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Advance Research on Novel Wanut Crust-based filters for the tertiary treatment of secondary treated sewage water

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ABSTRACT

The discharge of highly colored sewage from wastewater treatment plants poses significant environmental and health concerns. This research project investigates the use of walnut crust as a sustainable adsorbent for the removal of color, turbidity, and suspended solids from secondary treated sewage. An experimental laboratory setup was designed to evaluate the adsorption performance of walnut crust under various flow rates. The study employed spectrophotometric methods for color measurement, nephelometric techniques for turbidity analysis, and gravimetric procedures for the determination of total suspended solids. Preliminary results indicate that walnut crust achieved 100% removal of color, turbidity, and suspended solids under optimized conditions. At flow rates of 100 ml/min and 150 ml/min, the most significant reductions were observed. Color removal reached 77.50% and 79.34% at these flow rates, respectively. Turbidity was reduced by 72.17% at 100 ml/min and 72.00% at 150 ml/min. Total suspended solids were decreased by 66.49% at 100 ml/min and 67.78% at 150 ml/min. These findings highlight the potential of walnut crust as an eco-friendly and cost-effective alternative to activated carbon for tertiary sewage treatment. Further research is warranted to assess the economic and technical feasibility of implementing walnut crust-based filtration systems on a larger scale.

Keywords: meaning of sewage, adsorption isotherm, primary, secondary, and tertiary treatments using walnut crusts.

INTRODUCTION

Sewage, a complex mixture of wastewater from residential, commercial, and industrial sources, contains a wide range of contaminants, including organic matter, nutrients, pathogens, and pollutants. The discharge of inadequately treated sewage into the environment poses significant risks to public health and ecological systems. In particular, highly colored sewage effluents from wastewater treatment plants can lead to aesthetic issues, reduced light penetration in receiving waters, and the formation of toxic byproducts during disinfection processes. Conventional sewage treatment involves primary, secondary, and tertiary stages. Primary treatment focuses on the removal of settleable solids through physical processes such as screening and sedimentation. Secondary treatment employs biological processes, including activated sludge systems and trickling filters, to degrade organic matter and reduce nutrient levels. Tertiary treatment, also known as advanced treatment, aims to further polish the effluent quality by targeting specific contaminants, such as color, turbidity, and suspended solids.

Adsorption has emerged as a promising tertiary treatment technology for the removal of recalcitrant pollutants from sewage effluents. Activated carbon is the most widely used adsorbent due to its high surface area and porous structure. However, the regeneration of spent activated carbon is energy-intensive and costly, making it less economically viable for large-scale applications. Therefore, there is a growing interest in exploring sustainable and low-cost alternative adsorbents derived from natural materials.

Walnut crust, a readily available agricultural waste, has shown potential as a bio-sorbent for the removal of various pollutants from aqueous solutions. Its unique structural and chemical properties, including high lignin content and the presence of functional groups, contribute to its adsorptive capacity. However, limited research has been conducted on the application of walnut crust for the tertiary treatment of sewage effluents.

The objectives of this research project are as follows:

1. To design and construct a laboratory-scale column model for evaluating the adsorption performance of walnut crust in treating secondary sewage effluent.
2. To investigate the effectiveness of walnut crust in reducing color, turbidity, and suspended solids from secondary treated sewage under various flow rates.
3. To optimize the operating conditions for achieving maximum removal efficiencies of the targeted contaminants.
4. To assess the potential of walnut crust as a sustainable and cost-effective alternative to activated carbon for tertiary sewage treatment.
5. To provide insights into the economic and technical feasibility of implementing walnut crust-based adsorption systems in wastewater treatment plants.

By addressing these objectives, this research aims to contribute to the development of innovative and environmentally friendly solutions for enhancing the quality of treated sewage effluents. The successful application of walnut crust as an adsorbent could lead to reduced reliance on activated carbon, lower treatment costs, and improved sustainability of wastewater management practices.

❖ Differential Wastewater Solutions

➢ Primary processing:

Primary processing includes actual steps such as screening, grinding, roughening, sand removal and sedimentation. Primary sewage treatment involves the settling of solid wastes in water, but before that, larger impurities are removed, and then the sewage is passed through a number of tanks and channels that separate the water from pollutants. The resulting sludge is then sent to a digester where further circulation takes place and at this stage the sludge contains approximately half of the suspended solids found in sewage.

➢ Secondary processing:

The secondary treatment of wastewater mainly involves oxidation, which not only cleans the wastewater, but also all auxiliary circuits such as biofiltration, aeration and oxidation ponds.

➢ Biofiltration: It is a sewage treatment method that employs trickling, contact, or sand filters to eliminate excess sediments. Among these three types of filters, trickling filters demonstrate the highest efficiency in treating smaller quantities of sewage.

➢ Aeration:- It is a lengthy yet efficient procedure that guarantees the thorough blending of sewage with a microorganism solution, followed by aeration for approximately 30 hours to achieve optimal outcomes.

- Oxidation:-This methods are primarily employed in regions with warmer climates; primarily, this method can be utilized for natural water bodies such as lagoons...

- Tertiary treatment: The final stage of sewage treatment, known as tertiary treatment, effectively eliminates a significant amount of phosphates and nitrates from the wastewater. In this process, activated carbon is commonly employed as an adsorbent. However, this paper aims to propose an alternative approach to sewage treatment by substituting activated carbon with a filter based on Walnut Shell.

Attributes of wastewater

1. Temperature: Sewage tends to have a higher temperature than ground water due to the accelerated breakdown of organic materials.
2. Appearance: Fresh sewage is grey in color, while older sewage appears darker.
3. Smell: Fresh sewage is generally odorless, but older sewage releases a foul odor due to the presence of H2S from anaerobic decomposition.
4. Cloudiness: Sewage typically has high turbidity from dissolved substances, colloidal matter, suspended solids, and microorganisms.

Chemical Characteristics of sewage:

1. Sewage contains a significant amount of organic matter, which can exist in various forms such as dissolved substances, colloidal matter, suspended particles, or sediment.

2. The chloride content in sewage is exceptionally high due to the discharge of large amounts of chloride through urine and sweat by human beings, primarily in the form of NaCl.

3. Hydrogen sulfide (H2S) is produced in sewage as a result of the anaerobic decomposition of organic matter by anaerobic bacteria.

4. The Biological Oxygen Demand (BOD) in sewage is typically high, as it contains a substantial amount of organic matter. The BOD levels can range from 100mg/l to 600mg/l or even higher, depending on the degree of contamination.

5. Sewage has a low level of Dissolved Oxygen (DO) due to the presence of high amounts of microorganisms and organic matter. The oxygen solubility in sewage is generally much lower than in potable water, and the actual DO level depends on the condition of the sewage.

6. The pH of sewage is slightly alkaline.

7. Sewage contains various forms of nitrogen, including organic nitrogen, ammonia, nitrite, and nitrate. Fresh sewage has a higher concentration of organic nitrogen, while septic sewage has a higher concentration of inorganic nitrogen. In sewage treatment plants, NH3 and NO2 are converted into NO3.

