RESEARCH PAPER

Development of A Banana Stem-Based Biofilter for The Removal of Natural Dyes from Contaminated Water and Evaluation of Stain Stability

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ABSTRACT

Due to the growing popularity of sustainable agriculture, innovative methods have developed to improve the quality of food being produced while decreasing the amount of food lost after harvesting. One of these methods that has gained traction is the use of an aquaponics-based fodder production system, which is both ecological and consists of aquaculture (the raising and harvesting of fish and other aquatic animals) and hydrophonics (using water to grow plants).

The challenge with aquaponic-based fodder production systems is that there is a lot of moisture in the harvested fodder when it is taken out of the system, which leads to spoilage being rapid through both moisture, microbes and by the environment (air exposure etc.). This research proposes the use of bio-derived nanomaterials as an effective solution for improving the storage of fodder produced by an aquaponics system. Bio-derived nanomaterials are produced using materials from nature such as plant extracts, biopolymers, and agricultural waste. These types of nanomaterials have many advantages, including biodegradability, non-toxicity, and compatibility with the environment. Bio-derived nanomaterials have properties (antimicrobial, antioxidant, and moisture-regulating) that make them good to use in extending the shelf life of fresh fodder. Nano-cellulose, chitosan nanoparticles and plant-based metallic nanoparticles are examples of bio-derived nanomaterials that have been researched for how effective they are in reducing the growth of microorganisms, as well as for the maintaining the nutritional quality of fodder while in storage. When these types of nanomaterials are being used in processes such as coating, packaging or spraying during the post-harvest handling of fodder, the nanomaterial creates a barrier to protect the fodder from spoilage. In addition, the ethylene production control mechanism of these nanoparticles, as well as their ability to decrease oxidized stress and maintain chlorophyll concentrations, directly uphold the palatability and retention of freshness of the Agri-fodder. The importance of this is particularly relevant for aquaponics systems, due to the continuous nature of the processes used within them. Therefore, if the Agri-fodder can have a longer preservative capacity, there will be reduced losses due to spoilage and increased availability to provide livestock with adequate source of feed. Furthermore, the biobased nanoparticles can create products that meet the principles of the circular economy since they are produced using renewable materials instead of synthetic preservatives, which will help to improve the economic sustainability of integrated aquaponic systems and improve environmental outcomes through a reduction of chemical residues and waste. In conclusion, the use of biobased nanoparticles has the potential to be an innovative means of sustainable post-harvest preservation in aquaponic integrated feed systems. Future research should investigate optimizing synthesis processes, conducting long-term safety evaluations, and applying these materials at an increased scale for the practical production of food and feed. These findings highlight an advancement in sustainable agricultural practices, as well as the potential of nanotechnology to improve the long-term security of food and enhance the efficient use of resources.

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1. INTRODUCTION

Water pollution is one of the major environmental concerns due to rapid industrialization, urbanization, and agriculture. One of the types of pollution is water contamination with different kinds of harmful substances including dyes. Dyes are quite resistant to physical and chemical effects, therefore, cannot be easily disposed. Nowadays natural dyes have been widely employed in textile, food, and cosmetics industry. Although they are not as dangerous as synthetic ones, too much discharge of these substances into water may cause the reduction of light penetration into water layers and degradation of water environment [1].

The traditional methods of elimination of dyes from water including chemical oxidation, coagulation, and membrane filtration technologies are usually rather expensive and even may result in formation of some additional contaminants. Thus, today there is a need in application of more sustainable techniques. One of these technologies involves the usage of agro wastes as biofilters due to their availability, biodegradability, and natural adsorption ability owing to their lignocellulose nature. One of the most perspective biofilter agents is banana stem. This type of agricultural waste contains large quantities of such substances as cellulose, hemi-cellulose, and lignin. The stems contain Fibers and cellulose. The banana stems will be used as a biofilter to clean the contaminated water. They serve as a sustainable option for industries seeking to prevent or reduce dye contamination. The focus of this study is to create a biofilter made of banana stem Fibers. The biofilter is then tested for effectiveness in absorbing natural dyes from water. The effectiveness of the biofilter is based on the surface area and absorption capacity of the banana stem Fibers. The other important part of this study is the determination of stain stability. Stain stability is defined as the ability of the dyes to be locked within the biofilter or released into water [2]. It is essential to understand this concept to make the biofilter effective.

