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DEVELOPMENT AND EVALUATION OF GREEN MUSSEL SHELL (PERNA VIRIDIS) AS FILTER OF GREYWATER FOR HOUSEHOLD CLEANING

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ABSTRACT

This study investigated the potential of green mussel shells (Perna viridis) as a natural filtration medium for treating greywater, addressing the pressing need for sustainable water management. In line with the 6th United Nations Sustainable Development Goal (SDG 6: Ensure availability and sustainable management of water and sanitation for all, 2015), the research aimed to provide a solution to water scarcity challenges. Employing an experimental research design, the study develops and assesses a water filtration device utilizing mussel shell powder as the primary medium. Research objectives included evaluating the physicochemical and microbiological attributes of both filtered and unfiltered greywater. Parameters studied include color, pH, total suspended solids, oil and grease, and total and fecal coliform bacteria. Results highlighted the evaluation of mussel shell filtration in reducing oil and grease, total suspended solids, and certain microorganisms in greywater. The process enhances water quality, suitable for non-potable applications like household cleaning. Compliance with regulatory standards set by the Department of Environment and Natural Resources is achieved for filtered greywater. In summary, green mussel shells presented a promising natural filtration solution for sustainable water management, addressing both water scarcity and waste management issues. While direct discharge into water bodies remains restricted due to microbial concerns, the study underscores the potential of filtered greywater for safe use in non-food contact sanitation solutions.

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INTRODUCTION

Sustainability, as defined by the United Nations (2018), is *meeting the needs of the present without compromising the ability of future generations to meet their own needs*. With the climate crisis worsening by the second accompanied by various global problems, the need for sustaining the world's current resources is a must at these times. Sustainability is central to everything being done in the food service industry. Various food service establishments pursue sustainable agendas through zero-waste practices, recyclable packaging, energy audits, and more. The formation of the 17 Sustainable Development Goals (SDG) serves as a framework for global partnership to improve people's lives and achieve sustainability in various aspects—environmental, economic, and social. The 6th SDG covers solutions to provide safe and secure water systems to every person, address problems of water availability, and improve water and sanitation management. Water is the most valuable resource on our planet. It is the essential chemical compound that brought life to Earth and continues to be an important part of a human's everyday life. The planet consists mainly of water, having 70 percent saltwater and 2.5 percent freshwater. Only one percent of the planet's freshwater, however, is accessible to humans (National Geographic Society, 2021). Over the past 300 years, wetland areas around the world have decreased by more than 85 percent. Although the quantity of freshwater in the nation is plenty, most is concentrated in a few places, mainly in the northern region. As a result, there is severe water shortage in many areas of the Philippines, especially during the dry season. This causes uneven distribution of water resources that leads to water scarcity. The over-extraction of groundwater in areas where it is limited leads to the depletion of aquifers. The demand for freshwater use grows as more households and industries utilize water for everyday use. Sustainable water management practices lead to the concept of reusing greywater or wastewater from washing and bathing. Greywater is typically less polluted than domestic wastewater, usually from toilet flush (Gross, *et al*., 2015). The non-potable reuse of greywater contributes to water conservation practices (Borges, *et al*., 2023). It minimizes water expenditure and contaminates wastewater into sewage. Utilizing the amount of saltwater available on the planet, the production of shellfish is becoming a global industry that contributes to revolving the global economy. Each year, global marine bivalve production for human consumption totals more than 15 million tons. In the Philippines, green mussels (*Perna viridis*), locally known as *tahong*, is the most produced species. A total of 74,993.02 MT of shellfish, including mussels and oysters, were produced in 2020 (Bureau of Fisheries and Aquatic Resources, 2022). With the increase in production comes equivalent shell waste. Mussel shells were among biodegradable wastes that were recovered in an underwater and coastal cleanup in Legazpi City, Albay (Calipay, 2022). Discarded mussel shells from households or restaurants are commonly thrown in garbage disposals and end up in landfills. Shellwaste, along with other seafood wastes, accumulate in landfills where it poses great threat to health and the environment. The goal of the study was to addressed problems of the current water situation in the Philippines by utilizing greywater. Researchers addressed this by developing a water filtration device with mussel shells. The utilization of this shell waste provided not only a solution to the efficient greywater reuse system but also the waste management problems that come along its improper disposal. Researchers provided a solution to greywater reuse through first-stage treatment via filtration.