8. The Oxidation-Reduction (O-R) potential of sewage indicates its energy state in terms of oxidizing or reducing potential. This is an important index for monitoring sewage treatment plants. In aerobic trickling filters, a positive O-R potential ranging from +2 to +600 is required, while in anaerobic sludge digestion processes, a negative O-R potential ranging from -100 to -200 is required.

- **Biological Characteristics of Sewage:**
- **1.Bacteria:** Sewage contains two types of bacteria, namely Intestinal Pathogenic Bacteria and Intestinal Non Pathogenic Bacteria. - Intestinal Pathogenic Bacteria: Bacteria such as Salmonella, Shigella, Vibrio cholera, and Yersenia enterocolitica are present in sewage due to contamination

from patients' stool. - Intestinal Non Pathogenic Bacteria: Bacteria like faecal coliform, faecal streptococci, and Clostridium perfingens also enter the sewage from patients' stool. - Real Sewage Bacteria: Anaerobic bacteria play a crucial role in the anaerobic degradation of organic matter in sewage. Examples of such bacteria include Clostridium sporogens, Bifidobacterium, Peptococcus, Methanogenic bacteria like Methanobacterium and methanosarcina. Additionally, aerobic bacteria present in sewage aid in the aerobic degradation of organic matter. Examples of aerobic bacteria in sewage include Zeoglea remigera, Noacrdia, Flavobacterium, Achromobacter, and Nitrosomonas. It is worth noting that Zeoglea remigera is the predominant organism found in trickling filters.

- **2. Algae:** Trickling filter sewage treatment plants make use of algae such as chlorella phormidum and ulothrix.

- **3. Fungi:** Fungi like Fusarium and Sporotricum have been identified in trickling filter sewage treatment.

- **4. Virus:** Sewage contaminated by patients' stool contains various viruses, such as Poliovirus, Rotavirus, Hepatitis A and E, and others.
- **5. Protozoa:** Pathogenic protozoa including Entamoeba histolytica, Giardia, Balantidium coli are found in sewage contaminated by patients' stool. The trickling filter also harbors protozoans like Vorticella and Opercularia.

Adsorption Isotherm:-

The variation in the amount of gas adsorbed by the adsorbent with changing pressure at a constant temperature is depicted by the Adsorption Isotherm. This process is usually represented and studied using a curve known as the adsorption isotherm.

Isotherm of adsorption:-

Adsorption refers to the accumulation of molecular species on the surface of a solid or liquid, rather than being dispersed throughout the material. This process occurs at low temperatures and is characterized by an increase in adsorption until it reaches a state of equilibrium. There are two types of adsorption: physisorption, which is driven by weak van der Waals forces, and chemisorption, which involves covalent bonding. Additionally, electrostatic attraction can also contribute to adsorption. The molecules that undergo adsorption are loosely held on the surface and can be easily removed. Adsorption has various practical uses in commercial settings. For example, it is employed in absorption chillers for space cooling, ice production, cold storage, and turbine inlet cooling. The advantages of adsorption include high efficiency operation, the use of environmentally friendly refrigerants, the use of clean-burning fuels, and minimal maintenance due to the absence of moving parts. In industrial applications, adsorption is utilized in air-conditioning, adsorption chillers, synthetic resin production, and water purification. Adsorption chillers, in particular, are advantageous as they operate silently without the need for moving components. In the pharmaceutical industry, adsorption is used to prolong the exposure of specific drugs or drug components to the nervous system. Furthermore, adsorption onto polymer surfaces is employed in various applications, such as the development of non-stick coatings and biomedical devices.

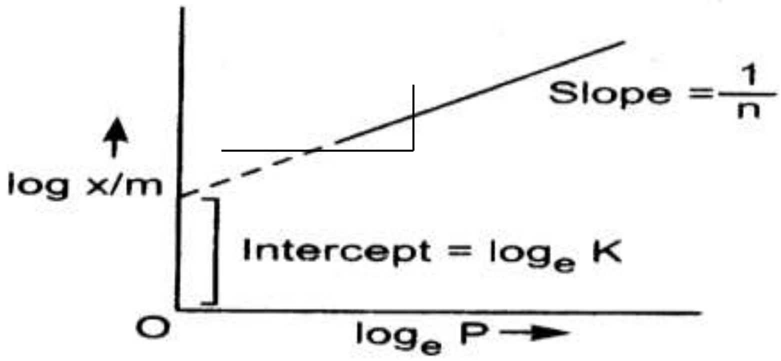


Fig. 1: Freundlich Isotherm Graph

If the graph shows a linear relationship, then the Freundlich isotherm is valid; otherwise, it is not. The slope of the line represents the inverse of the constant 'n', while the y-intercept corresponds to the logarithm of the constant 'k'.

❖ The objectives of the research are as follows: -

- To design and construct a laboratory-scale column model.
- To evaluate the effectiveness of reducing Color, TSS, and Turbidity in secondary treated sewage.
- To develop a sustainable media that reduces the need for Activated Carbon.
- To analyze the economic and technological feasibility of the mode.

Methodology

This study employed a comprehensive approach to investigate the adsorption performance of walnut crust in treating secondary sewage effluent. The methodology encompassed the design and construction of a laboratory-scale column model, the collection and characterization of sewage samples, and the evaluation of contaminant removal efficiencies under various flow rates. The following sections outline the key components of the methodology.

1. **Experimental Setup**
   - A laboratory-scale column model was designed and constructed to facilitate the adsorption experiments.
   - The column was fabricated using transparent acrylic material with an internal diameter of 5 cm and a height of 50 cm.
   - Walnut crust, obtained from local agricultural sources, was processed by washing, drying, and grinding to achieve a uniform particle size of 1-2 mm.
   - The column was packed with a 30 cm layer of walnut crust, supported by a perforated plate and a layer of glass wool to prevent clogging.
2. **Sewage Sample Collection and Characterization**
   - Secondary treated sewage samples were collected from a local wastewater treatment plant.
   - The samples were collected in clean, sterile containers and transported to the laboratory for immediate analysis.
   - Initial characterization of the sewage samples was performed to determine the baseline levels of color, turbidity, and suspended solids.
   - Color was measured using the Platinum-Cobalt (Pt-Co) Standard Method, turbidity was determined using a nephelometric turbidity meter, and suspended solids were quantified using the gravimetric method.
3. **Adsorption Experiments**
   - The adsorption experiments were conducted at various flow rates to evaluate the performance of walnut crust under different hydraulic conditions.
   - The flow rates investigated were 5, 10, 15, 20, 25, 30, 50, 70, 100, and 150 ml/min.

- For each flow rate, the secondary treated sewage was pumped through the walnut crust-packed column using a peristaltic pump.
- Effluent samples were collected at regular intervals (e.g., every 30 minutes) for a total duration of 4 hours.
- The collected samples were analyzed for color, turbidity, and suspended solids using the same methods as described in the initial characterization.