Using banana stems also ensures the recycling of agricultural waste products. In general terms, banana stem-based biofilters serve as an effective and sustainable means of water purification. This not only helps to prevent water contamination but also ensures the recycling of other products and protection of the environment [3].

2. OVERVIEW OF BANANA STEM-BASED BIOFILTERS AND NATURAL DYE REMOVAL

Water pollution is a critical issue affecting both the environment and human health. Colored wastewater from industries like textiles, food, and cosmetics is one of the major contributors to water pollution. The industries discharge natural and synthetic dyes into water, affecting aquatic plants and animals. The dyes in water interfere with photosynthesis, as they block sunlight from entering the water. The dyes may be toxic, posing health risks when ingested by humans and animals. The conventional methods used for purifying dyed water include chemical coagulation, oxidation, and filtration.

The conventional methods are expensive, and byproducts may be toxic. In order to overcome the problems, eco-friendly methods are being studied. One of the eco-friendly methods is using biofilters made from agricultural waste. The banana stems are usually discarded after harvesting. The banana stems are rich in natural fibers and cellulose. The use of banana stems as biofilters is an eco-friendly method. The project aims at designing a biofilter using banana stems. The biofilter has the ability to purify water by removing natural dyes. The biofilter efficiency is based on its surface area and ability to absorb dyes from contaminated water [4]. Using banana stems as biofilters is also a cost-effective and environmentally friendly option.

The present project is to develop a water purification system using banana stems as a biofilter. The biofilter can be used to remove natural dyes from water. The efficiency of the biofilter depends on the surface area and absorption capacity of the banana stems. The other major part of the present project is to test the stability of the stain. Stain stability is the ability of the dyes to remain in the biofilter and not return to the water. This is important to know to make the biofilter effective. The present project also shows the reuse of agricultural waste in real-life applications. Using banana stems as biofilters also reduces waste and pollution in the environment at the same time. It is a combination of effective waste management and water purification. It is a green and cost-effective option for small-scale industries and rural areas.

Using banana stems as biofilters is a good option for water contamination due to dyes. It is also a good option for the environment and for the reuse of agricultural waste. It is also a good option for water purification and for the environment [5].

3. WORKING PRINCIPLE OF BIOFILTER-NATURAL DYE REMOVAL

The banana stem-based biofilter is based on the principle of adsorption and filtration. Banana stems contain a number of fibers and cellulose, which have a porous structure. When contaminated water containing natural dyes is passed through the biofilter, the dyes get adsorbed on the surface of the fibers. As a result of this adsorption of dyes, the concentration of dyes in water is reduced, making the water clean. The biofilter can be designed in such a manner that the banana stems are arranged in layers to improve the efficiency of the process.The process is purely physical and chemical and does not involve the use of harmful chemicals. The efficiency of the biofilter depends on the time of contact between the contaminated water and the banana stems, as well as the thickness of the banana stem layer and the dyes used. After the filtration of dyes from water, the stability of the dyes is checked to prevent their leaching into water [6].

3.1 ADSORPTION MECHANISM OF BANANA STEMS

Cellulose fibers of banana stems contain hydroxyl (-OH) groups and other functional groups. These functional groups attract and hold dye particles from water by chemical and physical means. When water passes through the biofilter, dye particles are absorbed by the biofilter. This minimizes coloration of water. Multiple layers of banana stem biofilters are effective in dye adsorption [7].

3.2 EVALUATION OF STABILITY OF STAINS

The biofilter is then subjected to a test after dye particles are absorbed. This test is to ensure that the stains are not released back into the water. Stains that are stable indicate a biofilter that is effective and can be reused for water treatment purposes. This also shows that the biofilter has the ability to last for a long period of time [8].

