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Preliminary Study on the Removal of Selected Contaminants from Beauty Salon Wastewater Using Banana (*Musa acuminata x balbisiana BBB group*) Peelings and Young Coconut (*Cocos nucifera l.*) Exocarp

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Abstract— *The increasing environmental impact of improperly treated beauty salon wastewater necessitates the development of cost-effective and sustainable treatment solutions. This study investigated the adsorption potential of young coconut exocarp (Cocos nucifera L.) and banana peelings (Musa acuminata x balbisiana BBB group) as natural adsorbents for the removal of surfactants and chemical oxygen demand (COD). Four experimental setups were conducted to assess the performance of the natural adsorbents. Results demonstrated that Setup A exhibited the highest adsorption efficiency, reducing surfactant concentrations from 8.88 mg/L to an average of 7.22 mg/L, outperforming Setup B with 12.98 mg/L and Setup C 21.23 mg/L. Similarly, COD levels in Setup A decreased from 7,652 mg/L to an average of 4,129 mg/L, while Setup B and Setup C showed fewer effective reductions at 8,654 mg/L and 7,293 mg/L, respectively. The pH remained near-neutral in Setup A, averaging 7.23, indicating minimal alteration to water quality. In contrast, Setup B exhibited inconsistent COD removal, with an initial surge in values Trial 1 with the value of 13,507 mg/L organic leaching. Although none of the setups met DAO 2016-08 effluent standards for surfactants and COD, the results demonstrate the potential of young coconut exocarp as a sustainable adsorbent. Its performance may be improved through extended contact time, increased dosage, chemical or thermal activation, proper influent sampling, pre-treatment of adsorbents, and integration into a multi-stage treatment system with complementary methods.*

I. Introduction

1.1 Background of the Study

The wastewater treatment will continue to be critical to the safety of environmental integrity as well as public health. With cities still growing at a tremendous pace and commercial industries like the beauty industry on the rise, there is also expected to be a high growth rate in wastewater generation. The growth of beauty salons is likely to lead to high discharge of toxic pollutants, including synthetic dyes, heavy metals, and organic chemicals from a wide range of hair and beauty chemicals. If left untreated, such pollutants will lead to water turbidity, aquatic toxicity, and production of stench, hence ultimately posing threats to local water bodies and public health (Periyasamy, 2024).

In areas with development issues, weak policy enforcement will likely worsen these problems (Samudro et al., 2023). In Zamboanga City, while the Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB) is implementing measures to improve environmental quality, enforcement gaps are likely to continue impacting wastewater management. Left unchecked, water pollution and its related public health hazards are likely to worsen (Ndinda et al., 2024). To address this problem, cost-effective, innovative, and sustainable treatment technologies are urgently needed that can easily be adopted by local communities.

The use of cost-effective natural adsorbents is becoming more and more under consideration as a sustainable method for wastewater treatment (Kaur & Kumar, 2019). Agricultural waste materials, such as banana peelings (*Musa balbisiana acuminata x BBB group*) and young coconut exocarp (*Cocos nucifera* L.), have been reported to be useful for the removal of pollutants (Waseem & Khan, 2020). Studies suggest that the high cellulose content of banana peelings and the fibrous nature of the coconut exocarp will enhance their ability to adsorb heavy metals and organic dyes from polluted water sources (Periyasamy, 2024). Due to their low cost and eco-friendliness, the above materials can be a viable candidate for sustainable wastewater treatment technologies.

This study aimed to establish the adsorption capacity of *Musa balbisiana acuminata x BBB group* peelings and *Cocos nucifera* L. exocarp towards particular contaminants of beauty parlor wastewater. From the consideration of adsorption behavior of these agricultural by-products, this study will allow for the progress of work towards the formulation of environmentally safe treatment processes. The findings provided valuable insight into the practicability of applying natural adsorbents towards the prevention of water pollution, especially in areas with limited availability of advanced wastewater treatment facilities.

1.2 Statement of the Problem

A variety of pollutants, including heavy metals, synthetic dyes, and organic contaminants, are always present in beauty salon wastewater. These pose major threats to both human health and environmental ecosystems that it is inevitable that these contaminants will increase water pollution if it's not appropriately treated. The conventional treatment of wastewater will be expensive and advanced in nature, hence not affordable for medium to small beauty salons (Thomas, 2016; Lima et al., 2023). The emerging problem will be likely to create a huge demand for affordable and environmentally safe alternatives that will be effective in removing impurities without causing negative environmental effects.

This study sought to evaluate the adsorption capacity of banana peel (*Musa balbisiana acuminata x BBB group*) and young coconut exocarp (*Cocos nucifera* L.) in the removal of wastewater generated in beauty salons. These natural adsorbents with high cellulose and lignin content have shown favorable potential in contaminant removal in earlier research. Through their ability in reducing Chemical Oxygen Demand (COD) and surfactant levels, this study attempts to explore a new, cost-effective approach for wastewater treatment. Findings are expected to help create environmentally friendly treatment options, especially for business establishments that are not connected to conventional wastewater treatment facilities.

1.3 Objectives

This research was centered on establishing the viability of banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera* L.) as cost-effective, environmentally friendly adsorbents in minimizing pollutants in beauty salon wastewater. More particularly, it sought to:

1. Determine the quality of beauty salon wastewater in terms of pH, COD, and surfactant concentrations.
2. Evaluate the potential of banana peelings and young coconut exocarp powder in adsorbing surfactants, reduce COD, and regulate pH levels in various proportions:
   a. Setup A: 100% young coconut exocarp
   b. Setup B: 100% banana peelings
   c. Setup C: 50-50 combination of young coconut exocarp and banana peels
3. Compare the performance of these natural adsorbents to commercial activated carbon filters according to the DAO 2016-08 Class C Classification standards.

1.4 Significance of the Study

By evaluating the adsorption capacity of banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) for the removal of selected contaminants from beauty salon wastewater, this study contributed significantly to environmental protection (Ngeno et al., 2022). The use of these agricultural waste materials as natural adsorbents not only demonstrated an effective and eco-friendly approach to wastewater treatment but also promoted sustainable waste management practices. Their affordability and availability made them a viable alternative to conventional treatment methods, particularly for small and mid-sized salons with limited access to advanced wastewater treatment facilities (Ouettar et al., 2023). Furthermore, this research laid the groundwork for future studies on the potential of other agricultural by-products as cost-effective adsorbents, fostering innovation in sustainable water treatment technologies. By advancing knowledge in environmental science and engineering, this study contributed to the development of practical solutions for mitigating water pollution. Ultimately, its findings supported the promotion of healthier ecosystems, encouraged resource recovery from agricultural waste, and reinforced the importance of sustainable practices in wastewater management (Ogidi & Tawariowei, 2024).

1.5 Scope and Delimitations

This study was focused on the utilization of powdered banana peelings *Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) to evaluate their potential as low-cost, eco-friendly adsorbents for the removal of selected contaminants from beauty salon wastewater. Various proportions of these natural adsorbents were tested to determine their adsorption efficiency. Specifically, three different formulations were prepared: 50 g of banana peelings, 50 g of young coconut exocarp, and a combined mixture of 25 g of each. The adsorption performance of these materials was compared against conventional treatment methods such as activated carbon filtration, following the DAO 2016-08 Class C Classification standards for water quality.

The experiments were performed under a controlled laboratory setting using standardized samples made to utilize the beauty salon wastewater and accounting for potential variability of the actual contaminant concentration in natural settings. Only three significant water quality parameters—surfactants, COD, and pH values—were tested as they are the foremost markers of contamination in beauty salon effluents. Other contaminants that may exist were not given any consideration.

In order to evaluate the banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) adsorption efficacy, a single influent sample was analyzed for the duration of the study while corresponding effluent samples were gathered and analyzed simultaneously. Two secondary analyses were likewise conducted after an interval of five days to follow the changes within time. The wastewater samples were collected every hour for three consecutive days with an allotted contact period of one hour per test.

II. Review of Related Literature

With the expanding environmental concern about the ill-use of beauty parlor wastewater discharge, cost-saving and environmentally friendly treatment technology will be increasingly addressed through studies. Among such avenues, application of natural adsorbents such as banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera* L.) is particularly promising based on their cheapness, degradability, and high affinity to adsorption. These plant by-products are anticipated to be efficient in removing other impurities, such as surfactants, heavy metals, and organic compounds—typical salon wastewater contaminants. This chapter discusses current literature on the process of adsorption, with particular assessment of the possibility of banana peelings and young coconut exocarp in enhancing beauty salon wastewater treatment.

2.1 Population

Population increases and growing interest in personal care are driving the beauty salon industry's expansion. However, this increase results in more wastewater that is contaminated with chemicals and poisons, which is detrimental to our ecosystem. Since salons serve diverse clients with varying hair types, beauty standards, and treatment options, the wastewater from salons gets more complicated (Smith, 2021; Johnson & Lee, 2020). Millennials and young adults are driving this demand, seeing beauty treatments as part of a lifestyle rather than a regular maintenance activity (Taylor et al., 2019). Yet, increasing salon activity comes with increased wastewater pollution, making sustainable treatment more important than ever.

The treatments individuals select in salons directly affect the nature and quantity of wastewater generated. Women, for instance, tend to have more treatment options, including hair coloring and facials, putting more chemical contaminants in wastewater (Williams & Parker, 2018). As more consumers demand gender-inclusive services, salons are modifying their services for non-binary and transgender customers, further blending the cocktail of pollutants (Harrison et al., 2022). Salon wastewater thus has a broad variety of pollutants, ranging from synthetic dyes, surfactants, to organic compounds—all of which require efficient treatment. There is also a strong contribution from socioeconomic elements in the generation of salon wastewater. High-income consumers spend more time at salons and receive more complex treatments, including chemical-intensive processes (Brown & Thompson, 2020). Low-income consumers, in contrast, may use salons less frequently or choose home-based treatments, resulting in lower wastewater output from low-income communities (Reed, 2021). Understanding these trends can assist in the development of wastewater treatment methods that suit the unique requirements of various salon types.

As the population continues to age, preferences for salon services also change. Aging consumers require treatments focused on graying or thinning hair, with many treatments comprising specialized chemical treatments that contribute to wastewater pollution (Lewis, 2022). In response to these environmental factors, more salons are adding sustainable methods of operation, like the use of natural, biodegradable substances to reduce pollution (Williams, 2022). Consumer preference is also transforming, with customers increasingly asking for organic and environmental-friendly beauty services. Numerous salons are nowadays focusing on sustainability through transitioning to greener products and developing new wastewater treatment techniques. One of these is the utilization of natural adsorbents, including banana peels *(Musa acuminata x balbisiana BBB group)* and immature coconut exocarp (*Cocos nucifera* L.), which have been found to have high adsorption capacities for contaminants typically present in salon wastewater (Falco & Egan, 2021). These materials are not only efficient but also inexpensive and easy to acquire, making them a cost-effective substitute for traditional treatment options.

Technology has also changed the contemporary salon experience. Artificial intelligence, online booking apps, and virtual consultations are some of the digital tools that have increased access and tailoring of salon services (Gasenko, 2024). Yet, as salons embrace new beauty technologies, they also add new kinds of pollutants to their wastewater streams, increasing the need for cutting-edge treatment solutions (Roberts & Chang, 2022). Salons adopting green wastewater management—e.g., through the application of agricultural waste-based adsorbents—will not only decrease their environmental footprint but also enhance their brand credibility and competitiveness. With growing environmental consciousness regarding salon wastewater, this research emphasizes the critical need for efficient and eco-friendly treatment measures. By determining banana peelings and young coconut exocarp adsorption capacity, this study is intended to present a pragmatic, environmentally friendly method for treating salon wastewater, promoting public health as well as environmental preservation.

2.2 Local Studies

Many studies have ventured into the Philippines, examining some agricultural by-products such as banana peels and coconut husks as low-cost, alternative, and sustainable materials in wastewater treatment. This study showed that these natural adsorbents have a very high capacity for removing contaminants from wastewater and are, therefore, ecologically sound alternatives for conventional treatment.

Afolabi et al. (2020) investigated, in one study, the potential of coconut husks and banana pseudostems to filter lead (Pb) from wastewater in mines. The findings were encouraging—single-sheet banana filters removed 35.12% of Pb, whereas double-sheet filters removed a greater percentage of 43.23%. Coconut husk filters also removed 32.44% to 35.12% of lead. The research explained that these findings were due to the high lignocellulosic nature of these materials, which is very efficient in adsorbing metal ions.

At the same time, Reddy et al. (2020) studied the potential of banana peel powder to eliminate nitrates and phosphates from model pond water in a pilot-scale ceramic clay filtration setup. In their results, the most efficient filter was with 30% banana peel powder, which brought down the nitrates to 3.6 mg/L and phosphates to 3.1 mg/L. Statistical analysis proved that variations in the removal of contaminants from the different treatments were significant and highlighted banana peels as an effective natural adsorbent.