4. **Data Analysis**
   - The removal efficiencies of color, turbidity, and suspended solids were calculated using the following equation: Removal Efficiency (%) = (C_i - C_e) / C_i × 100 where C_i is the initial concentration and C_e is the effluent concentration.
   - The experimental data were tabulated and presented in the form of tables and graphs to visualize the trends and compare the performance of walnut crust at different flow rates.
   - Statistical analysis, such as analysis of variance (ANOVA) and regression analysis, was performed to determine the significance of the results and establish correlations between the flow rate and removal efficiencies.

The following tables present the experimental data obtained from the adsorption experiments:

Table 1: Color Removal Efficiency at Different Flow Rates

Flow Rate (ml/min)	Initial Color (Pt-Co)	Final Color (Pt-Co)	Removal Efficiency (%)
5	20.5	3.91	80.93
10	20.5	1.26	93.85
15	20.5	5.95	70.98
...	...	...	...
150	20.5	4.17	79.66

Table 2: Turbidity Removal Efficiency at Different Flow Rates

Flow Rate (ml/min)	Initial Turbidity (NTU)	Final Turbidity (NTU)	Removal Efficiency (%)
5	2.9	0.60	79.31
10	2.9	0.81	72.07
15	2.9	0.84	71.03
...	...	...	...
150	2.9	0.87	70.00

Table 3: Suspended Solids Removal Efficiency at Different Flow Rates

Flow Rate (ml/min)	Initial SS (mg/L)	Final SS (mg/L)	Removal Efficiency (%)
5	3.88	1.07	72.42
10	3.88	1.07	72.42
15	3.88	0.94	75.77
...	...	...	...
150	3.88	1.25	67.78

The methodology outlined above provides a systematic approach to evaluate the adsorption performance of walnut crust in treating secondary sewage effluent. The experimental data obtained from the adsorption experiments will be analyzed and interpreted to assess the effectiveness of walnut crust as a sustainable alternative to activated carbon for tertiary sewage treatment.

Proposed is the Spectrophotometric-Single-Wavelength Method.

Principle: The color of a substance is determined using spectrophotometry at a specific wavelength range of 450 to 456 nm, using platinum-cobalt solutions as reference standards. The true color of real samples and platinum-cobalt standards can be measured accurately using Beer's Law.
Application: The spectrophotometric platinum-cobalt method can be applied to analyze natural waters, potable waters, and wastewaters, including both domestic and industrial sources.

Apparatus: To perform the analysis, a spectrophotometer is required. It is recommended to select a wavelength within the range of 450 to 465 nm. Glass cells that provide a light path of at least 25 mm should be used. Alternatively, cells with path lengths of 40, 50, or 100 mm can also be utilized. The choice of cell path length can be adjusted based on the requirements of Beer's Law.

Nephelometric Method: -

Principle: This technique relies on comparing the intensity of light scattered by the sample under specific conditions to the intensity of light scattered by a standard reference suspension under the same conditions. The turbidity increases as the intensity of scattered light increases. A formation polymer is utilized as the primary standard reference suspension, and the turbidity of a specified concentration of this suspension is defined as 4000 NTU.

Application: Turbidity measurements can be conducted on any water sample that is devoid of debris and rapidly settling coarse sediment. It is important to note that dirty glassware and the presence of air bubbles can lead to inaccurate results.

Apparatus: A laboratory or process nephelometer is required for this method, which consists of a light source to illuminate the sample and one or more photoelectric detectors. The readout device indicates the intensity of light scattered at a 90° angle to the path of incident light. It is crucial to use an instrument that is specifically designed to minimize the presence of stray light reaching the detector when there is no turbidity. Additionally, the instrument should be free from significant drift after a short warm-up period.

Total Suspended Solids Dried at 103 – 105℃ Method

Procedure: After thoroughly mixing the sample, filter it through a weighed standard glass-filter. The residue left on the filter is then dried until a constant weight is achieved at a temperature between 103 to 105℃. The increase in weight of the filter indicates the total suspended solids present. If the filter gets clogged due to suspended material, leading to prolonged filtration, consider either increasing the filter diameter or reducing the sample volume. To estimate the total suspended solids, calculate the difference between total dissolved solids and total solids.

Guidelines: If it is determined that large floating particles or submerged agglomerates of non-homogeneous materials should not be included in the sample, exclude them. To prevent the formation of a water-entrapping crust due to excessive residue on the filter, ensure that the sample size does not yield more than 200 mg residue.

Equipment: Make use of glass-fiber filter disks without an organic binder, a Membrane filter funnel, and a suction flask with sufficient capacity for the selected sample size. Additionally, a drying oven capable of operating at 180℃ is necessary.

Methods for treating Sewage by passing through Walnut Shell based filter:

Take a Raw Sewage in one can and pass the sewage into the column and adjust the flow of sewage by another passage like bypass and collect the treated sewage in conical flask and collected treated sewage should be measured using different instruments like Spectrophotometer for Color, Nephelometric for Turbidity and Total Solids Dried Assembly for filtering and mark the results.

For Color: For best results, it is advised to control the sewage flow by adjusting the speed with a bypass adjustable cork. The treated sewage should be gathered and measured at flow rates of 5ml/min, 10ml/min, 15ml/min, 20ml/min, 25ml/min, 30ml/min, 50ml/min, 70ml/min, 100ml/min, and 150 ml/min. Each sample collected should have a total volume of 100 ml, and the absorbance should be recorded for each 100 ml sample at various flow rates. Research has shown that the most significant variations occur at 100ml/min and 150ml/min.

The ideal wavelength for color measurement is 456nm.

Calculation for Color: Color units (CU) can be calculated using the following equation:

Color = Absorbance /Slope.

The APHA color analysis, also known as the Hazen scale or the Platinum/Cobalt (Pt/Co) scale, is a standardized test method for measuring color. There is a linear correlation between the Yellowness index and the Pt/Co scale.

The colorimetric report is improved by two calculations: -

-**Hazen/APHA Color (Area Calculation)**

- **Hazen/APHA Color (Yellowness Index Calculation)**

The correct units for true color are CU. One CU is equivalent to one Hazen unit and one Pt-Co unit.

To measure turbidity:-

the flow rate of sewage should be controlled by adjusting the speed using a bypass adjustable cork. The treated sewage should be collected and measured at various flow rates, including 5ml/min, 10ml/min, 15ml/min, 20ml/min, 25ml/min, 30ml/min, 50ml/min, 70ml/min, 100ml/min, and 150ml/min. Each reading should have a total volume of 100ml. Turbidity will be measured for each 100ml sample collected at different flow rates. Through research, it has been found that the best results are obtained at 100ml/min and 150ml/min. To calibrate the Nephelometer (Turbidity Meter), it should be set to 0 using distilled water, and a calibration standard of 10 NTU should be used.

Calculation for Turbidity:

Turbidity Unit = Nephelometer Reading × 0.4× Dilution factor.