3.3 REGENERATION OF BIOFILTER

The banana stem biofilter has the ability to be regenerated after being saturated with dye particles. This is done by washing the biofilter with water. This makes the biofilter last for a long period of time. This biofilter is effective and cost-friendly [9].

4. DETERMINATION OF WATER QUALITY

The water that has come in contact with natural dyes from any industrial or domestic source has low transparency, a different colour, and could also be toxic in nature. The untreated water could affect the aquatic life and the environment if it is directly released. Once the water has gone through the banana stem-based biofilter, it is tested to check the quality of the water and the level of purification achieved. Some of the important parameters of the water are tested, such as the color of the water, turbidity of the water, pH of the water, and the overall look of the water to check the level of purification achieved by the removal of the dyes. The biofilter works on the principle of using the banana stem powder, where the dye particles get trapped on the surface. After this, the samples of the water are collected for comparison, indicating the effectiveness of the biofilter. The significant reduction in the color intensity and turbidity of the water shows the efficient purification of the natural dyes [10].

Furthermore, the presence of the contaminants, if any, in the purified water is also checked to ensure that the biofilter does not allow the trapped dye to come back into the water. The biofilter also works efficiently in different environmental conditions, such as the presence of solvents, indicating the effectiveness of the biofilter. The results obtained from the experiment clearly show the effectiveness of the biofilter, where the purified water is clearer, less colored, and safe for further use or for release into nature. The experiment also shows the effectiveness of the banana stem powder, which can be used for the purification of the water, indicating its reusability for the benefit of the environment [11].

5. SYSTEM ARCHITECTURE AND CONFIGURATION

To create a system architecture for the removal of natural dyes from contaminated water, a simple, effective design using banana stems as a natural filtering medium has been developed. This system utilizes banana stem materials in ecologically-friendly and economical manner to filter out impurities in drinking water. The first step in the process is to collect the contaminated water into a feed tank, where any large particulates or contaminants will be allowed to settle out. Next, the water is able to move from the feed tank into the main part of the system - which is the biofilter column. The biofilter column is filled with processed banana stem materials, including dried chunks, fibers, and powder. The processed banana stems possess high adsorptive properties, which allow them to capture and retain dye particulates on their surfaces. In addition, sand or gravel layers can be used to augment the filtering process and/or to provide better water flow through the filtering media. As water flows through the biofiltration column, the dye particles become trapped by the banana stem layers, allowing for reduction in color and impurities found in the wastewater. Water flow through the biofilter column can be controlled, either by natural means (gravity) or by the use of a valve system [12].

5.1 CONTAMINATED WATER INPUT

Initially, the contaminated water from natural dye processes is stored in a tank for biofiltration. Examples of sources of this natural dye contaminated water include the use of natural dyes in textile dyeing, small manufacturing operations that use natural dyes as well as lab experiments where natural dyes are utilized. In addition to the dyes, this contaminated water may also contain suspended solids, organic material and other minor impurities. Before the contaminated water enters the filtration unit, the water is usually left to sit for a short period of time to allow the heavier solids to settle to the bottom.

This process helps to decrease the load on the biofilter and improves overall efficiency. Additionally, some operators will use a pre-filtration method (either by using mesh or cloth) to remove larger debris. The design of the tank allows for a controlled and consistent flow of contaminated water to the next phase in the treatment process. It is important to handle the contaminated water properly at this stage so that the biofilter operates efficiently from the start. By providing moderately pre-treated and evenly supplied input water, the biofiltration system will produce a higher level of dye removal and have a longer filter life [13].

5.2 BANANA STEM BIOFILTER UNIT

Banana stem biofilter units are the primary component of the system, and this is where the actual purification of the water occurs. The first step in the purification process is to clean and dry the banana stems and then grind them into powder or fiber. This process significantly increases the surface area of the banana stems, thus enhancing the ability of the banana stems to adsorb impurities. Next, the prepared banana stem material is placed in a column filter that is vertically oriented, allowing for slow and even flow of water through the material. The column can be designed in a manner that allows for the banana stem material to be arranged into multiple layers to improve the overall efficiency of the column filter. For example, gravel or sand or some other material can be added with the banana stem material to promote filtration and reduce the chances of clogging.