Another research by Legiso et al. (2024) aimed to desorb chromium (Cr^{2+}) from laboratory wastewater with activated carbon prepared from rice husks and banana peelings of *saba*. Chromium desorption rates for banana peel-based activated carbon and rice husk-based activated carbon were 21% and 61%, respectively. Surprisingly, when the two materials were mixed at a 3.33g-to-6.67g ratio, the efficiency was 64%. This was believed to be due to interaction between C-O and O-H bonds that altered surface area available for adsorption.

All these studies bring out the possibility of using banana peels and coconut husks for cheap, environment-friendly solutions to wastewater treatment. Application of these materials for the treatment of wastewater from beauty salons may even prove to be revolutionary since it may be a real-time solution to pollutant reduction while recycling agricultural waste.

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2.3 Foreign Studies

World scientists are probing agricultural residues—banana peel, coconut husks—for wastewater management solutions that are inexpensive and sustainable. These studies continuously emphasize the amazing ability of these natural materials to remove pollutants from contaminated water and offer a feasible green alternative to traditional methods.

For example, Daverey et al. (2019) explored how natural coagulants derived from plants, such as banana peel powder, could enhance municipal wastewater treatment. Their results indicated that banana peel powder absorbed a maximum of 59.6% turbidity with an optimum dosage of 0.4 g/L. The authors credited the efficacy to the availability of functional groups like carboxylic acid, hydroxyl, and aliphatic amines, which neutralize impurities in water through coagulation and flocculation.

Brown et al. (2025) had a different solution, trying brown coconut husks as a filtration material in an anaerobic filter for on-site wastewater treatment. They found the results to be encouraging with the filter capable of removing as much as 68% COD. There was some initial leaching of phosphorus and nitrogen, but they were flushed out very quickly, limiting their contribution to effluent quality. Even after 10 months of constant usage, the coconut husks were still intact, demonstrating their durability as a long-term filter material.

Halfhide et al. (2019) set out to investigate nutrient removal using spent coconut husks. They established that thermally activated carbon from coconut husks can be successfully applied to nitrate (NO_3^--N) and phosphate (PO_4^{3-}-P) removal in wastewater. Thermal activation at 450°C increased the husks' adsorption capacity, which made them an economical substitute for traditional activated carbon.

Coupled, these overseas researches bolster the viability of banana peels and coconut husks as potential, natural adsorbents to treat wastewater. Utilizing them in beauty parlor wastewater treatment could pave the way for an environmentally friendlier, more sustainable method of processing pollutants while reclaiming agricultural refuse.

2.4 Beauty Salon Wastewater

Beauty parlor wastewater is a mix of pollutants, full of everything from hair color chemicals to heavy metals. With a combination of organic compounds, synthetic materials, and other byproducts, this wastewater isn't only an environmental issue—it's also a public health risk. Research has repeatedly demonstrated that unless salon effluents are treated, they can pollute nearby water bodies, killing aquatic life and deranging ecosystems. That makes discovering successful treatment strategies more critical than ever.

Most of this wastewater comes from common salon activities like hair washing, coloring, and chemical treatments. These processes release all sorts of contaminants, including ammonia, surfactants, hair residues, dyes, and heavy metals (Kumar et al., 2019). Because these pollutants interact in complex ways, basic filtration isn't enough—we need targeted treatment solutions to prevent long-term damage to water sources (Jones et al., 2021).

Salon wastewater's mixed composition, with a combination of pollutants like ammonia, dyes, and heavy metals, demands treatment procedures of a specific nature to effectively reverse environmental harm. Treatment failure, if wastes of this nature are not ideally treated, can negatively affect water and soil quality and even environmental and public health risks (Nzedinma et. al, 2024). Salon wastewater is alkaline in nature with a mean pH of 9.55 ± 0.42. COD and BOD are high with mean values of 60.04 ± 1.82 mg/L and 30.03 ± 9.11 mg/L, respectively. Dissolved oxygen values were very low with a mean value of 3.00 ± 0.53 mg/L. Nutrient concentration such as nitrate and phosphate is very high in the waste effluent of a salon. It has a mean nitrate concentration of 5.42 ± 0.36 mg/L and phosphate concentration of 23.61 ± 0.16 mg/L. Turbidity is equal to 20.29 ± 3.86 NTU, TDS to 1150.25 ± 262.10 mg/mL and EC to 1404.89 ± 114.11 μm/S. The wastewater alkalinity is 70.88 ± 2.59 mg/L, whereas acidity is 1.70 ± 0.01 mg/L. Such values along with the presence of chemicals and bacteria point out clearly to the periodic check and proper treatment practices needed (Nkansah et al., 2016).

Improper disposal of salon wastewater has serious consequences. Studies indicate that untreated effluents have the ability to impair water quality and endanger aquatic systems (Nguyen et al., 2020). Some of the synthetic chemicals being introduced into these wastewaters change natural processes resulting in stains that propagate in the environment (Smith & Lee, 2018). In order to counter such trends, regulations have been set by environmental authorities like the Environmental Protection Agency (EPA), establishing guidelines to be followed in treating wastewater prior to discharge (EPA, 2021). Following these guidelines not only preserves the environment but also promotes public health and encourages salons to employ better waste management techniques (Brown & Thomas, 2020). Nevertheless, though big enterprises can perhaps sustain compliance, small enterprises cannot always purchase expensive treatment equipment, prompting the demand for more cost-effective alternatives (Gopalakrishnan et al., 2023).

Some conventional wastewater treatment technologies—like membrane bioreactors, activated carbon filtration, and bioremediation—have been effective in eliminating pollutants (Choudhury et al., 2022; Fernandez et al., 2019). These methods, however, often stand with high capital equipment cost and infrastructural investments, rendering them unviable for most salons. Therefore, this is looking for alternative, cheap, and sustainable methods.

A potential method is reusing and recycling treated wastewater. Salons have already begun redirecting their treated wastewater to non-potable use such as irrigation or cooling, lowering both disposal and freshwater consumption (Rana et al., 2021; Patel et al., 2020). Case studies provide evidence of how the incorporation of water-conservation technologies and neighborhood recycling schemes lowered wastewater production with reduced total water consumption (Hawkins & Patel, 2023; Lopez et al., 2021).

Apart from technology, raising awareness is another major driver. Informing salon owners and clients of the environmental consequences of salon wastewater can fuel demand for sustainable products and services (Morris & Scott, 2022; Carter et al., 2023). When individuals realize the effects of inappropriately disposed waste, they are more likely to adopt sustainable practices.

Given all of this, it is quite apparent that effective, cost-saving, and environmental wastewater treatment strategies are in need. That is the purpose of this study. This study investigated the application of natural adsorbents—namely banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*)—in removing contaminants from beauty parlor wastewater. Both of these crop by-products possess high adsorption capacity and thus present an eco-friendly solution compared to standard treatments. By leveraging the potential of such natural materials, this study has the objective to offer a cost-effective, environmentally friendly means to enhance water quality and mitigate pollution.

2.5 Traditional Methods of Wastewater Treatment

Wastewater treatment is crucial to protecting water resources and human health. Traditional methods often integrate physical, chemical, and biological processes to remove contaminants. Physical processes such as sedimentation, filtration, and flotation serve as preliminary treatments to eliminate large particles and suspended solids. Chemical treatments employ coagulants, flocculants, and disinfectants to neutralize harmful chemicals and pathogens present in the effluent (Ahmed et al., 2021; Saleh et al., 2020; Musa & Idrus, 2021). Biological processes, including activated sludge systems, trickling filters, and biofilm reactors, utilize microorganisms to degrade organic pollutants, thereby reducing the overall contaminant load (Ahmed et al., 2021; Saleh et al., 2020).

Adsorption has emerged as a widely adopted method for removing organic pollutants from wastewater. This technique relies on adsorbents—ranging from activated carbon and zeolites to agricultural waste products—to capture contaminants through both physical and chemical interactions. Notably, organic adsorbents derived from natural materials, such as banana peelings and coconut exocarp, have attracted attention due to their cost-effectiveness, widespread availability, and environmental sustainability (Saleh et al., 2020; Kamarudin et al., 2021). The efficiency of adsorption depends largely on factors such as the adsorbent's surface area, pore size, and the presence of functional groups, all of which influence its capacity to bind contaminants like surfactants, heavy metals, and dyes (Kamarudin et al., 2021).

Despite their promise, organic adsorbents face challenges including limited adsorption capacity, difficulties in regeneration, and disposal issues. Ongoing research aims to enhance their performance through material modifications and the development of hybrid systems that integrate physical, chemical, and biological treatments (Kamarudin et al., 2021; Arni et al., 2019). Comparative studies have indicated that, under optimized conditions, organic adsorbents can perform as well as or even exceed the efficiency of conventional adsorbents like activated carbon in specific applications.

Beauty salon wastewater presents unique treatment challenges due to its complex composition. Generated primarily from hair washing, coloring, and chemical treatments, it typically contains organic and inorganic compounds—such as shampoos, conditioners, hair dyes, and various cosmetic chemicals—that contribute to high levels of biochemical oxygen demand (BOD) and COD (Nkansah et al., 2020). In addition to chemical pollutants, salon effluents often include heavy metals (e.g., lead and mercury), surfactants, and persistent organic compounds that are resistant to biological degradation. Furthermore, microbial contaminants pose significant risks as pathogenic bacteria thrive on the rich organic content, thereby demanding robust treatment protocols (Kamarudin et al., 2021).

Conventional treatment techniques—including sedimentation, filtration, and biological degradation—are sometimes inadequate for the complete removal of the diverse toxic substances present in salon wastewater. Advanced technologies, such as membrane bioreactor (MBR) systems, offer improved contaminant removal by combining biological treatment with membrane filtration (Yang et al., 2021). Similarly, constructed wetlands and water recycling systems, including graywater recycling, represent sustainable alternatives that can reduce freshwater consumption while meeting environmental discharge regulations (Carter et al., 2023; Patel et al., 2020; Lopez et al., 2021).

In this context, the development of organic adsorbents presents a promising approach for the treatment of beauty salon wastewater. Utilizing renewable, biodegradable materials such as banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) can not only enhance the removal of specific contaminants like surfactants, dyes, and heavy metals but also reduce reliance on non-renewable resources (Nikbeen & Nayab, 2023). These natural adsorbents may be regenerated or composted after use, thereby supporting circular economy principles. However, challenges such as variability in adsorption capacity and competition among adsorbates necessitate further research, particularly in optimizing pre-treatment methods and developing hybrid treatment systems to maximize long-term efficiency and cost-effectiveness (Bora & Dutta, 2014; Arni et al., 2019).

Given that wastewater treatment for salon is complex, organic adsorbents open promising possibilities. Chemicals like surfactants, colors, and heavy metals can be sustainably removed using organic materials such immature coconut exocarp (Cocos nucifera L.) and banana peels (Musa acuminata x balbisiana BBB group) (Nikbeen & Nayab, 2023). Given that such raw materials are cheap and bio-detergent able, and easy to acquire from the commonalities within surrounding environments, this reduces consumption dependency on unsustainable supplies. Furthermore, they can be re-grown or composted following use, with circular economy at heart.

Yet, as with any new technology, natural adsorbents have their challenges. Their performance is subject to variation based on pollutant concentration, water chemistry, and competition among various contaminants. Further research is required to optimize pre-treatment processes and investigate hybrid treatment systems that integrate adsorption with other methods for long-term efficiency and cost-effectiveness (Bora & Dutta, 2014; Arni et al., 2019).

As the salon beauty industry keeps expanding, the demand for proper wastewater treatment follows suit. Current methods can only accomplish so much, and advanced systems are too expensive and energy-hungry. Natural adsorbents, such as coconut husks and banana peels, are an attractive and green alternative. If optimized and studied further, these materials may prove to be very important in terms of making it more cost-efficient and sustainable to treat salon wastewater.

2.6 Natural Adsorbents in Wastewater Treatment

Treatment of wastewater is required to protect both the environment and public health. It uses a variety of techniques, mostly chemical, biological, and physical processes, to eliminate impurities. In essence, physical treatment involves the separation of big particles and suspended solids through sedimentation, filtration, and flotation. The biological processes that are triggered by biofilm reactors, trickling filters, and activated sludge systems mobilize microorganisms to break down organic pollutants and drastically reduce the total pollutant load (Ahmed et al., 2021; Saleh et al., 2020).