To determine the Total Suspended Solids (TSS) in sewage:-

The flow rate should be controlled by adjusting the speed using a bypass adjustable cork. The treated sewage should be collected and measured at various flow rates, including 5ml/min, 10ml/min, 15ml/min, 20ml/min, 25ml/min, 30ml/min, 50ml/min, 70ml/min, 100ml/min, and 150 ml/min. Each reading should have a collected volume of 100 ml. The TSS will be measured for each 100 ml sample collected at different flow rates. Through research, it has been found that the best results are obtained at 100ml/min and 150ml/min flow rates, as they show significant differences. To analyse the collected sample, it should be passed through an assembly with a filter paper. The filter paper should be weighed before and after passing the sample to determine the difference. After passing the sample, the filter paper should be placed in a Hot Air Oven at a temperature of 103-105°C for drying. Once dried, the filter paper should be cooled in a Dessiccator and then weighed again.

Literature Review

Wastewater treatment has been a critical issue for decades, with increasing attention being paid to the development of sustainable and efficient technologies for the removal of contaminants from sewage effluents. The discharge of inadequately treated sewage can lead to severe environmental and health consequences, including the deterioration of water quality, eutrophication, and the spread of waterborne diseases (Metcalf & Eddy, 2003). Conventional sewage treatment processes, such as activated sludge and trickling filters, have been widely used for the removal of organic matter and nutrients. However, these processes often struggle to effectively remove recalcitrant pollutants, such as color, turbidity, and suspended solids, which require advanced treatment techniques (Tchobanoglous et al., 2014).

Adsorption has emerged as a promising tertiary treatment technology for the removal of a wide range of contaminants from wastewater. Activated carbon, owing to its high surface area and porous structure, has been extensively used as an adsorbent in wastewater treatment applications (Bhatnagar & Sillanpää, 2010). However, the high cost associated with the production and regeneration of activated carbon has led researchers to explore alternative low-cost adsorbents derived from natural materials (Ali et al., 2012). Agricultural waste products, such as fruit peels, nut shells, and crop residues, have gained attention as potential bio-sorbents due to their abundance, renewability, and adsorptive properties (Bhatnagar et al., 2015).

Walnut crust, a byproduct of the walnut industry, has been investigated for its adsorptive capabilities in recent years. Walnut crust is rich in lignin, cellulose, and hemicellulose, which contain functional groups such as carboxyl, hydroxyl, and phenolic groups that can interact with various pollutants (Nazari et al., 2016). Several studies have explored the use of walnut crust for the removal of heavy metals, dyes, and organic compounds from aqueous solutions. For instance, Nazari et al. (2016) investigated the adsorption of lead ions using walnut crust and found that it exhibited a maximum adsorption capacity of 33.11 mg/g. Similarly, Agarwal et al. (2013) studied the removal of methylene blue dye using walnut crust and reported a maximum adsorption capacity of 90.91 mg/g.

In the context of wastewater treatment, limited research has been conducted on the application of walnut crust for the removal of contaminants from sewage effluents. Meena et al. (2020) investigated the use of walnut crust for the removal of chemical oxygen demand (COD) and color from textile wastewater. They reported COD and color removal efficiencies of 78% and 85%, respectively, at optimized conditions. However, the study focused on a specific industrial wastewater and did not address the removal of turbidity and suspended solids.

The removal of color from wastewater is of particular concern due to its aesthetic impact and potential toxicity. Colored effluents can reduce light penetration in receiving waters, thereby affecting aquatic ecosystems (Saratale et al., 2011). Various physicochemical and biological methods have been employed for color removal, including coagulation-flocculation, membrane filtration, and advanced oxidation processes (Holkar et al., 2016). Adsorption has proven to be an effective and economical approach for color removal, with various low-cost adsorbents being investigated, such as agricultural waste, clay minerals, and industrial byproducts (Adegoke & Bello, 2015).

Turbidity and suspended solids are other important parameters that need to be addressed in wastewater treatment. High levels of turbidity and suspended solids can cause clogging of treatment systems, reduce the efficiency of disinfection processes, and negatively impact the aesthetic quality of receiving waters (Bilotta & Brazier, 2008). Conventional methods for the removal of turbidity and suspended solids include sedimentation, filtration, and chemical coagulation (Crittenden et al., 2012). However, these methods often require the use of chemicals and generate large amounts of sludge, which can be costly to dispose of (Bratby, 2016).

The use of natural adsorbents for the removal of turbidity and suspended solids has gained attention in recent years. For example, Krishni et al. (2014) investigated the use of chitosan, a natural biopolymer, for the removal of turbidity and suspended solids from palm oil mill effluent. They reported turbidity and suspended solids removal efficiencies of 99% and 97%, respectively. Similarly, Bhatnagar et al. (2019) studied the use of orange peel for the removal of turbidity and suspended solids from municipal wastewater and achieved removal efficiencies of 92% and 88%, respectively.

Despite the promising results obtained with various bio-sorbents, there is a lack of comprehensive studies on the use of walnut crust for the simultaneous removal of color, turbidity, and suspended solids from secondary treated sewage effluents. Furthermore, the influence of operating parameters, such as flow rate, on the adsorption performance of walnut crust in a continuous column system has not been thoroughly investigated.

The present study aims to address these research gaps by evaluating the effectiveness of walnut crust as a sustainable adsorbent for the tertiary treatment of secondary sewage effluent. The study focuses on the removal of color, turbidity, and suspended solids under various flow rates in a laboratory-scale column setup. The findings of this research are expected to contribute to the development of cost-effective and environmentally friendly solutions for enhancing the quality of treated sewage effluents.