METHODOLOGY

The experimental research design was a method used for conducting the research, where one or more independent variables were altered and applied to one or more dependent variables to establish relationships between them and determine causative factors, as described by Zubair in 2023. Statistical analysis was employed to evaluate the information gathered from the experiments for significant relationships or differences. Prior to the main experiment, a pre-experiment was executed to test various formulations for improved results, guiding the need for further laboratory testing.

The study employed an experimental research design with laboratory analyses, including physicochemical and microbiological assessments. In this study, the mussel shell served as the independent variable, and the quality of filtered greywater was the dependent variable, influenced by the formulations of the independent variable. The research took place at Purok 7, Pansol, Calamba City, Laguna, where dark greywater was collected for the experiment. This greywater originated from the resort's main sink, primarily used for handwashing and dishwashing activities, and was expected to contain significant amounts of total suspended solids and oil and grease due to residual food particles from dishwashing. The resort accommodated 25 to 30 guests, with high occupancy levels, resulting in substantial water usage in Pansol, Calamba. In the context of Pansol, Calamba, which had a local population of 11,623 individuals (representing about 2.15 percent of Calamba's total population according to the 2020 Census), the study aligned with the need to address water wastage and promote sustainable water usage practices, particularly concerning the utilization of dark greywater within the locale. The study conducted by Alpha Laboratory Calamba Philippines Corporation involved physicochemical and microbiological tests to assess the quality of filtered greywater. In the physicochemical analysis, the researchers used various techniques, including a liquid-liquid gravimetric partition approach to determine oil and grease content, vacuum filtration and oven drying to measure total suspended solids, visual color comparison to a standard chart for color analysis, and electrometric pH measurement. These techniques followed standardized procedures outlined in the 22nd edition of water and wastewater examination methods and helped evaluate various physicochemical properties of the water.

Table 1. Materials

Material	Source	Specification
Wastewater	Household kitchen sink, Pansol, Calamba, Laguna	5 liters of dark greywater
Green Mussel Shells	Calamba Public Market	5 kg cooked, washed & dried shells Ground to 0.1016mm per grain
Baking Soda	Arm and Hammer Brand	¼ cup
Empty Filter Cartridge	Shopee	10SL refillable cartridge 10x2.5 inches
Water Jug	Shopee	5L plastic container
Fine Mesh Sieve	Mr. DIY Store	110-mesh size
Strainer	Mr. DIY Store	20-mesh size
Stock pot		7L stainless steel, 26cm diameter
Sample Bottle Container 1	Alphalab Calamba	1 gallon plastic container
Sample Bottle Container 2	Alphalab Calamba	1 liter glass bottle with sulfuric acid
Sample Bottle Container 3	Alphalab Calamba	150 ml glass bottle with sodium thiosulfate