Adsorption has become one of the most practical techniques for eliminating organic pollutants from wastewater among various treatment approaches. Activated carbon, zeolite, and even agricultural waste are examples of adsorbents that are used in this process to collect contaminants through physical and chemical interactions. Natural adsorbents are gaining recognition in recent years for their low, widely available, and eco-friendly nature as banana peel and coconut husks (Saleh et al., 2020; Kamarudin et al., 2021). The capacity for adsorption depends mainly on the surface area of the material, pore structures, and chemical properties, which influence its pollutant capture ability (specially surfactants, dyes, and heavy metals) (Kamarudin et al., 2021).

Organic adsorbents are not without challenges, even with their promise. Low adsorption capacity, regeneration challenges, and disposal issues may limit their widespread use. Scientists are ongoing working to better these materials through reinforcing their structure and combining them with other technologies of treatment (Kamarudin et al., 2021; Arni et al., 2019). Optimized natural adsorbents were in some research shown to equal—and sometimes better—conventional adsorbent materials such as activated carbon.

Beauty salon wastewater is a complex form of waste which is difficult to treat due to multiple contaminants. Most of this wastewater comes from the beauty procedures of washing hair, coloring, and treating with chemicals. In fact, a mix of organic and inorganic contains these wastewater pollutants like shampoos, conditioners, dyes, and the other chemicals in cosmetics. These organics lead to high BOD and COD (Nkansah et al., 2020). Salon effluents may also contain lead and mercury as heavy metals, besides surfactants and persistent organic pollutants which are not easily degradable. The presence of microbial contaminants adds to the problem, as bacteria thrive much in the nutrient-rich effluent, thus requiring robust treatment methods (Kamarudin et al., 2021).

These conventional treatments such as sedimentation, filtration, and biological degradation can treat some of the pollutants, but they are not all-completely effective for the pollutants traditionally found in hair salon waste. Membrane bioreactor (MBR) technology has come into play in combining biological treatment and membrane filtration technologies to improve contaminant removals (Yang et al., 2021). Constructed wetlands and graywater recycling systems are some of the other sustainable options that reduce water consumption and satisfy environmental discharge regulations (Carter et al., 2023; Patel et al., 2020; Lopez et. al., 2021).

As the salon beauty industry keeps expanding, the demand for proper wastewater treatment follows suit. Current methods can only accomplish so much, and advanced systems are too expensive and energy-hungry. Natural adsorbents, such as coconut husks and banana peels, are an attractive and green alternative. If optimized and studied further, these materials may prove to be very important in terms of making it more cost-efficient and sustainable to treat salon wastewater.

2.6.1 Banana (Musa acuminata x balbisiana BBB group) Peelings

Cconsidered a staple of the tropics, even more so in Southeast Asia and the Pacific, the *Musa acuminata x balbisiana* hybrid, popularly called the Saba banana, is durable and adaptable to a far range of environmental conditions (Bagabaldo et al., 2022). In contrast to dessert bananas, Saba bananas are bigger with thicker skins that change color from green through to yellow—occasionally reddish or brownish—when they mature (Bagabaldo et al., 2023). Aside from their uses in agriculture and food, Saba bananas offer promise in sustainable environmental purposes, with great potential in wastewater treatment.

The fibrous texture of banana peels and their abundance of bioactive chemicals make them an excellent option for adsorption-based water treatment. Peels are typically discarded. In terms of chemistry, they are abundant in vitamins (especially vitamin C), dietary fiber, antioxidants, and vital minerals. Their structure is rich in cellulose, hemicellulose, lignin, and pectin—substances that provide a strong framework for pollution removal—but their composition varies with ripeness (Estribillo et al., 2022). These natural properties make banana peels a resourceful material above food uses, especially for industrial and ecological purposes.

A lot of research works validated the possible use of banana peelings as a biosorbent for treating wastewater pollutants. Omar et al. (2022) discovered that banana peel powder was able to efficiently removes lead and cadmium from aqueous solutions; and Anggraini et al. (2023) demonstrated that banana peel could absorb methylene blue dye. Both findings underscore the broad application potentials of banana peels in variable forms of contaminants.

Apart from heavy metals and dyes, activated carbon produced from banana peel has been shown to be effective in eliminating more recalcitrant pollutants. Akpomie and Conradie (2020) found no discrepancy in the removal efficiencies of both banana peel-originated activated carbon and commercial activated carbon as far as chromium and lead are concerned. Also, they observed that banana peels significantly reduced biological oxygen demand (BOD) in municipal wastewater, thus promising better water quality.

In fact, the most important advantage of using banana peels as adsorbents for treating wastewater is that they are cost-effective. As an agricultural waste product, they are plentiful and cheap, thus an economical substitute for synthetic adsorbents (Gumban et al., 2024). Their local availability in tropical areas also reduces the costs of transportation and processing and provides economic benefits to local communities by converting waste to value-added product (Khan et al., 2019).

There are, however, limitations such as change in chemical composition of banana peel being due to different environmental factors like soil and climatic conditions which will affect the adsorption capacity (Kumar et al., 2016; Buwono et al., 2018). They have shorter lifetimes when compared to conventional adsorbents, which could create the need to constantly replace them. It therefore necessitates conducting more research on pre-treatment methods and modifications that can enhance performance and durability.

Beauty salon wastewater treatment is especially controversial, being a combination of organic compounds, heavy metals, dyes, and synthetic chemicals. Nevertheless, it has been reported recently that banana peelings could be an option of such effluents. Ashka et al. (2023) and Bishnoi et al. (2023) reported that banana peel adsorbents were efficient in dye, heavy metal, and organic pollutant removal from beauty salon wastewater. Gupta et al. (2023) also found that banana peels provide an eco-friendly substitute to synthetic adsorbents in dealing with contaminants commonly found in salon effluents.

In addition to adsorption, banana peels may also promote coagulation and sedimentation of contaminants in waste effluents. The study carried out by Azamzam et al. (2024) revealed that banana peel powder would bring an improvement in suspended particle removal, which reduces turbidity and results in clearer water overall. This strengthens further the case for banana peel-infused multifunctional, sustainable treatments in wastewater treatment. Saba banana peelings (*Musa acuminata x balbisiana*) are quite abundant in their natural occurrence and have great potential as a bioadsorbent for the treatment of wastewater. These are biodegradable, environmentally well-balanced in their use, and do not generate by-products that might be health hazardous.

2.6.2 Young Coconut (Cocos nucifera L.) Exocarp

Cocos nucifera, the coconut palm, is one of the most highly valued tropical crops worldwide, valued for its multipurpose uses (Souza et al., 2024). This tree reaches a maximum height of thirty meters and produces very large, fiber-covered fruits that undergo a color change as they develop: from green at earlier stages to brown when perfectly matured (Akter et al., 2023). The coconut consists of three layers: the exocarp (the smooth outer skin), mesocarp (the fibrous husk which is also called coir), and the endocarp (which forms the hard shell enclosing the seed). The exocarp has recently attracted some attention as a potential eco-friendly wastewater treatment material, especially from young coconuts, in addition to the consumption of coconut water and copra (the white flesh inside).

The exocarp of a young coconut is defined as the thin, protective outer covering of the fruit, smooth and green when immature, maturing to yellow or brown (Anwar et al., 2024). Though quite thin when compared with the husk, the exocarp possesses a unique fibrous structure and porosity that make it into an interesting adsorbent for pollutants. Thus, its primal function within nature is protection of the inner fruit body from environmental hazards, such as pests, pathogens, or physical damage (Warzukni et al., 2022); however, studies have found that it does much more.

In chemical composition, young coconut exocarp has a prominence of organic compounds, namely cellulose, hemicellulose, and lignin, which are highly regarded for their structural stability and adsorption potential (D'Agostino et al., 2021). It has minerals such as potassium, calcium, and magnesium, as well as phenolic compounds and antioxidants, all of which further add to its ability to bind pollutants (Mazumder & Zhang, 2023; Leliana et al., 2022). These properties provide the exocarp of young coconuts with a natural edge in removing contaminants found in wastewater.

Few studies showed the promising performance of young coconut exocarp for natural adsorbent purposes. According to D'Agostino et al. (2021), it could remove more than 90% of lead and cadmium under optimal conditions. Similar findings by Leliana et al. (2022) indicate that it can remove organic dyes like methylene blue and rhodamine B from wastewater. Such findings support the idea of coconut exocarp being a natural, powerful, and sustainable tool for water purification.

Various researchers showed the efficiency of young coconut exocarp in purging pollutants in wastewater. For instance, D'Agostino et al. (2021), in *"Adsorptive Performance of Young Coconut Exocarp for Heavy Metal Removal: An Experimental Study*," reported removal efficiencies of above 90% lead and cadmium under optimal conditions. Leliana et al. (2022) also observed the potential of young coconut's exocarp as an adsorbent for dyes in "*Kinetic Study on the Adsorption of Organic Dyes Using Young Coconut Exocarp*". The research concluded that adsorbent performance was largely influenced by pH, contact time, and concentration of the pollutants.

One of the most viable uses of young coconut exocarp is its application for the treatment of beauty salon wastewater, which is typically a blend of organic compounds, heavy metals, and synthetic chemicals. Due to its natural abundance, biodegradability, and low cost, coconut exocarp presents a viable alternative to costly synthetic adsorbents such as activated carbon (Mazumder & Zhang, 2023; D'Agostino et al., 2021). Moreover, utilizing coconut waste in this manner supports the principles of a circular economy by converting agricultural by-products into valuable environmental solutions (Leliana et al., 2022).

Though it has numerous benefits, the application of young coconut exocarp in wastewater treatment has some drawbacks. The material's chemical structure can change with environmental conditions, which might influence its adsorption ability (D'Agostino et al., 2021). Secondly, processing techniques such as drying and grinding need to be optimized to ensure a consistent level of performance (Mazumder & Zhang, 2023).

To overcome these limitations, scientists have been exploring methods of increasing the material's adsorption potential. Vieira et al. (2024) demonstrated that introducing metallic ions to young coconut exocarp enhanced its potential for adsorbing targeted pollutants in real-world wastewater streams significantly. Such modifications can be highly effective in treating beauty salon wastewater, which tends to have recalcitrant pollutants such as phenolic compounds and surfactants (Vieira et al., 2024).

Young coconut exocarp has proved to offer a good, sustainable, cost-effective alternative for the effective treatment of waste water. Its natural composition is a high adsorption buffer and widely available; hence, it becomes an environment-friendly remedy to water pollution scourge. Although there are further hurdles to be crossed, such as the improvement of processing techniques and efficiency of treatment, ongoing research shows that this lowly coconut by-product may realize great improvements in greener waste water technologies.

2.7 Related Readings

In light of the growing concern about wastewater pollution, researchers have been in search of cheap, natural materials for industrial effluent treatment. Among them, young coconut exocarp and banana peels have been discovered to be promising alternatives owing to their superior adsorption capacities. Some of those treatments involve the utilization of banana peels and coconut husk, which were being looked into because of their good adsorption properties. These agricultural wastes have the presence of key chemical components such as lignin, cellulose, and hemicellulose and functional groups with hydroxyl (-OH) and carboxyl (-COOH) that may bind and remove pollutants. Various research works have demonstrated the potential of these adsorbents for the treatment of wastewater, especially beauty salon wastewater, which contains surfactants, organic materials, and heavy metals.

Water-soluble heavy metals such as lead (Pb) or chromium (Cr) are also being retained into the banana peels from wastewater bodies. Another tier of research conducted by Tariq et al. (2024) shows that the incorporation of banana peel powder into the ceramic filtration module substantially lowered nitrates and phosphate from water, and this emerges as a good candidate for wastewater treatment.

The internal structure of such materials has numerous sites of binding with impurities. Research conducted by Akpomie and Condradie (2020) demonstrated that lignocellulosic compounds, specifically hydroxyl and carboxyl functional groups, have a very significant role to play in dye adsorption, organic contaminants, and heavy metals. Further, it has been demonstrated that the banana peel powder, which was modified, can effectively decrease surfactants and COD in industrial waste (Abd-Talib et al., 2020). Hence, it becomes a candidate for treating the wastewater from beauty salons, which tend to contain artificial chemicals from conditioners, shampoos, and hair dyes.

Like banana peel, young coconut exocarp has been recognized as a good biosorbent with the same fibrous structure and high lignin content. The coconut husk with similar lignocellulosic constituents had been tested for use in wastewater treatment. In one study by James and Yadav (2021), coconut husk filters significantly reduced COD and suspended solids in wastewater. In addition, activated carbon derived from coconut husks has been shown to effectively remove dyes and organic pollutants, making it a viable option for wastewater treatment from beauty salons.

Luis-Zarate et al. (2018) indicated that coconut-derived adsorbents show high affinity to organic pollutants, particularly surfactants and COD. Similarly, Bhatnagar et al. (2020) reported excellent pollutant removals when coconut husk and exocarp were utilized in wastewater treatment. Young coconut exocarp, being biodegradable and naturally occurring, presents a promising sustainable option for the treatment of industrial wastewater.