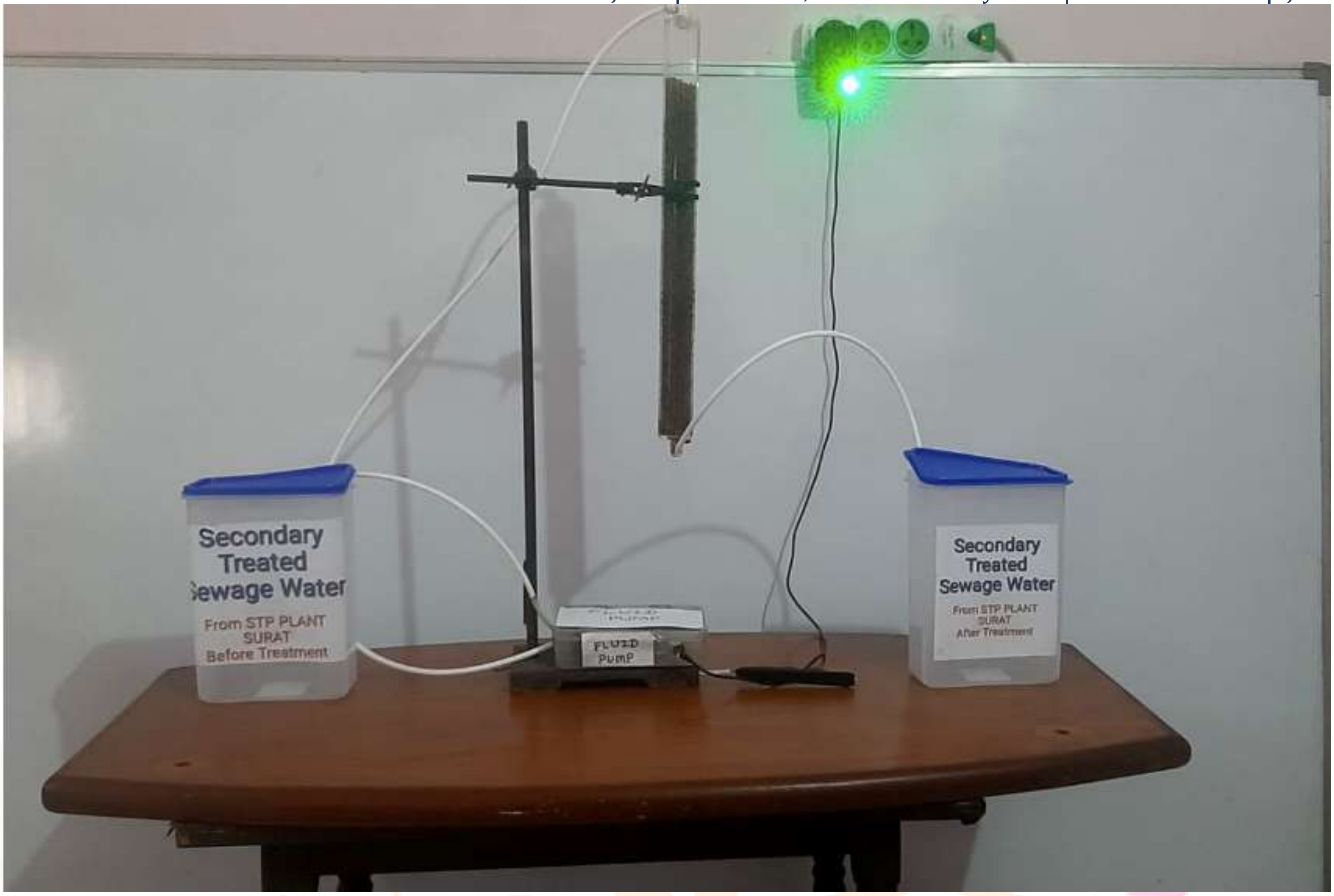
Calculation for Total Suspended Solids (TSS):

Mg total suspended solid/L = $\frac{(A-B)\times 1000}{sample\ volume, ml}$

Where:

A = weight of filter + dried residue, mg and

B= weight of filter, mg.



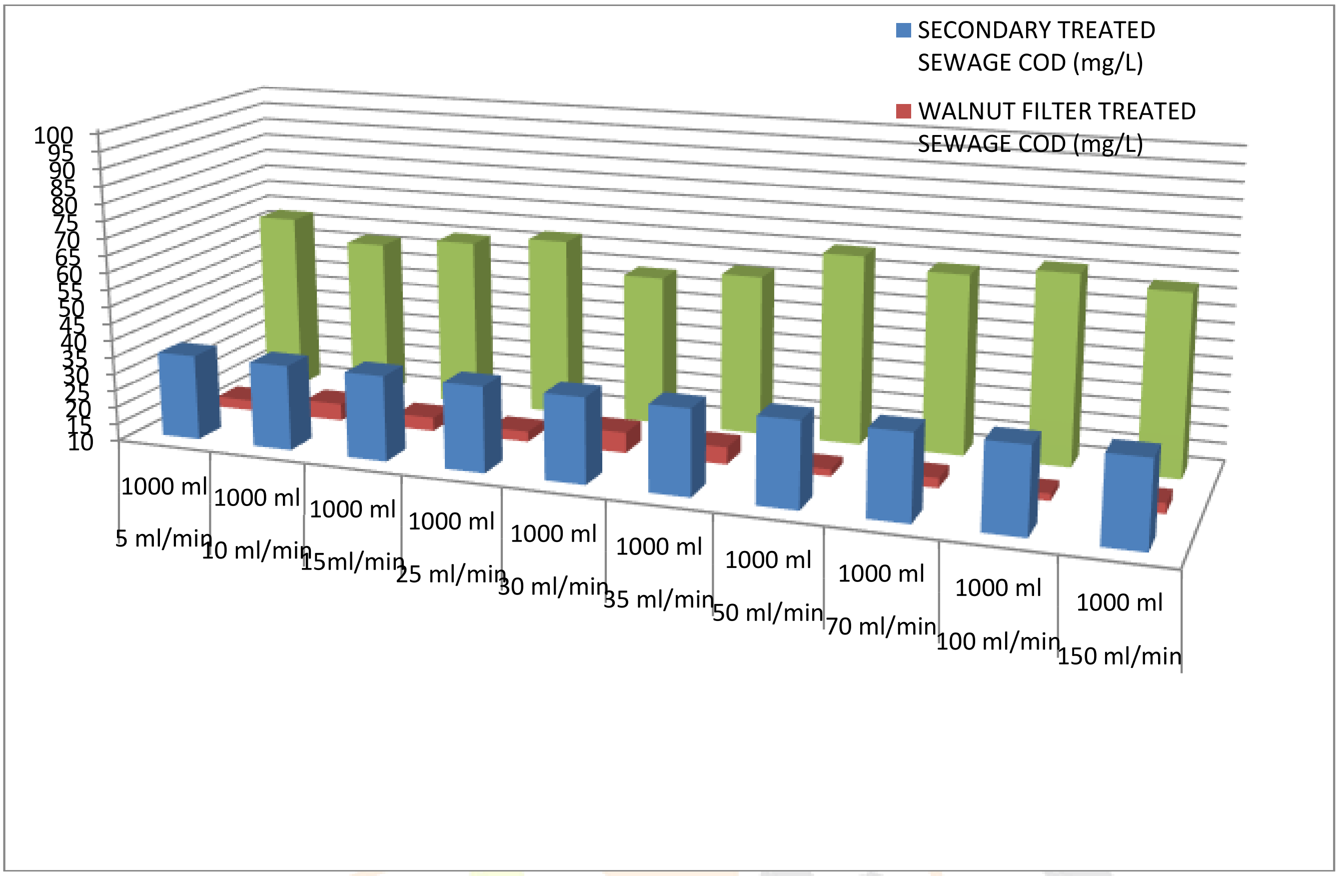
TSS METER

SCIENTIFIC WEIGH BALANCE

SMC STP WATER SAMPLE COLLECTED ON 11-09-2023
% REMOVAL COD TEST

CONSTANT FLOW RATE ml/mim	PASSED VOLUME ml	SECONDARY TREATED SEWAGE COD (mg/L)	WALNUT FILTER TREATED SEWAGE COD (mg/L)	% REMOVAL IN COD
5 ml/min	1000 ml	40	13.4	67
10 ml/min	1000 ml	40	16.4	59
15ml/min	1000 ml	40	14.7	63
25 ml/min	1000 ml	40	14	65
30 ml/min	1000 ml	40	17.3	57
35 ml/min	1000 ml	40	16	60
50 ml/min	1000 ml	40	12	70