Once the contaminated water enters the column filter, it flows through the column filter layer by layer. The porous nature of the banana stem material in the column filter serves as a natural adsorber of the dye molecules and other impurities from the water by pulling those molecules into the material's pores and storing them on the surface of the material. The result is a lower concentration of dye, lower turbidity, and lower organic content in the wastewater stream compared to before it went through the filtration process [14].

5.3 CLEAN WATER COLLECTION

Water that has been treated with the banana-stem biofilter column is placed into another container that is unsoiled. This container is the last place that the filtered water is housed after it has passed through the filtration system. It is set up so that no contaminated material can contact any of the filtered water, thus maintaining a higher quality of treated water through no possibility of re-contamination. When the water exits the column, it is expected to have a much lower colour, less turbidity, and far fewer impurities than when it entered the banana-stem biofilter column contaminated. The collection container for the treated water is typically kept closed and clean to help retain the purity of the water that has been treated by the system. In order to assess the performance of the biofilter system, a number of different water quality parameters are typically recorded at this point in the process. Some of the common parameters that are used to assess the effectiveness of the system include pH level and turbidity, colour, and in some instances chemical oxygen demand (COD) and/or biological oxygen demand (BOD) based on the specific study that is being conducted. These parameters are used to assess the degree to which the system has removed certain natural colorings and other pollutants. By completing regular monitoring of the water quality parameters created by the biofilter as part of the collection process, it becomes possible to assess the performance of the filter and determine when the filter media needs to be replaced or regenerated. This ensures that the filter can continue to function effectively and reliably [15].

6. RAW MATERIAL SELECTION AND BIOFILTER PREPARATION

For the development of an effective biofilter, the selection of banana stems is a critical step. In this step, fresh and healthy banana stems are gathered from local farms or agricultural waste. However, while collecting banana stems, damaged and decayed areas are avoided. The use of fresh banana stems is beneficial for the biofilter development process since the presence of fiber and cellulose content in the banana stem is effective for dye adsorption. The banana stems are cleaned properly by washing them with fresh water. After cleaning the banana stems, they are cut into pieces to ensure effective drying. The banana pieces are then dried properly to remove moisture from the banana pieces. Once this is done, the banana stems are shredded or powdered into a fine powder.

Powdering the banana stems provides a large surface area, enabling the biofilter to increase its adsorption potential. Depending on the design of the filter system, the powdered banana stems can be arranged into a column filter or a mesh filter. Prior to use, the biofilter may be tested for consistency to ensure effective dye removal from contaminated water. Through the use of banana stems in the biofilter, the process becomes sustainable and eco-friendly. This process of creating a biofilter from agricultural waste provides a cost-effective and environmentally friendly means of removing natural dyes from contaminated water [16].

6.1 CHOPPING AND DRYING OF BANANA STEM

After the selection of fresh banana stems, the next step is the preparation of the banana stems for use in the biofilter. The banana stems are first cut into smaller pieces using a knife or cutter. The cutting of the banana stems into smaller pieces makes the drying of the banana stems easier, as well as grinding them into a smaller powder form. After the banana stems have been cut into smaller pieces, they are then washed using clean water. The washing of the banana stems ensures that the biofilter works effectively, as well as ensuring that no impurities are introduced into the water. After washing the banana stems, they are then dried using the sun drying method or the air-drying method. The drying of the banana stems is crucial, as it ensures that the banana stems do not spoil. The drying of the banana stems ensures that the banana stems do not spoil, thus ensuring the effectiveness of the banana stems in the biofilter. The cleaned banana stem pieces are then dried either through natural sunlight or using the air-drying method [18].

The simplest method for drying the banana stem pieces is the sun drying method, which also helps in the drying process without the growth of microorganisms. The drying process is also important because, without it, the banana stem will spoil or its efficiency in adsorption will be low. Once the banana stem pieces are completely dried, they will be hard, making it easier to grind them into powder form. The drying process not only enhances the efficiency of the biofilter but also makes it easier to store the banana stem for longer before using it. The simple chopping and drying method ensure the banana stem material is clean, dry, and ready for further use in creating an efficient biofilter for the removal of natural dyes from contaminated water [19].