Although activated carbon is the norm in wastewater treatment because of its high adsorption rate, its expense keeps it from being used extensively. Thankfully, research has indicated that natural adsorbents are equally effective but much cheaper. Dehghani et al. (2023) have discovered that natural adsorbents, when modified, are as good as activated carbon, particularly when a combination of more than one material is employed.

Fouda-Mbanga et al. (2024) analyzed the impact of the simultaneous utilization of multiple adsorbents and concluded that composite materials are better adsorbents due to heterogeneity of the functional groups and varied porosity. This, in turn, means that synergy of banana peels and young coconut exocarp can serve as a better adsorbent for the treatment of pH imbalance, COD levels, and surfactant concentration of beauty salon wastewater.

The application of agricultural waste products for wastewater treatment is in accordance with international sustainability objectives. Ahmad (2023) highlighted that the application of natural adsorbents not only offers an environmentally friendly option to chemical application for wastewater treatment but also minimizes waste treatment and disposal costs. With their potential application on a large scale in local communities and industries, these materials can be key to achieving sustainable wastewater management. The study reviewed offers strong evidence that banana peel and young coconut exocarp are effective in decontaminating wastewater. Their ability to reduce pH imbalance, COD, and surfactant concentration suggests that they can be employed as effective alternatives to conventional methods. However, further studies need to be carried out to enhance their adsorption abilities and explore possible modifications to make them more effective in real-world applications.

2.8 Comparative Studies of Adsorbents

The determination of economically sound and sustainable processes for wastewater treatment has become a growing concern. Studies suggest that natural adsorbents such as fruit peels, plant fibers, and agricultural waste products can be a potentially beneficial substitute for conventional materials like activated carbon. While activated carbon is highly effective, it comes with high expenses and sustainability concerns as well. Thus, much research has been done to compare natural adsorbents with promising results in pollutant removal.

Patel et al. (2019) compared neem tree bark, cotton, and orange peels with activated carbon for wastewater treatment. The natural adsorbents, especially tree bark and cotton, were adequate at significantly less cost, although activated carbon had the highest adsorption efficiency. The other example is of Arshi Khan (2024), who focused on peanut hulls, coconut husks, and sugarcane bagasse which are cost-efficient and biodegradable in heavy metal removal. On the other hand, Adarsh et al. (2023) proved that even industrial by-products, such as fly ash and wood ash, may significantly bring down contaminants from wastewater like BOD, COD, TDS, and TSS, hence proving their potential as possible substitutes for large-scale use.

Adsorption is one of the processes of capturing contaminants on the surface of a material, thus it turns out to be among the more widely places application methods in treatment water. Chen and Li (2018) explain different physical forms of adsorbent powders, granules, and fibers based on field applications. This advanced porosity and high surface area of adsorbents like activated carbon creates effectiveness in capturing pollutants, making them an attractive option for saving in terms of water and air purification.

Activated carbons and zeolites-have been most studied adsorbents owing to their well-developed pore structures. According to the finding of Li et al. (2022), activated carbon undergoes surface areas of 500-1500 m2/g, and is very effective in the removal of large varieties of contaminants. The other side of the coin is that zeolites have high cation exchange capacity, and they are known for heavy metal and ammonia removal (Aslani et al., 2023). The fact that these adsorbents are both effective and did not aid man at the expense of nature has necessitated the search for alternatives in the natural environment.

Biomass-based adsorbents like peanut shells, sawdust, and fruit peels give an ecological solution to wastewater treatment. Raikar et al. (2015) noted that the porosity of natural adsorbents is often less than that of activated carbon, yet these biomass-based materials are renewable and cheap, making them attractive for large-scale applications. Research also looked at the challenges of using activated carbon, which is extracted from nonrenewable sources and consumed vast amounts of energy to regenerate (Zhao et al., 2023); hence, the trade-off between efficiency and sustainability fuels the interest of using agricultural waste materials for wastewater treatment.

Different factors that impact adsorption effectiveness include temperature, pH, contact time, and adsorbent dosage. According to Kayan and Kayan (2021), adsorption processes proceed more efficiently at lower temperatures, while Minceva et al. (2008) have confirmed that pH is an important parameter in the efficiency of adsorption. In addition, the efficiency of natural adsorbents for the adsorption of pollutants may be improved through chemical or thermal modification. Recent research has determined the viability of natural adsorbents. Aslani et al. (2023) utilized an activated banana peel macro composite (ABPM) to purify river water, removing more than 90% turbidity, and also reducing BOD and TSS by notable amounts. In a similar fashion, Khader et al. (2021) discovered rice husks removed more than 90% of azo dyes from wastewater—barely short of activated carbon's 99.81% removal. The results indicate natural adsorbents are probably well-suited to be applied at a large scale, particularly where cost is the primary factor.

Chemical modification of natural adsorbents can also improve their performance. According to Li et al. (2022), activated carbon subjected to acid treatment bears improved adsorption capacity due to the increase in the number of hydroxyl and carboxyl moieties. Zhao et al. (2023) investigated hybrid adsorbents comprising mixtures of activated carbons and zeolites, hence increasing the variety of pollutants that could be absorbed from the aqueous phase into different adsorbents. These studies indicate the possibility of optimizing natural adsorbents for particular applications.

In the context of the research paper entitled "Preliminary Investigation on the Removal of Selected Contaminants from Beauty Salon Wastewater Using Banana (*Musa acuminata x balbisiana BBB group*) Peelings and Young Coconut (*Cocos nucifera* L.) Exocarp," the current line of research encourages the utilization of adsorbents derived from agricultural residues. Research involving banana peels (Aslani et al., 2023) and coconut husk (Arshi Khan, 2024) indicates their potency in contaminant removal, while comparative research (Patel et al., 2019) indicates that such materials can serve as effective, low-cost alternatives to conventional adsorbents. The recent thrust on sustainability further underscores the significance of exploring such natural materials as a means to treat beauty salon wastewater. Finally, although activated carbon is still the gold standard for adsorptive performance, natural adsorbents present a sustainable, economical, and efficient option. Through optimization, it is possible to create efficient wastewater treatment techniques that are compatible with ecological as well as economic objectives.

III. Methodology

This chapter details the experimental techniques and approaches used to evaluate the removal of selected contaminants from beauty salon wastewater using banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*). The section outlines the data gathering process, study location, research design, and the step-by-step procedure implemented to assess the adsorption performance as natural adsorbents.

3.1 Data Gathering

Data were gathered from peer-reviewed journals and technical publications that explained the utilization of agricultural waste in the form of banana peelings and coconut exocarp as adsorbents for the treatment of wastewater. Laboratory experiments were also conducted to test the adsorption capabilities of the powdered materials. Relevant guidelines and standards such as the DAO 2016-08 Class C Classification were used to compare the performance of these bio-adsorbents with the traditional treatment technologies.

3.2 Research Locale

The experimental study was conducted in Upper Cabatangan, Zamboanga City. The experimental study was conducted at Ilustrado's Residence, wherein the required

Argel Dhianey Aquino Ilustradon and Lizamyl R. Laping, "Preliminary Study on the Removal of Selected Contaminants from Beauty Salon Wastewater Using Banana (Musa acuminata x balbisiana BBB group) Peelings and Young Coconut (Cocos nucifera l.) Exocarp," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 8, Issue 2, pp. 203-230, 2025.

apparatus for adsorption experiments and observations were available. While, the laboratory analysis was conducted at Chempro Analytical Services Laboratories Inc. – Zamboanga Branch.

3.3 Research Design

A laboratory-based experimental design was adopted to investigate the adsorption properties of the natural adsorbents. A series of controlled adsorption trials were conducted using powdered banana peelings and young coconut exocarp in varying proportions. The experimental setups were as follows:

- Setup A: 100% young coconut exocarp
- Setup B: 100% banana peelings
- Setup C: A combination of 50% young coconut exocarp and 50% banana peelings
- Controlled Setup: 100% commercial activated carbon

Each setup was designed to treat one (1) liter of beauty salon wastewater, with the dosage for the natural adsorbents fixed at 50 mg per liter (or 25 mg each for the combined setup) to facilitate a direct comparison of adsorption efficiencies.

The framework of this study is presented in Figure 3.1.

3.4 Research Procedure

The research procedure comprised several sequential phases, as outlined below:

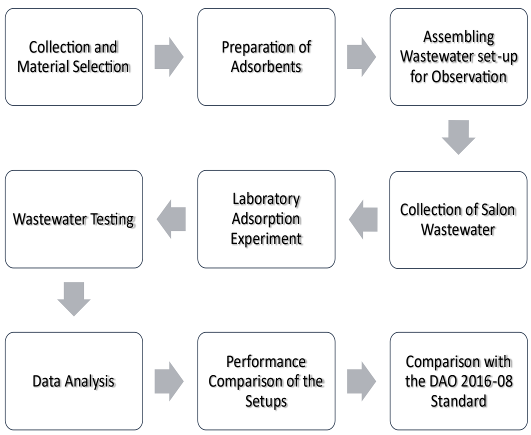

Figure 3.1. Research Study Process Flow

3.4.1 Collection and Material Selection

Young coconut exocarp (Cocos nucifera L.) and banana peelings (Musa acuminata x balbisiana BBB group) were purchased from local vendors in Barangay Sta. Maria, Zamboanga City, who sold buko juice and banana cues. Upon collection, the materials were separated, then sun-dried for approximately one week to reduce moisture content to about 10–15% as shown in Figure 3.2. The dried materials were subsequently ground into fine powder using a food processor to enhance the surface area for adsorption.

3.4.2 Preparation of Adsorbents

The dried banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) powders were further processed by sieving, using sieve number 4 (4.75 mm) to achieve a uniform particle size, which increases the availability of active adsorption sites. The prepared powders were stored in airtight containers to prevent moisture reabsorption and contamination until used in the experiments, see Figure 3.3.

Figure 3.2. First day of drying collected materials

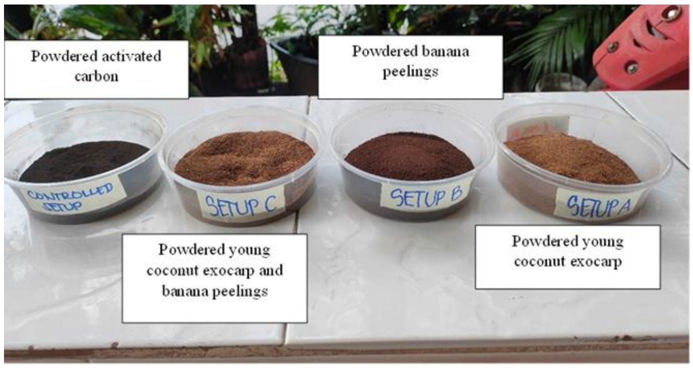

Figure 3.3. Ground powdered 100% activated carbon, 50% young coconut exocarp and 50% banana peelings, 100% banana peelings, and 100% young coconut exocarp

3.4.3 Laboratory Adsorption Experiment

This part outlined laboratory procedures that were used to determine the performance of banana (*Musa acuminata x balbisiana BBB group*) peelings and young coconut (*Cocos nucifera L.*) exocarp in the treatment of beauty salon wastewater. Salon wastewater was prepared to utilize the contaminant concentrations, mainly surfactants and COD. Additionally, weighed portions of each natural adsorbent were added to individual containers with predefined volumes of influent.

3.4.4 Collection of Salon Wastewater

Wastewater samples were obtained from Sir J SalonBarbers, a beauty parlor in Sta. Maria, Zamboanga City. To ensure the integrity and representativeness of the samples, 45 liters of wastewater was collected in a big, clean, and white container, as shown in Figure 3.4. From the collected volume, one (1) liter was carefully extracted and brought to Chempro Analytical Services Laboratories Inc. for baseline characterization. The initial analysis focused on key water quality parameters, including surfactant concentrations, COD, and pH levels. pH level was monitored in situ using the pH meter owned by the researcher.

Figure 3.4. Beauty Salon Wastewater Collection

On the same day, the wastewater was further analyzed after adsorption tests with various experimental setups. These setups—labeled as Setups A, B, C, and the Control Setup—each consisted of the treatment of the wastewater with adsorbent materials blended in accordance with predetermined ratios. The resulting water quality changes were then measured to determine the efficiency of the adsorption process in removing contaminants.

3.4.4 Assembling Wastewater Setup for Observation

Figure 3.5 shows the four (4) 1,000-ml laboratory beakers utilized in the experiment, each designated for one of the four test setups (Setups A, B, C, and the Control Setup). Each beaker contained one liter of beauty salon wastewater that was mixed with the assigned adsorbent(s) in calculated ratios.

