addition. the different color results might relate to particle size and distribution of the matrix due to refractive index, concentration, size, and chromophoric materials would appear the different lightness to each of the dressing emulsion samples (Quintana et al., 2022). However, Tunnarut et al. (2022) reported the color of cooked plant-based patties was not significantly different with the addition of different hydrocolloids (methylcellulose, carrageenan, and xanthan) and had no visual impact.

The lowest syneresis of CMC addition results might be due to the interaction between starch (modified starch in composition) and CMC would decrease starch-starch interaction, CMC acted as a water binder to retain water and contributed to low syneresis in the sample (Veronese et al., 2018). The trends of low syneresis in the sample would have high WHC, especially with CMC addition. CMC could be soluble in either cold or hot water according to concentration, and molecular weight to emerging the aqueous dispersion behavior (Saha & Bhattacharya, 2010).

Bakhsh et al. (2021) reported that increasing methylcellulose in meat analogues would decrease water release and cooking loss due to the binding moisture in product formulation and gel-forming upon heating. The higher cooking yield with CMC addition might be due to the higher WHC of emulsion. These results were similar to Basati & Hosseini (2018) that report the reduction in cooking loss might be attributed to the increase in water holding capacity. However, the result of cooking yield could not significant difference between hydrocolloids addition.

The texture properties might be the multi-molecule junction zones of κ-carrageenan that would be more rigid and less easily restructure even disturbed by shearing force (Saha & Bhattacharya, 2010). However, the addition of CMC could increase adhesiveness and cohesiveness when mixed with LBG and carrageenan (CMC+LBG+Carra). Moreover, the addition of carrageenan showed the highest gumminess and chewiness. The hydrocolloid addition affected meat analogue patties in different behavior due to the type of hydrocolloids and composition in the matrix. Tunnarut et al. (2022) reported that plant-based patties containing methylcellulose would have the highest hardness, springiness, cohesiveness, and chewiness followed by carrageenan and xanthan, respectively. During the gelation of hydrocolloids, junction zones formed a three-dimensional network by aggregation of inter-chain linkages, and the physical arrangement would be according to many factors such as temperature, presence of ions, and inherent structure of hydrocolloid to setting gel in a different way of mechanisms as ionotropic gelation, cold-set gelation, and heat-set gelation (Saha & Bhattacharya, 2010).

The taste was the main reason for consumers' choice. The key drive for plant-based meat development as an alternative product would be produced to equal nutrition, taste, and texture, among them convenience products (Osen & Schweiggert-Weisz, 2016). The CMC addition might be good properties for syneresis, WHC, and cooking loss. However, the carrageenan addition was higher hardness, gumminess, and chewiness in the texture properties, and more acceptability from sensory results.

6. Conclusion

The physicochemical properties and sensory evaluation of emulsion in meat analogue patties were affected by hydrocolloids addition such as carboxyl methylcellulose, carrageenan, and locust bean gum. The syneresis after the 5th freeze-thaw cycle was

shown that the carrageenan mixed emulsion was the highest syneresis while the CMC mixed emulsion was the lowest syneresis. These results were related to the high WHC of the CMC mixed emulsion. The result of cooking yield could not significant difference between hydrocolloids addition. The textural properties of meat analogue patties would be different with using different hydrocolloids. The interaction of hydrocolloids would be involved many factors such as temperature, the presence of ions, the inherent structure of hydrocolloids, and composition in the matrix. The carrageenan mixed emulsion in meat analogue patties had the highest percent acceptability from sensory evaluation. Thus, the carrageenan mixed emulsion in meat analogue patties was suitable for this experiment.

7. Acknowledgement

8. References

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