6.2 GRINDING AND POWDER PREPARATION

After the banana stem pieces are properly dried, they are subjected to the grinding process. The dried stems are crushed or ground into a fine powder using simple equipment such as a grinder, blender, or mortar and pestle. This step is important because it increases the surface area of the material, which improves its ability to adsorb dye molecules from contaminated water. The ground material is then sieved to obtain a uniform particle size and to remove any larger, unprocessed pieces.

A fine and consistent powder ensures better packing in the biofilter and allows water to pass evenly through the material during filtration. The prepared banana stem powder is stored in a clean, dry container to prevent moisture absorption and contamination before use. Proper storage helps maintain the quality and effectiveness of the biofilter material. This grinding and powder preparation step plays a key role in enhancing the efficiency of dye removal, making the banana stem biofilter more effective and reliable for water purification [20].

6.3 ASSEMBLY AND FILTRATION SETUP

Once the banana stem powder has been prepared and treated, it is ready to be assembled into the biofilter. The powder is carefully packed into a filter column, mesh, or layered container, ensuring even distribution to allow smooth water flow. Proper layering increases the contact surface area, which enhances the efficiency of dye adsorption. The filtration system is set up so that contaminated water containing natural dyes passes through the banana stem biofilter. The flow rate is controlled to provide sufficient contact time between the water and the powder, allowing maximum adsorption of dyes onto the banana stem Fibers. A clean collection container is placed at the outlet to collect treated water. This setup ensures that the water passes entirely through the biofilter, preventing any bypass and maximizing purification efficiency. This assembly is simple, cost-effective, and eco-friendly, demonstrating how agricultural waste can be transformed into a functional water treatment system. The setup can also be easily scaled up or modified for larger volumes of contaminated water [21].

6.4 PROCESS OF DYE REMOVAL

As soon as the banana stem biofilter is assembled, the filtration begins. Impure water with natural dyes is poured into the inlet of the biofilter system. The rate of flow of the water is maintained such that it passes slowly and smoothly over the packed banana stem powder.

As the water passes over the biofilter, the pores of the Fibers and the cellulose in the banana stem powder adsorb the dye particles. This adsorption happens because of the physical and chemical interactions of the dye particles with the biofilter material. The packing of the powder in layers maximizes the surface area of the adsorbent material for effective adsorption of the dyes.

During this process of filtration, other impurities are also removed by the powder, and the water becomes clear and less coloured. The water is collected at the outlet in a clean and dry container. The observations made during this experiment prove the efficiency of the biofilter used for water purification. In order to make the experiment more accurate and to prove the efficiency of the biofilter, the experiment can be repeated for various batches of contaminated water. The efficiency of the biofilter can also be checked for reuse for the removal of dyes from water. This experiment proves to be an effective and eco-friendly way of removing natural dyes from contaminated water at a low cost, along with utilizing agricultural waste for beneficial purposes [22].

6.5 EVALUATION OF TREATED WATER

The treated water, after passing through the biofilter, is collected for analysis. The objective of this step is to evaluate the efficiency of the biofilter in the removal of natural dyes from the contaminated water. The colour, turbidity, and pH values of the water are measured, and the results are compared to the untreated water. The significant reduction in the colour intensity and turbidity of the water clearly shows the efficiency of the banana stem biofilter in the adsorption of the natural dye, trapping it inside the biofilter. The pH level of the water is also checked to ensure that the filtration process does not disrupt the chemical composition of the water. The repeated evaluation also shows the efficiency of the biofilter over time, proving the reusability and sustainability of the biofilter.

The evaluation of the treated water clearly shows the efficiency of the banana stem biofilter in the removal of natural dyes from the contaminated water, proving it to be an eco-friendly method for the purification of the water [25].