Figure 3.5. Experimental Setups for Observation of Trial 1

3.4.5 Wastewater Testing

To assess the efficiency of the process of adsorption, a group of wastewater test processes was performed under standardized conditions. The experiments on adsorption were carried out with each trial having a one-hour contact time, on the four test setups (Setups A, B, C, and the Control Setup) where thorough mixing was achieved by means of a hand-held froth. This method allowed for even dispersion of the adsorbent and increased contaminant-adsorption medium interactions. Trial 1 was run on the same day for all three parameters when influent was analyzed, while trials 2 and 3 were run five days later. The surfactants and COD were done at the Chempro Analytical Services Laboratories Inc., while the pH monitoring was done in situ as shown in Figure 3.6.

Figure 3.6. Measuring the pH for Experimental Setups Across the Trials

The samples were analyzed to measure important physicochemical parameters of importance in measuring treatment efficiency. The main parameters that were measured were:

3.4.5.1 Surfactants

Several studies highlight the importance of eliminating surfactants from beauty salon wastewater to minimize environmental effects and operational challenges in water treatment plants. Research by Starov et al. (2020) discusses the environmental impact of synthetic surfactants, emphasizing their toxicity and persistence in water bodies. The study suggests replacing synthetic surfactants with biosurfactants to reduce ecological harm. Furthermore, excessive surfactants contribute to foaming issues in wastewater treatment, necessitating their removal to improve treatment efficiency.

3.4.5.2 COD

In beauty salon wastewater, COD is an important parameter that has been employed for determining the load of pollutants, both organic and inorganic in nature. Juliano and Magrini (2017) discuss how cosmetics from beauty salons contain dyes, hair treatments, shampoos, conditioners, lotions, and chemical by-products of numerous beauty products contribute to environmental pollution and have been identified as emerging contaminants due to their persistence, bioaccumulation potential, and impact on ecosystems. Most of these chemicals have a high COD, reflecting a lot of oxidizable pollutants.

3.4.5.3 pH Levels

pH Monitoring of beauty salon wastewater is essential in monitoring changes throughout the treatment process. Keeping pH at tolerable levels ensures the viability of the treatment system and conformity to environmental regulations. Beauty salons discharge various chemicals from dyes, bleaches, shampoos, and other products, significantly affecting wastewater pH. Research on industrial wastewater highlights the need for pH adjustments to neutralize these effects before treatment, ensuring that wastewater does not disrupt subsequent treatment stages (Smol et al., 2020). Frequent pH monitoring assists in making adjustments to ensure proper treatment efficiency and regulation compliance.

3.4.6 Data Analysis

The results from the adsorption experiments were gathered and examined. The efficiency of removal for every contaminant was calculated through comparison of the initial and final concentrations, which allowed for a comparative evaluation of the performance of the adsorbents.

3.4.7 Performance Comparison of the Setups

The efficacy of banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) was compared directly with that of commercial activated carbon. The comparison was based on surfactant and COD removal efficiencies, as well as pH levels, allowing an evaluation of not only the effectiveness of the natural adsorbents but also their suitability for long-term, sustainable use in wastewater treatment.

3.4.8 Comparison with DAO 2016-08 Standards

The treated wastewater samples were compared to the DAO 2016-08 Class C Classification standards. The end concentrations of surfactants, COD, and pH were analyzed and determined to check if natural adsorbents were successful in lowering contaminants to acceptable levels described in these guidelines.

IV. Results And Discussions

This chapter has shown the results and discussion of the study that examined the capacity of banana peelings (*Musa acuminata x balbisiana BBB group*) and the young coconut exocarp (*Cocos nucifera L.*) regarding adsorption of contaminants from beauty salon wastewater. The investigation focused on pH, COD, and surfactant concentration as quality indicators by comparing water before and after treatment.

There were three setups tested during experimentation. Setup A was the setup for young coconut exocarp at 100% concentration; Setup B was the setup for banana peelings at 100% concentration; and Setup C was a combined setup (50:50) for both adsorbents. A comparison was made against a control setup (Setup D), which used commercial activated carbon, and results were evaluated against the DAO 2016-08 Class C Classification standards.

4.1 Determining the Wastewater Quality of the Beauty Salon Wastewater

The influent wastewater sample collected from the beauty salon exhibited a pH of 7.08, a surfactant concentration of 8.88 mg/L, and a COD value of 7,652 mg/L. Table 4.1 contained the laboratory results for the influent wastewater sample collected at the beauty salon, listing three parameters: pH, Surfactant (mg/L), and COD (mg/L).

Table 4.1. Influent Laboratory Results of Beauty Salon Wastewater

Parameter	pH	Surfactant (mg/L)	COD (mg/L)
Influent	7.08	8.88	7,652

A pH value of 7.08, being near neutral, is desirable since it enhances the best possible operation of most biological and chemical treatment processes while minimizing the chances of equipment fouling and disruption of the environment (Akin, 2011; Zuwu et al., 2018). However, the influent's surfactant level of 8.88 and exceptionally high COD (7,652 mg/L) indicate significant organic pollution, which underscores the necessity for effective treatment methods to reduce these contaminants before discharge (Pal et al., 2022).

4.2 Evaluation of the Adsorption Capacity of Banana Peelings and Young Coconut Exocarp Powder with the Influent

Adsorption, which involves the adherence of contaminants to the surface of an adsorbent, is an effective mechanism for water treatment (Wang et al., 2024). In this study, the adsorption efficiency of banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) was assessed through a series of experiments over three trials. Table 4.2 summarizes the observed variations in pH, surfactant concentration, and COD across the four setups.

Table 4.2. Results of pH, Surfactant, and COD Measurements Across Three Trials in the Different Setups

Parameters	Test Method	Setups												Influent	DAO 2016-08 Effluent Standard
		A			B			C			D				
		1	2	3	1	2	3	1	2	3	1	2	3		
pH	pH Meter Portable Kit	7.72	7.04	6.94	7.43	7.38	6.91	7.50	7.09	6.80	7.12	7.01	6.93	7.08	6.0-9.0
Surfactant (mg/L)	Open Reflux/Titrimetric/SMEWW 52200 B	9.01	6.98	6.96	15.68	13.91	11.68	29.25	23.56	19.86	24.32	24.32	22.25	8.88	1.5
COD (mg/L)	Anionic Surfactants as MBAS/SMEWW 5540 C	5,034	4,832	3,222	13,507	7,151	6,356	11,521	9,932	7,548	8,740	7,548	7,151	7,652	100

4.2.1 pH

Table 4.3 shows the recorded pH for all trials for the various treatment setups. The differences in pH between setups observed can be attributed to the chemical composition of the adsorbents, the natural buffering property of the adsorbents, and the timing of sample analysis. Setup A was prone to higher pH readings than the other setups, except in Trial 2 when it recorded the lowest reading. This can be accounted for by the naturally occurring alkaline minerals in the young coconut exocarp, which include calcium, potassium, and magnesium, known to raise pH in aqueous solution (Periyasamy, 2024; Waseem & Khan, 2020). The minerals are weak buffering agents that neutralize acidity and are responsible for the slightly higher pH recorded in the majority of trials in Setup A.

Table 4.3. Results of pH Across Trials

pH Level	Setups			
	Setup A	Setup B	Setup C	Setup D
Influent	7.08	7.08	7.08	7.08
Trial 1	7.72	7.43	7.50	7.12
Trial 2	7.04	7.38	7.09	7.01
Trial 3	6.96	6.91	6.80	6.93

But lower-than-expected pH level of Setup A in Trial 2 indicates leaching of organic acids or the commencement of microbial degradation processes as shown in Figure 4.1.

Argel Dhianey Aquino Ilustradon and Lizamyl R. Laping, "Preliminary Study on the Removal of Selected Contaminants from Beauty Salon Wastewater Using Banana (Musa acuminata x balbisiana BBB group) Peelings and Young Coconut (Cocos nucifera l.) Exocarp," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 8, Issue 2, pp. 203-230, 2025.

Leachate formation is possible due to a characteristic of coconut in which lignin and cellulose start degrading with the lapse of time, particularly in humid air. These by-products like acetic and formic acids can lower the pH (Kaur & Kumar, 2019). Degradation of organic matter by microbial activity during longer contact period may have also been responsible. Temporal effects on analysis of the sample were a primary concern. For Trial 1, which had on-the-day analysis on the same day influent was received, Trials 2 and 3 were analyzed five days from treatment due to laboratory scheduling constraints and the lag in transporting samples. This duration was most likely introduced additional physicochemical and biological reactions, especially under untreated or less stable conditions, altering the pH reading. Delayed analysis would have introduced additional microbial degradation and exchange ion reactions, both of which have been known to affect the final pH (Samudro et al., 2023).

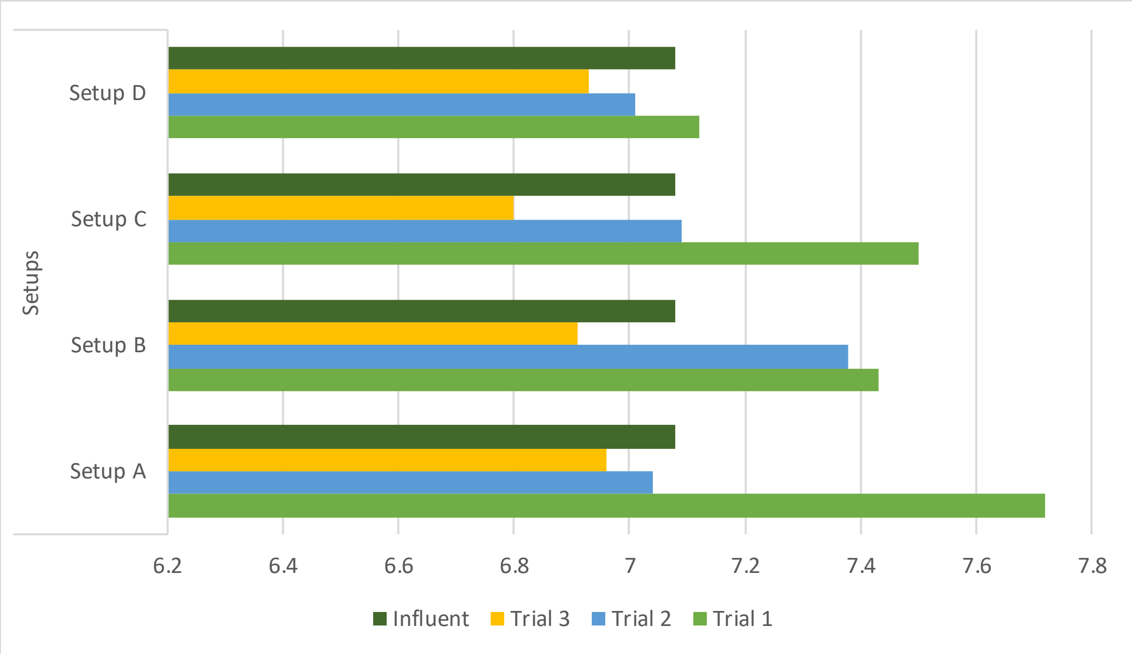

Figure 4.1. Analysis of pH Results Across Three Trials in Different Setups

Over the period, natural biochemical and microbial processes could have shifted pH levels. Microbial growth can lead to the production of acidic or basic end products based on what metabolic process is prevailing. Degradation of the organic matter could produce organic acids that would have accounted for the lowering of pH during Trial 2 for Setup A. Oppositely, ammonia formed or other alkaline reactions in Setup B could have accounted for the highest level of pH during Trial 2. Setup C (50% Banana Peelings & 50% Coconut Exocarp) exhibiting lower pH values (with the Exception of Trials 1 & 2), mixing banana peelings and coconut exocarp in Setup C resulted in lower pH values than in Setup A, possibly because there were more acidic ingredients from banana peels.

In Trials 1 and 2, Setup C with 50% young coconut exocarp and 50% banana peelings showed pH levels similar to or just above those found in Setup A. This can be explained by the initial leaching of alkaline minerals like calcium, magnesium, and potassium from the coconut exocarp that occurred early on, naturally buffering the wastewater conditions during the initial exposure (Waseem & Khan, 2020; Periyasamy, 2024). Later on, however, microbial activity became the predominant influence, particularly under the extended contact time seen in Trial 3. Such microbial processes have the potential to cause organic matter degradation and resultant release of acidic products, gradually decreasing the pH in subsequent trials (Kaur & Kumar, 2019).

Notably, Setup B had the highest pH in Trial 2. This is perhaps because the complex biochemical composition of banana peelings contains bioactive molecules like polyphenols, flavonoids, and amino acids that interacted with the wastewater matrix in a streatment because of laboratory scheduling, microbial degrading of the banana peel material potentially went further than Trial 1. Microbial degrading can lead to the release of ammonia and other nitrogenous basic substances, which temporarily raised the pH (Samudro et al., 2023). This emphasizes the dynamic chemical activity of natural adsorbents and the time-dependent nature of pH alterations caused by chemical and biological reactions.