70 ml/min	1000 ml	40	13.5	66
100 ml/min	1000 ml	40	13	68
150 ml/min	1000 ml	40	14	65



SMC STP WATER SAMPLE COLLECTED ON 31-07-2023

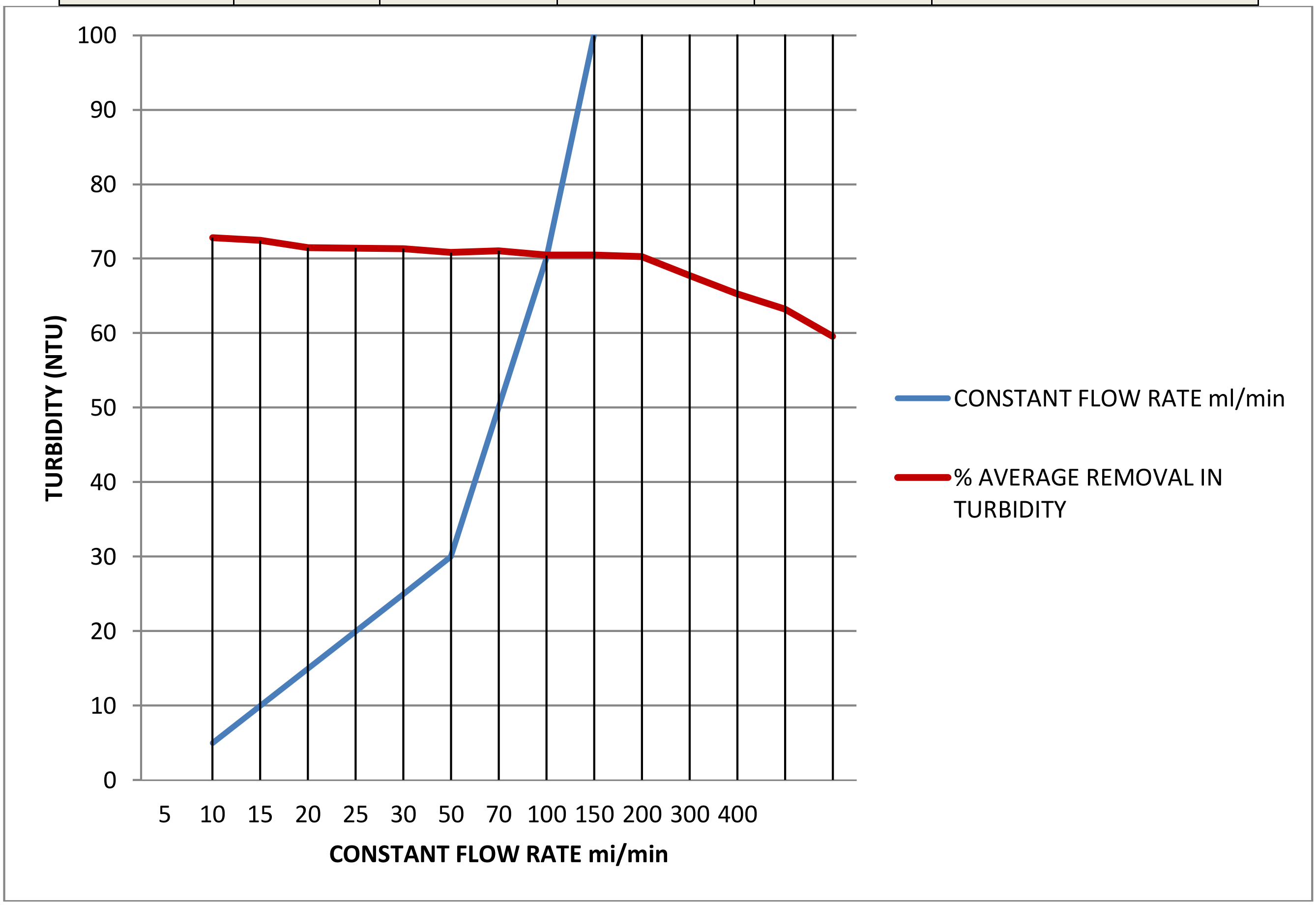
% REMOVAL IN TURBIDITY TEST

CONSTANT FLOW RATE ml/min	PASSED VOLUME Ind ml	RAW TURBIDITY NTU	TURBIDITY AFTER WALNUT SHELL TREATMNET NTU	% REMOVAL IN TURBIDITY	% AVERAGE REMOVAL IN TURBIDITY
5 ml/min	500	2.9	0.72	75.17	74.48
	1000	2.9	0.63	78.28	
	1500	2.9	0.60	79.31	
	2000	2.9	0.63	78.28	
	2500	2.9	0.65	77.59	
	3000	2.9	0.83	71.38	
	3500	2.9	0.93	67.93	
	4000	2.9	0.77	73.45	
	4500	2.9	0.83	71.38	
	5000	2.9	0.81	72.07	
10 ml/min	500	2.9	0.66	77.24	74.14
	1000	2.9	0.67	76.90	
	1500	2.9	0.72	75.17	
	2000	2.9	0.73	74.83	
	2500	2.9	0.73	74.83	

	3000	2.9	0.80	72.41	
	3500	2.9	0.83	71.38	
	4000	2.9	0.80	72.41	
	4500	2.9	0.75	74.14	
	5000	2.9	0.81	72.07	
15 ml/min	500	2.9	0.69	76.21	**73.17**
	1000	2.9	0.70	75.86	
	1500	2.9	0.81	72.07	
	2000	2.9	0.80	72.41	
	2500	2.9	0.76	73.79	
	3000	2.9	0.80	72.41	
	3500	2.9	0.85	70.69	
	4000	2.9	0.73	74.83	
	4500	2.9	0.80	72.41	
	5000	2.9	0.84	71.03	
20 ml/min	500	2.9	0.71	75.52	**73.24**
	1000	2.9	0.70	75.86	
	1500	2.9	0.73	74.83	
	2000	2.9	0.77	73.45	
	2500	2.9	0.82	71.72	
	3000	2.9	0.76	73.79	
	3500	2.9	0.78	73.10	
	4000	2.9	0.81	72.07	
	4500	2.9	0.85	70.69	
	5000	2.9	0.83	71.38	
25 ml/min	500	2.9	0.71	75.52	**73.03**
	1000	2.9	0.64	77.93	
	1500	2.9	0.75	74.14	
	2000	2.9	0.67	76.90	
	2500	2.9	0.69	76.21	
	3000	2.9	0.85	70.69	
	3500	2.9	0.92	68.28	
	4000	2.9	0.89	69.31	
	4500	2.9	0.84	71.03	
	5000	2.9	0.86	70.34	
30 ml/min	500	2.9	0.77	73.45	**72.76**
	1000	2.9	0.82	71.72	
	1500	2.9	0.76	73.79	
	2000	2.9	0.80	72.41	
	2500	2.9	0.71	75.52	
	3000	2.9	0.74	74.48	
	3500	2.9	0.85	70.69	
	4000	2.9	0.83	71.38	
	4500	2.9	0.84	71.03	
	5000	2.9	0.78	73.10	
50 ml/min	500	2.9	0.88	69.66	**72.79**
	1000	2.9	0.66	77.24	
	1500	2.9	0.76	73.79	
	2000	2.9	0.79	72.76	
	2500	2.9	0.79	72.76	
	3000	2.9	0.75	74.14	