6.6 ASSESSMENT OF DYE RETENTION

At the end of the process, the banana stem powder that has already been used will be assessed to understand how well it retained dye that was absorbed. This evaluation is important for determining the stability of the dye that has been removed from water and attached to the biofilter material. Following the filtration process, the dye particles will remain attached to the surface of the banana stem powder, and an evaluation will be completed to determine if these dye molecules will remain bound to the biofilter material or if they have any potential to be released back into the environment. This can be accomplished through visual analysis as well as additional testing such as washing or desorption testing.

By evaluating the retention of the dye, it will give an indication of the amount of force with which the dye molecules are bound to the banana stem material; a greater retention indicates better adsorption efficiency and stability; therefore, it is a better indication of whether the biofilter will be reliable for long-term usage. Additionally, the results from this assessment will assist in determining how to safely handle or dispose of the biofilter material after it has been used. In some cases, the assessment may also provide insight into whether the material is capable of being reused or regenerated for additional filtration cycles [26].

7.SOXHLET EXTRACTION

In order to assess the dye retention capacity of the banana stem biofilter more precisely, Soxhlet extraction is carried out. In this method, the prepared banana stem powder is filled into the Soxhlet apparatus, and the solvent, such as ethanol or methanol, is passed through the material repeatedly. The solvent's constant flow will aid in the extraction of the dye molecules, if any, that are not fixed strongly on the material's Fibers.

The amount of dye extracted into the solvent will allow us to assess the efficiency and stability of the biofilter. Soxhlet extraction will also help in the quantitative assessment of the retention capacity of the dye, along with the solvent's conditions, in retaining the adsorbed dye maximally. This will allow us to assess the reusability of the biofilter, thus keeping the banana stem material long-lasting for the purification of water [27].

7.1 SAMPLE PREPARATION AND SETUP

The first step of the Soxhlet extraction process is the preparation of the sample and setup of the apparatus. After the filtration process of the banana stem powder, the powder is first dried properly to ensure that there is no moisture content. This is a significant step since moisture content can influence the efficiency of the process. An accurate weight of the dried banana stem powder is then weighed and placed inside a thimble made of filter paper. This is a container that holds the banana stem powder while at the same time allowing the solvent to pass through it. After this step, the thimble is then placed inside a main chamber of a Soxhlet extractor apparatus. A round-bottom flask is then connected below the main chamber and filled with a specific solvent such as ethanol or methanol. Finally, a condenser is connected at the top of the apparatus while cold water is circulated through it [28].

7.2 EXTRACTION PROCESS

During the second phase of the experiment, a suitable extraction solvent is used to extract dye molecules from the banana stem powder. This extraction method typically employs an extraction system, perhaps a Soxhlet extraction apparatus, to allow for an efficient extraction system. The extraction solvent is first added to a round-bottom flask, where it is heated using either a heating mantle or hot plate. The solvent begins to boil, generating vapour as the temperature increases. The vapour makes its way upwards through the apparatus to the condenser section.

At the condenser, the vapour is cooled with cold water flowing through the condenser, allowing it to re-condense into liquid and drop onto the banana stem powder located inside a thimble holder. As the liquid extraction solvent passes through the banana stem powder, it dissolves dye molecules that are weakly adhering to the banana stem powder. This extraction process continues until all the dye is dissolved by the extraction solvent and the extraction chamber is filled with solvent solution containing dissolved dye [29].

7.3 REPETITION AND ANALYSIS

The extraction cycle is continued repeatedly until the final cycle has been completed. After each cycle has been completed, you will examine the product(s) obtained from each cycle through analytical methods. The design of your extraction assembly allows for the evaporation of the solvent and condensation of vapor within the assembly to occur in a continuous manner, allowing for the continual passage of solvent through the powder being extracted (banana stem trial - the last extraction) [29]. Each time the solvent comes into contact with the sample (the powder being extracted), it will remove more and more of the dye molecules that may still be found in the sample. This allows for optimal dye extraction from the sample being used for extraction. The cycles will continue until the extraction chamber no longer has any coloured solvent (the solvent is clear), indicating significant quantities of dye do not remain in the sample being extracted [30]. Once this has occurred, the heating element will be turned off (to stop the heating process) and the extraction apparatus will be allowed to completely cool before the next step can be completed. After cool down, the solvent containing the extricated dyes will be found in the round bottom flask [31]. The next step to be completed is to analyse the amount of dye that has been removed from the sample using the solvent(s) collected. There are several ways to analyse the dye concentration in the collected solvents, including, but not limited to: (a) visually, determining the colour; (b) measuring the concentration; or (c) using spectral methods. These analyses will provide an indication of the degree of efficiency of the extraction process [32].