As time passed, additional breakdown of organic matter in the adsorbent materials might have led to slight acidification of the treated wastewater, especially noted in the final trials. The measured pH changes in various setups and trials illustrate the intricate interactions among chemical leaching, microbial processes, and the inherent qualities of the natural adsorbents. In particular, the five-day lag in analyzing Trials 2 and 3—compared to Trial 1, which was evaluated right after setup—provided enough time for microbial and chemical processes to progress. It is probable that these processes included the decomposition of organic materials like lignin and cellulose, common in both banana peels and young coconut exocarp, resulting in the liberation of organic acids and other byproducts that gradually decreased the pH (Kaur & Kumar, 2019; Samudro et al., 2023).

Nevertheless, systems with young coconut exocarp (Setups A and C) typically showed elevated pH levels because of the naturally found alkaline minerals like calcium, potassium, and magnesium, which provide a buffering effect to the system (Waseem & Khan, 2020). Nonetheless, this buffering effect seemed to diminish over time as microbial activities became more dominant, especially in Trial 2, where the leaching of organic acids might have exceeded the neutralizing ability of the coconut exocarp. This corresponds with the results by Periyasamy (2024), who observed that extended exposure of natural plant-based adsorbents to wastewater conditions frequently leads to dynamic chemical changes caused by microbial breakdown and the alteration of organic substances

4.2.2 Surfactant Concentrations

Table 4.4 shows the surfactant concentrations (mg/L) of various adsorption setups treating beauty salon wastewater. This result is further presented in Figure 4.2. The influent is the initial untreated concentration of surfactant, which was 8.88 mg/L. The experiments were conducted using four setups: Setup A, Setup B, Setup C, and Setup D.

Table 4.4. Results of Surfactants Across Trials

Surfactants	**Setups**			
	Setup A	**Setup B**	**Setup C**	**Setup D**
Influent (mg/L)	8.88	8.88	8.88	8.88
Trial 1 (mg/L)	9.01	15.68	29.25	24.32
Trial 2 (mg/L)	6.98	13.91	23.56	24.32
Trial 3 (mg/L)	6.96	11.68	19.86	22.25

As evident from Figure 4.2, Trial 1 was done straight away using the influent wastewater freshly obtained. For this trial, Setup A recorded the maximum reduction of surfactant levels—bringing the concentration up from the initial level of 8.88 mg/L to 9.01 mg/L. Though it had increased from the original value, Setup A indicated considerable interaction with the wastewater's surfactant content. In comparison, Setup B showed a higher surfactant concentration of 15.68 mg/L, while Setup C unexpectedly showed the highest level at 29.25 mg/L. Setup D, which used commercial activated carbon, recorded a surfactant level of 24.32 mg/L. The increased surfactant concentrations in Setups B, C, and D—compared to the influent—might be due to multiple factors, such as adsorption inefficiencies, desorption of surface-adsorbed compounds from the adsorbents, or leaching of organic materials that react with surfactants or mimic their chemical properties during testing (Waseem & Khan, 2020; Daverey et al., 2019).

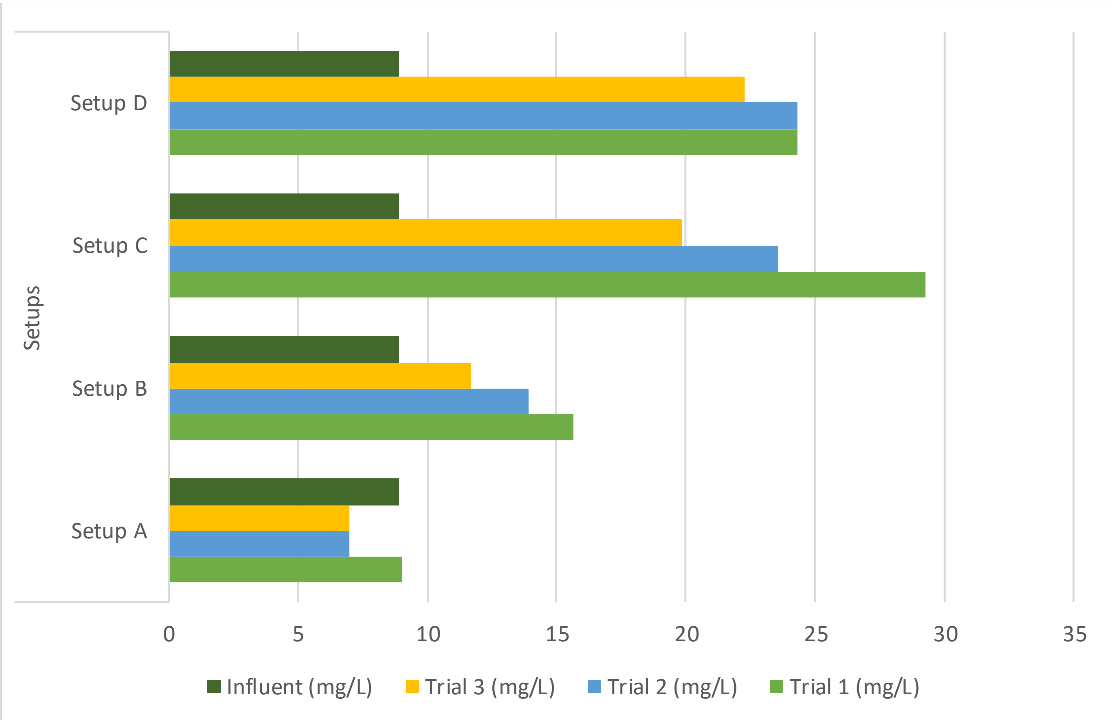

Figure 4.2. Surfactant Results Across Three Trials in Different Setups

During Trial 2, Setup A continued to demonstrate better performance at a surfactant level of 6.98 mg/L. Setup B fell to 13.91 mg/L, while Setup C also decreased slightly to 23.56 mg/L. Surprisingly, Setup D remained constant at 24.32 mg/L, suggesting minimal or no extra adsorption activity, possibly as a result of saturation or deactivation of the commercial activated carbon surface (Periyasamy, 2024). The sustained reduction in surfactant levels in Setups A, B, and C highlights the potential of natural adsorbents—especially young coconut exocarp—to enable pollutant removal not just through primary adsorption but also by promoting secondary interactions, such as microbial activity and biofilm formation (Kaur & Kumar, 2019).

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In Trial 3, carried out five days following Trial 2 under identical storage conditions, a persistent drop in surfactant levels was noted across every setup, with Setup A experiencing a slight reduction from 6.98 mg/L to 6.96 mg/L. This minor variation—characterized as a difference of under 0.1 mg/L—indicates that the adsorption process had likely reached equilibrium by Trial 2 and that only negligible additional removal took place (Kaur & Kumar, 2019). Setup B demonstrated a notable reduction from 13.91 mg/L in Trial 2 to 11.68 mg/L in Trial 3. Nonetheless, this remains in contrast to the results of Abd-Talib et al. (2019), who indicated that modified banana peel powder was very effective in reducing surfactants and COD levels in industrial wastewater. The difference might arise from the banana peels utilized in this research being unaltered, indicating that their adsorption capacity wasn't improved via chemical or thermal activation, which greatly restricts surface area and accessible functional groups (Abd-Talib et al., 2019; Waseem & Khan, 2020).

Setup C, which contained both banana peelings and young coconut exocarp, decreased to 19.86 mg/L—still significantly higher than the original concentration of 8.88 mg/L in the influent. This continued increase suggests possible leaching of organic substances or surfactant-like substances from the natural adsorbents, particularly when combined. In fact, 10 out of the 12 experimental data points (for all setups and trials) had surfactant concentrations higher than the influent levels.

In particular, Banana peels have also been identified as biosurfactant-like compounds with natural sources, given their intrinsic organic nature. Halder et al. (2014) proved that banana peels are good substrates for biosurfactant production, meaning there are surface-active agents embedded in the matrix of the peels. Also, the addition of raw banana peels to wastewater has been linked to enhanced biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels. These high values indicate the discharge of biodegradable and chemically oxidizable compounds, primarily organic matter. Although certain research on young coconut exocarp is less common, it is logical to deduce that, similar to banana peels, they can also include natural chemicals that can leach into wastewater.

This may be attributed to the initial discharge of soluble organic compounds or surface-active agents present in both banana peels and coconut exocarp upon initial contact with wastewater (Daverey et al., 2019). Additionally, microbial degradation of organic matter in retained wastewater might have yielded products that either interfere with or mimic the presence of surfactants during measurements (Periyasamy, 2024).

Setup D, utilizing commercial activated carbon, remained relatively ineffective throughout the trials, recording 22.25 mg/L in Trial 3. This outcome could be due to saturation of adsorption sites, poor regeneration, or the competition of multiple organic and inorganic constituents in the beauty salon wastewater that limited surfactant adsorption (Samudro et al., 2023). Commercial activated carbon may also exhibit desorption behavior, where previously adsorbed compounds are released back into the solution under certain equilibrium shifts, further explaining its suboptimal performance (Kaur & Kumar, 2019).

Trials 2 and 3 took place five days after Trial 1, utilizing the same batch of stored influent wastewater. The postponement was mainly caused by lab scheduling limitations. The storage duration unintentionally permitted natural biological and chemical processes, including microbial degradation and oxidation, to affect the wastewater, possibly changing surfactant levels prior to adsorption testing (Samudro et al., 2023). As a result, the findings from Trial 2 indicated an overall reduction in surfactant levels in most configurations, implying some natural degradation of contaminants throughout the storage duration.

Figure 4.2 presents more clearly than any other means the variation among setups (A, B, C, and D) regarding surfactant concentrations run through three trials and resulting removal performance capabilities. Setup A remained the least concentration in surfactants as would be expected based on its superior adsorption or degrading of surfactant efficiency.

Setup B indicated higher surfactant concentrations compared to Setup A, which performed comparatively better but was still lower than the maximum surfactant concentration levels found in Setup C in Trial 1, which later, in the next phases, began to decrease. In between Setup B and C, Setup D (the control with activated carbon) must have assisted in surfactant reduction but did not outperform Setup A. These results illustrated further the unique adsorption strengths of each of the materials, with Setup A exhibiting the least variation in surfactant removal efficacy.

4.2.3 COD

COD values from wastewater treated by several adsorption configurations are indicated in Table 4.5. Effluents from beauty salons are known to have oxidizable material—mostly organic in the form of shampoo, conditioner, hair treatment, and cosmetics—in fairly high levels. In addition, the presence of such compounds is the main cause of high COD, which indicates that they demand increased oxygen for chemical oxidation processes and hence indicate high loading for contaminating material in wastewater.

Table 4.5. Results of COD Across Trials

COD	Setups			
	Setup A	Setup B	Setup C	Setup D
Influent (mg/L)	7,652	7,652	7,652	7,652
Trial 1 (mg/L)	5,034	13,507	11,521	8,740
Trial 2 (mg/L)	4,832	7,151	9,932	7,548
Trial 3 (mg/L)	3,222	6,356	7,548	7,151

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High COD levels suggest high levels of oxidizable organic matter, which, if released untreated, may consume dissolved oxygen in receiving water bodies and adversely affect aquatic ecosystems (Smith & Jones, 2020). Results measuring the performance of different adsorbents in terms of lowering COD levels are reported across four configurations: Setup A employed 100% young coconut exocarp, Setup B employed 100% banana peelings, Setup C used a mixture of 50% banana peelings and 50% coconut exocarp, and Setup D utilized commercial activated carbon as the control treatment.

The influent COD concentration of the recently collected beauty shop wastewater is 7,652 mg/L. With all setups, Setup A for Trial 1 alone shows a decrease in COD concentration, with a value of 5,034 mg/L. For the other setups, the rest show an increase, of COD ranges from 8,740 to 13,507 mg/L, higher than the influent concentration.

The observed COD values across Trials 2 and 3 provide insights into the adsorption efficiency and stability of different adsorbents over time. Since the trials were conducted five days apart using the same wastewater batch, changes in COD reflect both the adsorption capacity and possible interactions between the adsorbents and organic matter in the wastewater.