	3500	2.9	0.80	72.41	
	4000	2.9	0.79	72.76	
	4500	2.9	0.83	71.38	
	5000	2.9	0.84	71.03	
70 ml/min	500	2.9	0.76	73.79	72.14
	1000	2.9	0.76	73.79	
	1500	2.9	0.83	71.38	
	2000	2.9	0.80	72.41	
	2500	2.9	0.85	70.69	
	3000	2.9	0.83	71.38	
	3500	2.9	0.79	72.76	
	4000	2.9	0.75	74.14	
	4500	2.9	0.85	70.69	
	5000	2.9	0.86	70.34	
100 ml/min	500	2.9	0.82	71.72	72.17
	1000	2.9	0.80	72.41	
	1500	2.9	0.77	73.45	
	2000	2.9	0.76	73.79	
	2500	2.9	0.78	73.10	
	3000	2.9	0.74	74.48	
	3500	2.9	0.85	70.69	
	4000	2.9	0.83	71.38	
	4500	2.9	0.87	70.00	
	5000	2.9	0.85	70.69	
150 ml/min	500	2.9	0.79	72.76	72.00
	1000	2.9	0.72	75.17	
	1500	2.9	0.76	73.79	
	2000	2.9	0.79	72.76	
	2500	2.9	0.83	71.38	
	3000	2.9	0.82	71.72	
	3500	2.9	0.84	71.03	
	4000	2.9	0.83	71.38	
	4500	2.9	0.87	70.00	
	5000	2.9	0.87	70.00	
200 ml/min	500	2.9	0.86	70.34	69.38
	1000	2.9	0.85	70.69	
	1500	2.9	0.88	69.66	
	2000	2.9	0.86	70.34	
	2500	2.9	0.89	69.31	
	3000	2.9	0.88	69.66	
	3500	2.9	0.92	68.28	
	4000	2.9	0.90	68.97	
	4500	2.9	0.93	67.93	
	5000	2.9	0.91	68.62	
250 ml/min	500	2.9	0.95	67.24	66.93
	1000	2.9	0.93	67.93	
	1500	2.9	0.95	67.24	
	2000	2.9	0.93	67.93	
	2500	2.9	0.97	66.55	
	3000	2.9	0.96	66.90	
	3500	2.9	0.98	66.21	

	4000	2.9	0.95	67.24	
	4500	2.9	1.00	65.52	
	5000	2.9	0.97	66.55	
300 ml/min	500	2.9	1.01	65.17	64.90
	1000	2.9	0.98	66.21	
	1500	2.9	1.03	64.48	
	2000	2.9	1.00	65.52	
	2500	2.9	1.03	64.48	
	3000	2.9	1.00	65.52	
	3500	2.9	1.04	64.14	
	4000	2.9	1.02	64.83	
	4500	2.9	1.04	64.14	
	5000	2.9	1.03	64.48	
350 ml/min	500	2.9	1.10	62.07	61.21
	1000	2.9	1.07	63.10	
	1500	2.9	1.12	61.38	
	2000	2.9	1.09	62.41	
	2500	2.9	1.14	60.69	
	3000	2.9	1.11	61.72	
	3500	2.9	1.15	60.34	
	4000	2.9	1.14	60.69	
	4500	2.9	1.18	59.31	
	5000	2.9	1.15	60.34	