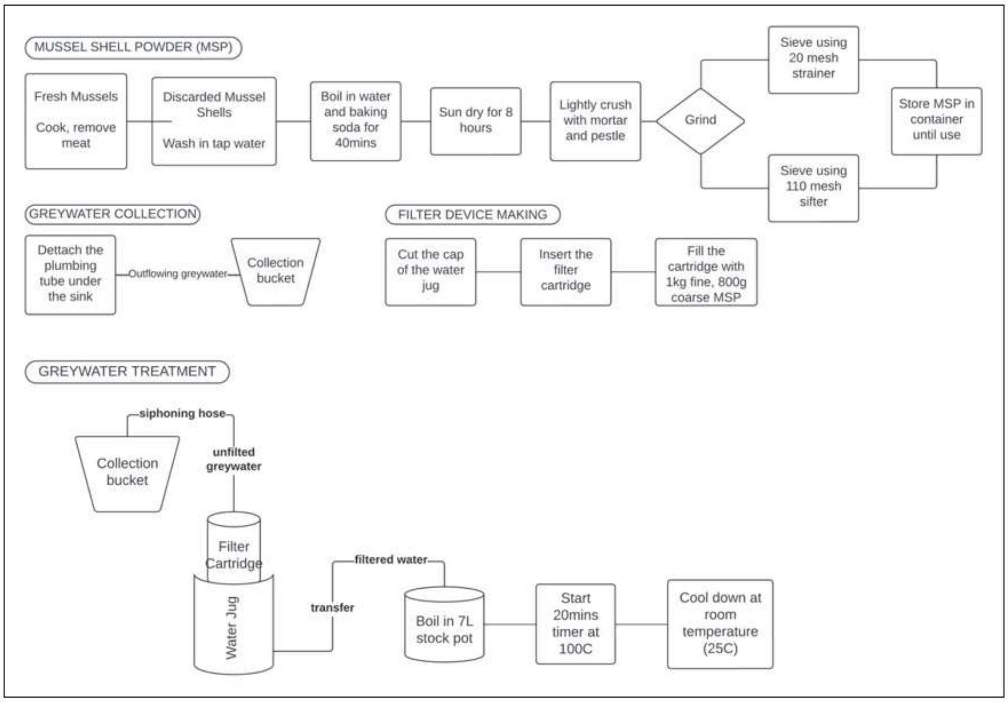

Figure 1. Process Flow Diagram of the Study

In the microbiological analysis, the study employed the Multiple Tube Fermentation (MTF) technique to identify and quantify coliform bacteria, specifically total coliforms and fecal coliforms, in the water samples. This process involved sample collection, dilution, inoculation, incubation, interpretation, and calculation. The presence of gas bubbles in Durham tubes following incubation indicated bacterial growth and fermentation, suggesting the potential presence of coliform bacteria. The count of positive tubes at different dilution levels was used to estimate the concentration of coliform bacteria in the initial water sample, expressed as a Most Probable Number (MPN) value, providing an approximation of the bacterial count.

RESULTS AND DISCUSSION

This study utilized two analytical tests (physicochemical and microbiological) on unfiltered and filtered greywater. The test was conducted by Alpha Laboratory Calamba, an accredited water analysis laboratory by the Department of Environment and Natural Resources (DENR).

Table 2. Analytical test results for wastewater physicochemical analysis

Particulars	Unfiltered greywater		Filtered greywater	
	Results	Unit	Results	Unit
Oil and grease	24	mg/L	3.5	mg/L
Total suspended solids	139	mg/L	13	mg/L
Color	20	TCU	20	TCU
pH @ 21c	5.9	-	6.7	-

The data in Table 1 indicates that the filtration process, utilizing crushed or powdered mussel shells, effectively reduces the concentration of oil and grease in greywater. The concentration of oil and grease decreased from 24mg/L in unfiltered greywater to 3.5mg/L in filtered greywater. The mussel shell filtration method effectively reduces oil and grease pollutants, demonstrating its potential for wastewater treatment. This reduction is attributed to adsorption, similar to the amino-rich sponge highlighted by Liu, *et al*. (2021) and Murphy, *et al*. (2020), where mussel shells act as an *inorganic sponge* for oil remediation. Further, it shows total suspended solids decreased from 139mg/L to 13mg/L. This higher number indicates that the sample has a higher percentage of non-dissolved solid particles. On the filtered side, the concentration of total suspended solids was reduced. After filtering, 13mg/L of suspended particles remained per liter of liquid. It follows that the decrease in total suspended solids from 139mg/L to 13mg/L in the filtered greywater shows that the water has undergone successful treatment and has enhanced quality, making it more appropriate for use in a variety of applications including non-potable water usage or discharge into the environment while causing the least number of environmental effects. The data in Table 1 shows that the result of the color has no difference, unfiltered greywater has 20TCU, and filtered water also has 20TCU. The color of the water in the result is based on TCU, not on the visual color of the water. TCU or true color unit is true color which results from only dissolved species in water, such as naturally occurring organic matter, minerals, or chemicals, which is the color in the sample after it has been filtered to remove suspended materials like algae and particulates that cause turbidity. The term *color* can be used to describe either apparent or true colors, apparent colors are made up of both dissolved and suspended colors. True colors are made after suspended materials have been removed using a filter or centrifuge (Hancock, 2022).