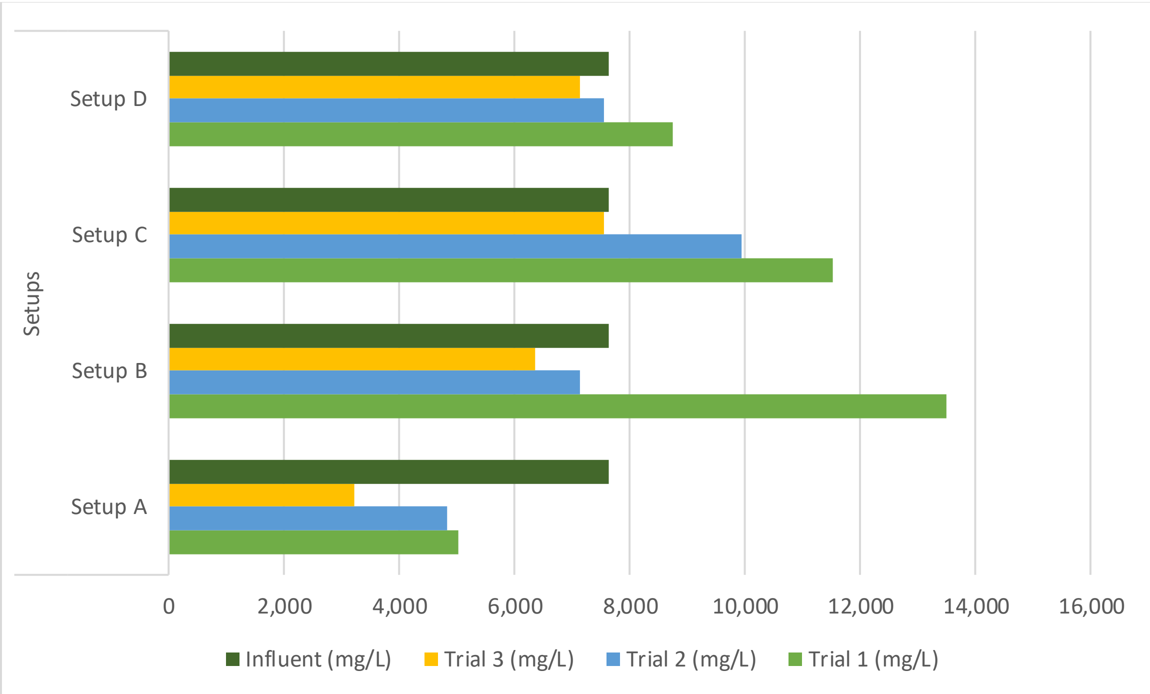

Figure 4.3. COD Results Across Three Trials in Different Setups

Figure 4.3 shows COD levels over three trials in four treatment configurations. As can be seen, COD measures the amount of oxygen needed to chemically oxidize organic and inorganic substances in water. Although it does not measure organic pollutants directly, it is a valuable proxy for determining the total oxidizable load in wastewater.

In Setup A, similar reduction in COD throughout the trials indicates stable and progressive adsorption of oxidizable materials. The fibrous and porous texture of coconut exocarp with abundant functional groups including hydroxyl (-OH) and carboxyl (-COOH) may ensure stable adsorption over time. These groups are in contact with different oxidizable compounds by hydrogen bonding and ionic interactions (Kaur & Kumar, 2019; Chen & Wang, 2021). Its relatively stable performance between trials indicates that its adsorption sites do not get saturated and can keep on binding oxidizable compounds at all times, which makes coconut exocarp a good long-term natural adsorbent (Waseem & Khan, 2020).

In Setup B, there was an anomaly high COD reading of 13,507 mg/L for Trial 1. Even if COD cannot specifically show the number of organic pollutants, the peak is an indicator of a high concentration of easily oxidizable compounds leached from the raw banana peels. Banana peels have water-soluble substances such as polyphenols, flavonoids, and sugars that add to the oxygen requirement in chemical oxidation (Garcia et al., 2019; Periyasamy, 2024). This highlighted a disadvantage of utilizing untreated peels: they can be a source of oxidizable load at the beginning, not decreasing it. Across consecutive trials, the COD values decreased, indicating that once the readily leachable organics were depleted, the fibrous nature of peels containing cellulose, hemicellulose, and lignin began to act as an effective adsorbent (Abd-Talib et al., 2019). These emphasized the necessity for pre-treatment in order to limit the primary release of oxygen-demanding substances.

Setup C, revealed intermediate COD values throughout all trials. In Trial 1, the COD was quite high, probably due to the addition of soluble oxidizable matter from banana peels. But as trials went on, COD levels decreased. This indicated that the use of both materials formed a complementary adsorption system. The coconut exocarp presented a consistent adsorption platform, whereas the banana peel evolved from an oxidizable matter source to a successful adsorbent upon its soluble

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component reduction. Synergy is presumably responsible for an adsorption mixed-mode mechanism by which different functional groups tackled a wider array of oxidizable material, hence the overall efficiency increased (Chen & Wang, 2021).

Setup D, the commercial activated carbon control setup, always had the lowest COD values in all trials. This is to be expected, since activated carbon has a high surface area and dense network of micropores that enable fast and effective adsorption of a broad range of oxidizable substances (Doe et al., 2018; Samudro et al., 2023). Its effectiveness further justifies its status as a standard for adsorption-based wastewater treatment.

4.3 Performance Comparison with DAO 2016-08 Class C Classification

The DAO 2016-08 Class C Classification sets stringent guidelines for acceptable water quality, including specific limits for pH, surfactants, and COD. While the influent wastewater exceeded the permissible levels for surfactants (1.5 mg/L) and COD (100 mg/L), treatment with the natural adsorbents resulted in marked reductions. Although none of the experimental setups completely met the DAO standards, Setup A exhibited the greatest overall reduction in both surfactants and COD relative to the influent.

This finding supports the potential of young coconut exocarp as a sustainable and cost-effective alternative to conventional adsorbents, particularly in contexts where complete regulatory compliance may require further treatment optimization (Brown & Thomas, 2020; Gopalakrishnan et al., 2023). Table 4.6 presents data comparing pH across three trials in four different setups (A, B, C, and D) with the influent and DAO 2016-08 Class C guidelines.

Table 4.6. Results of pH Across Trials with the DAO 2016-08 Effluent Standard

pH Level	Setups			
	Setup A	**Setup B**	**Setup C**	**Setup D**
Influent	7.08	7.08	7.08	7.08
Trial 1	7.72	7.43	7.50	7.12
Trial 2	7.04	7.38	7.09	7.01
Trial 3	6.96	6.91	6.80	6.93
DAO 2016-08 Effluent Standard	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0

Figure 4.4 compares the pH values observed in three trials for each setup (A, B, C and D) against the DAO 2016-08 effluent standard. All setups generally maintain pH levels within or near the acceptable range (6.0–9.0) prescribed by DAO 2016-08, indicating that none of the trials produced highly acidic or alkaline conditions. Setup A exhibits the highest initial pH in Trial 1, then gradually declines in Trials 2 and 3. Setup B and Setup C follow similar patterns, with minor fluctuations around near-neutral values. The close alignment of these pH measurements with the DAO 2016-08 standard suggests that the treatment processes in each setup effectively maintain pH conditions suitable for environmental discharge, despite slight variations over the three trials.

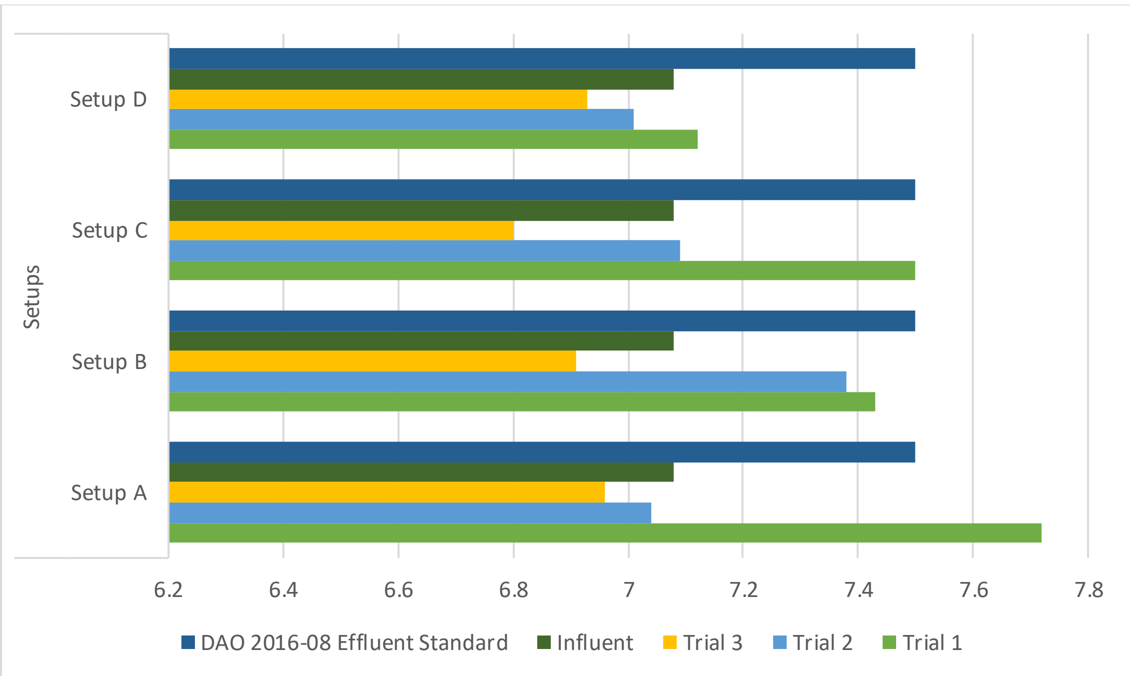

Figure 4.4. pH Comparison with Effluent Standards

Table 4.7 summarizes the performance of surfactant removals of various treatment arrangements with banana peelings (*Musa acuminata x. balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera L.*) as natural adsorbents in three trials. The starting influent surfactant concentration for all the preparations was 8.88 mg/L, which is higher than the DAO 2016-08 discharge criteria of 1.5 mg/L. Configuration A did best in removing surfactants, considerably reducing its level from 9.01 mg/L in Trial 1 down to 6.98 and 6.96 mg/L in Trials 2 and 3, respectively. On the contrary, Setup B achieved only slight reduction, whereas in Setups C and D, surfactant levels increased, highest in Setup C at 29.25 mg/L in Trial 1. The trend indicates that there might be degradation of the adsorbent material and/or desorption of contaminants in Setups C and D. Therefore, despite remarkable performance, none of the setups managed to meet the very stringent DAO 2016-08 standard for surfactants in effluent. Nevertheless, the study demonstrated the promise of young coconut exocarp and banana peelings as cheap and natural materials for the partial removal of surfactants, requiring further optimization for treatment efficiency to meet standards.

Figure 4.5 compares surfactant concentrations in three trials for Setups A, B, C and D against the DAO 2016-08 effluent standard (horizontal line at 1.5 mg/L). All setups record surfactant levels exceeding the DAO 2016-08 regulatory threshold, underscoring the need for further refinement in treatment processes. Although, Setup A consistently displays the lowest surfactant values, suggesting relatively more effective removal compared to the other setups, but it still remains above the standard. Setup B reflects moderate surfactant concentrations, which legit rise from Trial 1 to Trial 3. Setup C always shows higher values with a peak in Trial 1 and slightly less in the next trials as surfactants are later removed from the water. Despite some improvement in late trials, the four setups did not comply with the 1.5 mg/L guideline, illustrating the difficulties in removing surfactants present in this type of wastewater and the potential need for enhanced or additional treatment strategies.