8. ROLE OF NATURAL BIOFILTERS AND EXTRACTION TECHNIQUES IN WATER PURIFICATION

There is a growing interest in the use of natural and cost-effective biofilters for water purification. Among the agricultural wastes, banana stem, coconut husk, and rice husk have been studied extensively. The use of banana stem as a biofilter for water purification is gaining importance, especially due to the high cellulose content, which is useful in the adsorption of the dye present in water [33]. The use of banana stem biofilters is an alternative method for water purification, replacing the conventional use of chemicals. The use of chemicals for water purification results in the production of harmful byproducts, which is not the case with the use of natural biofilters. The use of natural biofilters results in the use of simple adsorption, which does not harm the environment. Another important factor to be considered while assessing the biofilters is the stability of the adsorbed dye [34]. It does not make sense for the material to adsorb the dye, but it also needs to retain it, i.e., the material must not leach the dye back into the water. This is where Soxhlet extraction becomes an important tool. Soxhlet extraction helps in understanding the binding nature of the dye molecules on the biofilter material using ethanol and methanol as solvents. So, if the amount of dye leached from the biofilter material during the repeated cycle of Soxhlet extraction is low, it means the stability of the stain on the biofilter material is high [35]. This evaluation becomes important for understanding the reusability of the material. In conclusion, a complete understanding of biofilter efficiency and longevity can be obtained by combining natural biofilters with analytical tools like Soxhlet extraction, thus paving the way for eco-friendly, cost-effective, and sustainable water treatment technologies to combat actual problems facing our environment [36].

9. LIMITATIONS OF BANANA STEM-BASED BIOFILTERS

Banana stem-based biofilters are quite efficient and eco-friendly, although they have some limitations. The adsorption capacity of the material may reduce over time, as the material gets saturated with the dyes. The material may need regeneration or replacement over time. The efficiency of the material in removing the dyes may vary depending on the type of dye, pH, and the rate of water flow [37]. In some cases, the removal of the dyes may not be complete, especially for concentrated dyes. Another limitation of the banana stem-based biofilter is the stability of the stains, whereby some dyes may leach out when the material is exposed to solvents like ethanol or methanol. This implies that not all the dyes in the solution adhere to the banana stem material [38]. The effectiveness of the material in removing other contaminants like heavy metals or chemicals may not be the same unless the material is altered. Lastly, the material may not be quite efficient in dealing with large volumes of water, as the simple setup may not effectively handle the water. The material may need optimization [39].

10. CONCLUSION:

The main objective of this research was to create a low-cost, biodegradable filter using banana stems for eliminating natural colors from polluted water supplies. Based on the results obtained from this study, there are clear indications that banana stem powder can absorb a substantial amount of color and contaminants from polluted waters. When the attempts to filter contaminated water using the banana tree material were performed, the use of a layered construction (column) slowed down the rate at which the contaminated water flows through the filter. During the test, I noted that the amount of colour in the filtered water was less than in the unfiltered water due to the ability of the banana tree material to hold onto dye particles.

Banana trees are a natural, inexpensive material that can also be optimally used to treat/dispose of wastewater on a small scale in an environmentally-friendly manner. There were also repeated tests conducted to see if additional amounts of dye could be removed from the remaining water in addition to identifying any additional dissolved colours in the collected solvent. The results indicate that the biofilter successfully retained and stored all dye removed from the wastewater sample. This project has provided me with a greater understanding of using agricultural waste products in water treatment processes. The results collected from this study were satisfactory, and the system was simple to manufacture, low-cost, and environmentally safe. If improvements can be made to the current design of the system, it will become possible to implement the use of this type of water treatment process at a much larger volume for the removal of dyes from waste-water.

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