Table 3. Analytical test results for wastewater microbiological analysis

	Unfiltered greywater		Filtered greywater	
Particulars	Results	Unit	Results	Unit
	(MPN index/100mL)		(MPN index/100mL)	
Fecal Coliform	1.1 x 1010	MPN	1.1 x 104	MPN
Total Coliform	1.1 x 1010	MPN	1.1 x 104	MPN

The microbiological analysis of greywater filtration unveils a remarkable reduction in microorganism levels when comparing unfiltered and filtered greywater. Initially, unfiltered greywater exhibited alarmingly high concentrations of fecal coliform and total coliform bacteria, indicating potential contamination, and posing significant water safety concerns. However, the filtration process, utilizing a medium composed of crushed or powdered mussel shells treated with baking soda, proved highly effective in mitigating these microorganisms. This reduction can be attributed to a dual mechanism involving physical entrapment and surface adhesion inherent in the filtration process. The mussel shell-based filtration system functions as a selective barrier, allowing water to pass through while entrapping particles and microorganisms. The porous structure of the mussel shell medium plays a crucial role in physically trapping microorganisms, such as fecal coliform and total coliform bacteria, within the interstitial spaces between shell particles and on the surfaces of these particles. This constrains their passage and diminishes their presence in the filtered greywater. Additionally, research by Liu *et al*. (2021) supports these findings, highlighting the capability of mussel shell particles' surfaces to facilitate microorganism attachment. This surface adhesion further contributes to the reduction of fecal coliform and total coliform bacteria in the filtered greywater. In summary, the reduction in microorganism levels in filtered greywater results from a combination of physical entrapment within the porous medium and microorganism adhesion to surfaces. These mechanisms underline the efficacy of the filtration method in reducing microorganisms, aligning with the goal of sustainable wastewater treatment and reinforcing findings from studies such as Mahmoud *et al*. (2022), which employed microwave heating for disinfection.

Table 4. Analytical test results for wastewater in comparison with the DENR

Particulars	Unfiltered greywater		DENR GES Class A	
	Results	Unit	Limit	Unit
Fecal coliform	1.1 x 104	MPN	100	MPN
Total coliform	1.1 x 104	MPN	3,000	MPN
Oil and grease	3.5	mg/L	5	mg/L
Total suspended solids	13	mg/L	70	mg/L
Color	20	TCU	100	TCU
pH @ 21c	6.7	-	6.0-9.0	-

General Effluent Standards for Class A water: Table 4 shows that most parameters of the wastewater analysis are within the limits set by the DENR General Effluent Standards. The filtered greywater passes the DENR GES for the physicochemical analysis on particulars—oil and grease, total suspended solids, color, and pH. The parameter value for oil and grease is 3.5mg/L which is less than the limit of 5mg/L. The total suspended solids concentration of filtered greywater is well below the DENR GES at 13mg/L and 70mg/L, respectively. This indicates that the filtration process through the mussel shell powder has been effective in binding suspended solids to reduce its concentration. The color of the filtered greywater is 20TCU, 80 units below the DENR requirement. A low TCU indicates that most dissolved and suspended materials in the wastewater have been removed. The truecolor of the water can only be seen after the removal of certain particulates that cause turbidity (Thermo Scientific, 2020). The pH level of the filtered greywater falls at 6.7 which is within the acceptable pH range based on the DENR GES which is 6.0 - 9.0.

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