Table 4.7. Results of Surfactants Across Trials with the DAO 2016-08 Effluent Standard

Surfactants	Setups			
	Setup A	Setup B	Setup C	Setup D
Influent (mg/L)	8.88	8.88	8.88	8.88
Trial 1 (mg/L)	9.01	15.68	29.25	24.32
Trial 2 (mg/L)	6.98	13.91	23.56	24.32
Trial 3 (mg/L)	6.96	11.68	19.86	22.25
DAO 2016-08 Effluent Standard (mg/L)	1.5	1.5	1.5	1.5

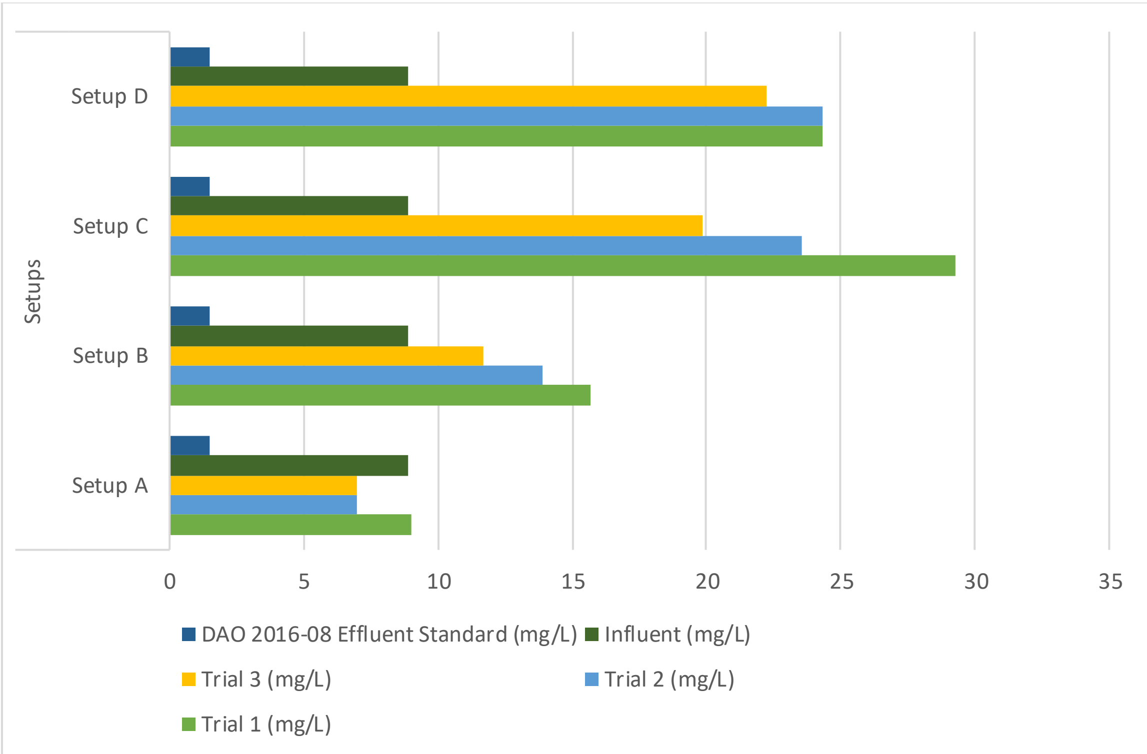

Figure 4.5. Surfactants Comparison with Effluent Standards

The COD measurements, reflecting the organic pollutant load, showed a steady decline across the trials: 5,034 mg/L (Trial 1), 4,832 mg/L (Trial 2), and 3,222 mg/L (Trial 3). While these values remain far above the guideline limit of 100 mg/L, the decreasing trend suggests gradual improvement in the treatment process's ability to reduce organic pollutants over time.

Table 4.8 shows the COD results for three trials of four experimental configurations treating beauty salon wastewater, compared with the DAO 2016-08 effluent standard of 100 mg/L. Setup A, which employed a synergistic combination of banana peelings (*Musa acuminata × balbisiana, BBB group*) and young coconut exocarp (*Cocos nucifera L.*), showed the highest COD reduction, from an influent concentration of 7,652 mg/L to 5,034 mg/L, 4,832 mg/L, and 3,222 mg/L in Trials 1 to 3, respectively. Setup B first registered a large peak of COD in Trial 1 (13,507 mg/L) most probably through leaching of easily oxidizable material from the raw banana peels, prior to exhibiting an impressive decline in subsequent trials. Setups C and D too showed COD decreases though less prominently, with the ultimate COD of 7,548 mg/L and 7,151 mg/L, respectively. Despite the fact that none of the setups met the

DAO 2016-08 limit, the findings demonstrate the potential of agricultural wastes, particularly the combination of banana peelings and young coconut exocarp, as affordable wastewater pre-treatment materials. These emphasized the necessity of further process optimization to maximize removal efficiency and comply with regulations.

Table 4.8. Results of COD Across Trials DAO 2016-08 Effluent Standard

COD	Setups			
	Setup A	Setup B	Setup C	Setup D
Influent (mg/L)	7,652	7,652	7,652	7,652
Trial 1 (mg/L)	5,034	13,507	11,521	8,740
Trial 2 (mg/L)	4,832	7,151	9,932	7,548
Trial 3 (mg/L)	3,222	6,356	7,548	7,151
DAO 2016-08 Effluent Standard (mg/L)	100	100	100	100

Figure 4.6 compares the COD levels observed in three trials (green, blue, and yellow lines) for Setups A, B, and C against the DAO 2016-08 effluent standard of 100 mg/L (horizontal line). All COD values substantially exceed this regulatory benchmark, indicating that none of the setups achieve full compliance with the standard. Setup B exhibits the highest COD levels overall, peaking in Trial 1 and then declining in subsequent trials. Setup A maintains relatively lower COD readings across all trials, although it remains above the permissible limit. Setup C falls between these two extremes, showing moderate COD levels that gradually decrease from Trial 1 to Trial 3. Despite the observed reductions, all setups stay well above the 100 mg/L guideline, emphasizing the challenge of managing high organic loads in beauty salon wastewater and pointing to a need for further refinement or supplementary treatment methods.

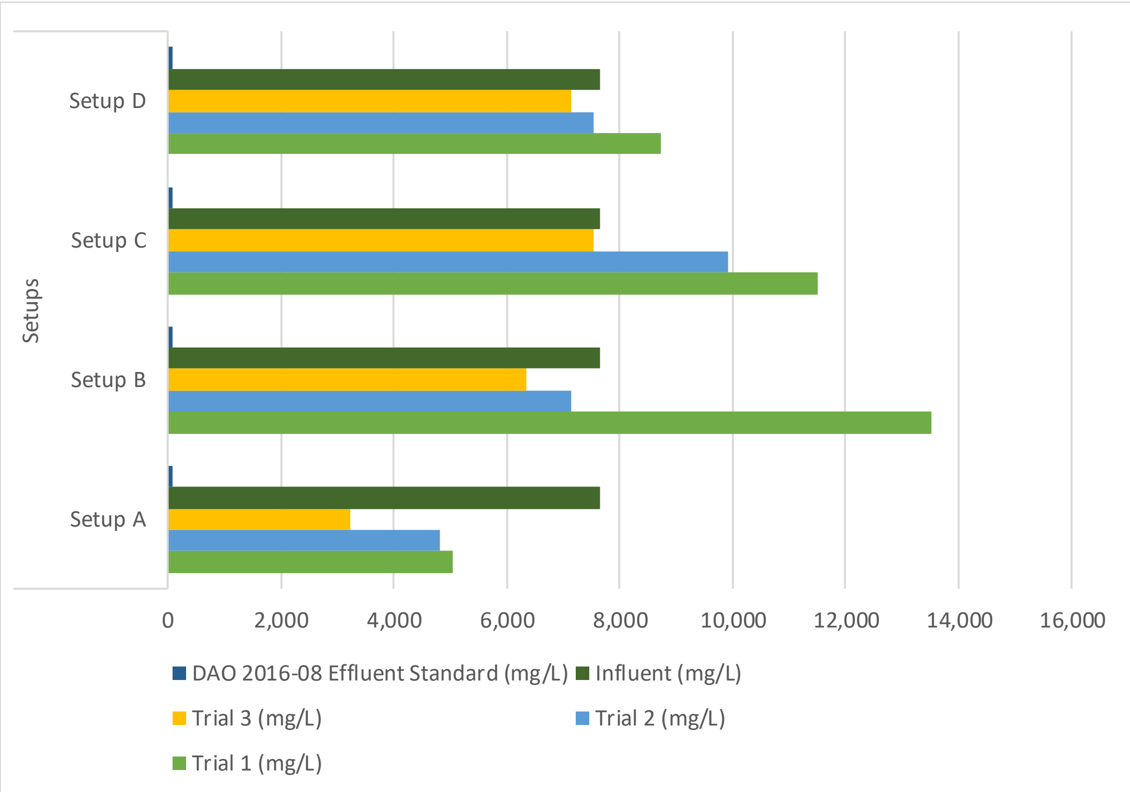

Figure 4.6. COD Comparison with Effluent Standards

4.4 Discussion and Comparative Analysis

The results indicate that both banana peelings and young coconut exocarp have considerable potential as natural adsorbents for treating beauty salon wastewater. Setup A was the only configuration that gave consistently good results of near-neutral pH, lowest surfactant, and reduced concentration COD. The possible reason for its superior performance in the young coconut exocarp could perhaps be an attribute of its fibrous- and porous-like structure and active functional groups such as hydroxyl and carboxyl that support high efficiency of adsorption (D'Agostino et al., 2021; Mazumder & Zhang, 2023).

On the contrary, banana peelings under Setup B also contributed to the removal of pollutants, but showed variation in their results. In fact, even at the initial phases of treatment application, the COD was quite high along with very variable surfactant results. The blended approach in Setup C did not yield additive benefits and, in some instances, resulted in less effective adsorption compared to using young coconut exocarp alone. The control setup with commercial activated carbon (Setup D) demonstrated moderate removal efficiency but did not outperform the best-performing natural adsorbent.

These indicated that while activated carbon is still one of the best adsorbents, natural alternatives such as young coconut exocarp can also be a competitively viable and environmentally sustainable choice in situations that require cost and environmental impact to be vital considerations (Zuwu et al., 2018; Pal et al., 2022).

The gradual improvement of the COD values is particularly true in Setup A, suggesting that the adsorption process might require a longer contact time or more treatment cycles. Such an approach could further enhance the removal efficiencies and help achieve closer alignment with environmental standards.

V. Conclusion And Recommendations

The preliminarily study aimed at investigating the adsorption potential of banana peelings (*Musa acuminata x balbisiana BBB group*) and young coconut exocarp (*Cocos nucifera* L.) for the removal of pollutants from beauty salon wastewater.

5.1 Conclusions

These examinations proved young coconut exocarp and banana peelings to be promising natural adsorbents suited for the treatment of salon wastewater based on their really good abilities to reduce surfactant concentration and COD in wastewater.

1. The raw beauty salon wastewater had a near-neutral pH of 7.08, which is ideal for most biological and chemical treatment processes and also safeguards equipment from corrosion or fouling (Akin, 2011; Zuwu et al., 2018). However, its surfactant concentration of 8.88 mg/L was nearly six times the DAO 2016 08 Class C limit of 1.5 mg/L, which indicates high foaming potential and aquatic toxicity risks (Pal et al., 2022). Its measured COD value of 7,652 mg/L in the influent in Figure 4.3 far surpasses the DAO 2016-08 limit of 100 mg/L, which reflects a high oxidizable material content in raw beauty salon wastewater. These high values of COD indicate a high concentration of oxygen-consuming substances—presumably from leftover dyes, conditioners, and other chemical-containing hair products—that, if released without being treated, would heavily deplete dissolved oxygen concentrations in receiving water bodies and impose ecological stress (Pal et al., 2022).
2. Of the three natural-adsorbent setups, 100% young coconut exocarp (Setup A) provided the overall best performance—surfactants decreased from 8.88 to an average of 7.22 mg/L and COD decreased to 4,129 mg/L—while keeping pH close to 7.23. Its effectiveness is attributed to the fibrous, porous matrix of the exocarp and the high density of hydroxyl/carboxyl groups that support a slow-release adsorption process (D'Agostino et al., 2021; Mazumder & Zhang, 2023). The banana-peel equipment (Setup B) first increased COD to 13,507 mg/L as a result of soluble polyphenol and sugar leaching, before reaching 8,654 mg/L as those leachable were consumed and the rest of the lignocellulosic frame adsorbed organics (Abd-Talib et al., 2020). The 50:50 mixture (Setup C) exhibited mid-level removals—21.23 mg/L surfactants and 7,293 mg/L COD—indicating no synergistic advantage when using the two materials together, most probably due to initial banana-peel leachate partially compensating coconut exocarp's adsorption until subsequent trials (Chen & Wang, 2021; Kaur & Kumar, 2019).
3. Commercial activated carbon (Setup D) lowered surfactants to 23.25 mg/L on average and COD to 7,477 mg/L, but was surpassed by coconut exocarp under the same conditions. None of the four treatments, including activated carbon, met the DAO 2016 08 Class C limits (1.5 mg/L surfactants, 100 mg/L COD), demonstrating the need for process enhancements to satisfy regulatory requirements, such as longer contact times, higher adsorbent dosages, or multi-stage treatment (Brown & Thomas, 2020; Gopalakrishnan et al., 2023). Nevertheless, young coconut exocarp's affordability, environmental-friendliness, and competitive removal efficiencies establish its potential as a sustainable alternative for remediation of beauty salon wastewater.

5.2 Recommendations

Based on these findings, several recommendations can be made for future guidance:

a. Extended contact periods and higher exocarp dosages should be explored to further lower surfactant and COD levels.
b. Chemical or thermal activation of coconut exocarp and banana peels to enhance its characteristics in improving adsorption capacity.
c. Combining natural adsorbents with other low-cost materials or biological processes to achieve compliance with stringent effluent standards.
d. Washing or applying mild chemical treatments should be evaluated to remove leachable organics and stabilize performance.
e. Consider correct influent sampling over the study period instead of a single influent sample to better reflect variability in the wastewater characteristics enhance the treatment performance evaluations.
f. Integrate multi-stage treatment to blend the adsorbents with other low-cost or biological treatment in a multi-stage system to achieve effluent standards more effectively

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