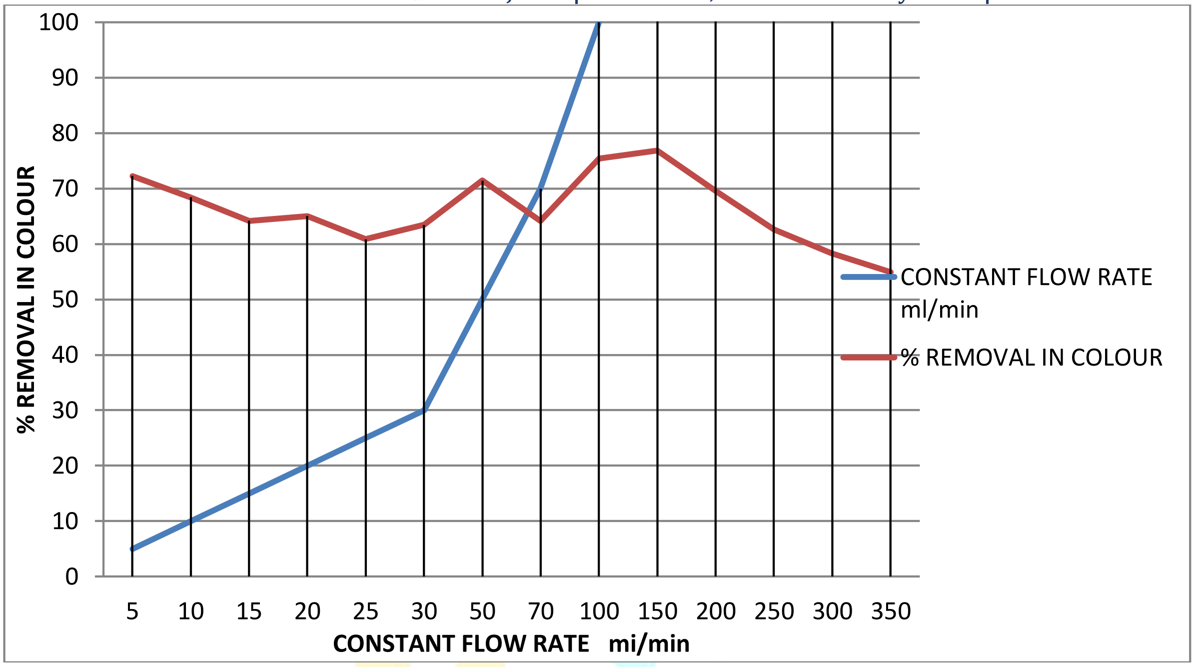


% REMOVAL IN COLOUR

CONSTANT FLOW RATE ml/min	PASSED VOLUME IN ml	RAW COLOUR pt.co.	TREATED COLOUR pt.co.	% REMOVAL IN COLOUR	% REMOVAL IN COLOUR
5 ml/min	500	20.5	5.95	70.98	73.63
	1000	20.5	7.6	62.93	
	1500	20.5	5.7	72.20	
	2000	20.5	5.67	72.34	
	2500	20.5	5.6	72.68	
	3000	20.5	5.39	73.71	
	3500	20.5	4.92	76.00	
	4000	20.5	4.57	77.71	
	4500	20.5	4.75	76.83	
	5000	20.5	3.91	80.93	
10 ml/min	500	20.5	9.03	55.95	70.87
	1000	20.5	8.6	58.05	
	1500	20.5	7.88	61.56	
	2000	20.5	7.47	63.56	
	2500	20.5	7.11	65.32	
	3000	20.5	6.65	67.56	
	3500	20.5	4.4	78.54	
	4000	20.5	4.17	79.66	
	4500	20.5	3.14	84.68	
	5000	20.5	1.26	93.85	
15 ml/min	500	20.5	7.68	62.54	66.60
	1000	20.5	7.25	64.63	
	1500	20.5	7.06	65.56	
	2000	20.5	6.68	67.41	
	2500	20.5	7.03	65.71	
	3000	20.5	6.77	66.98	
	3500	20.5	7.36	64.10	
	4000	20.5	6.44	68.59	
	4500	20.5	6.24	69.56	
	5000	20.5	5.95	70.98	
20 ml/min	500	20.5	6.55	68.05	67.49
	1000	20.5	7.44	63.71	
	1500	20.5	6.43	68.63	
	2000	20.5	6.61	67.76	
	2500	20.5	6.61	67.76	
	3000	20.5	6.54	68.10	
	3500	20.5	6.91	66.29	
	4000	20.5	6.83	66.68	
	4500	20.5	6.33	69.12	
	5000	20.5	6.4	68.78	
25 ml/min	500	20.5	9.84	52.00	63.28
	1000	20.5	9.42	54.05	
	1500	20.5	8.48	58.63	
	2000	20.5	8.76	57.27	
	2500	20.5	6.75	67.07	

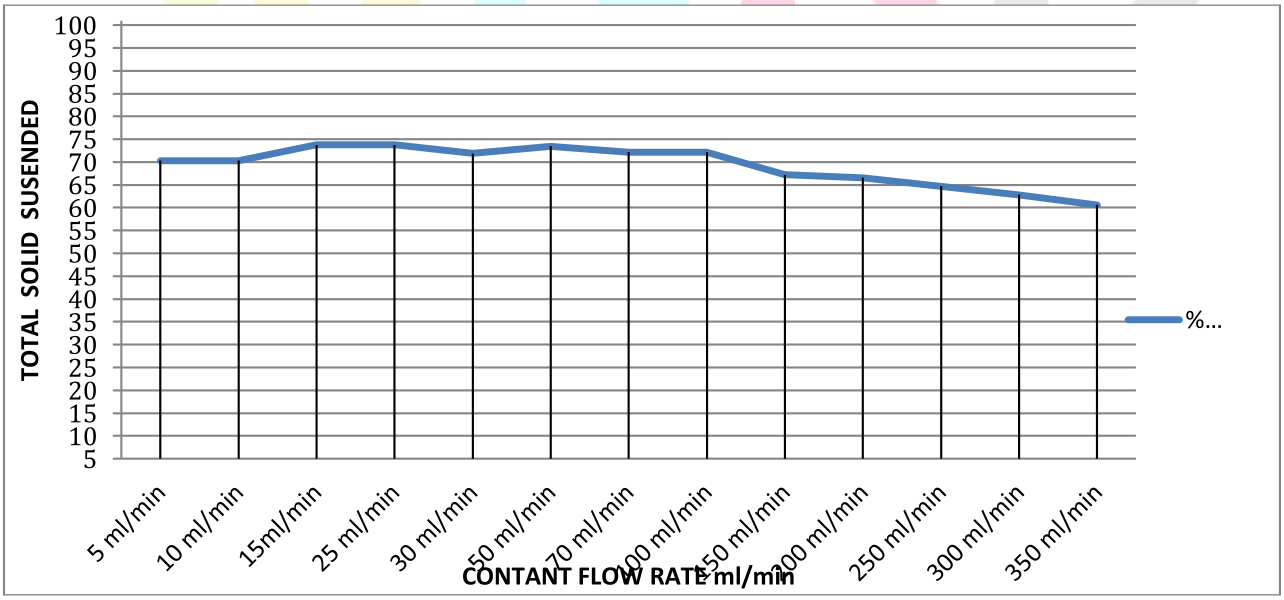
	3000	20.5	6.79	66.88	
	3500	20.5	6.48	68.39	
	4000	20.5	6.58	67.90	
	4500	20.5	6.13	70.10	
	5000	20.5	6.04	70.54	
30 ml/min	500	20.5	7	65.85	65.91
	1000	20.5	7.06	65.56	
	1500	20.5	6.83	66.68	
	2000	20.5	6.32	69.17	
	2500	20.5	7.22	64.78	
	3000	20.5	6.99	65.90	
	3500	20.5	7	65.85	
	4000	20.5	7.14	65.17	
	4500	20.5	7.14	65.17	
	5000	20.5	7.19	64.93	
50 ml/min	500	20.5	5.22	74.54	73.07
	1000	20.5	6.98	65.95	
	1500	20.5	6.7	67.32	
	2000	20.5	5.7	72.20	
	2500	20.5	4.78	76.68	
	3000	20.5	5.55	72.93	
	3500	20.5	5.61	72.63	
	4000	20.5	5.17	74.78	
	4500	20.5	4.91	76.05	
	5000	20.5	4.58	77.66	
70 ml/min	500	20.5	6.98	65.95	66.55
	1000	20.5	5.45	73.41	
	1500	20.5	6.51	68.24	
	2000	20.5	7.19	64.93	
	2500	20.5	6.78	66.93	
	3000	20.5	6.78	66.93	
	3500	20.5	7.17	65.02	
	4000	20.5	7.17	65.02	
	4500	20.5	7.33	64.24	
	5000	20.5	7.22	64.78	
100 ml/min	500	20.5	7.11	65.32	77.50
	1000	20.5	6.6	67.80	
	1500	20.5	6.35	69.02	
	2000	20.5	5.83	71.56	
	2500	20.5	4.79	76.63	
	3000	20.5	3.64	82.24	
	3500	20.5	3.35	83.66	
	4000	20.5	3.33	83.76	
	4500	20.5	2.42	88.20	
	5000	20.5	2.7	86.83	
150 ml/min	500	20.5	4.91	76.05	79.34
	1000	20.5	4.52	77.95	
	1500	20.5	3.93	80.83	
	2000	20.5	4.17	79.66	
	2500	20.5	4.36	78.73	
	3000	20.5	4.09	80.05	

	3500	20.5	4.11	79.95	
	4000	20.5	4.11	79.95	
	4500	20.5	3.99	80.54	
	5000	20.5	4.17	79.66	
200 ml/min	500	20.5	4.9	76.10	71.38
	1000	20.5	4.91	76.05	
	1500	20.5	5.01	75.56	
	2000	20.5	6	70.73	
	2500	20.5	5.78	71.80	
	3000	20.5	6.41	68.73	
	3500	20.5	6.39	68.83	
	4000	20.5	6.61	67.76	
	4500	20.5	6.43	68.63	
	5000	20.5	6.24	69.56	
250 ml/min	500	20.5	6.55	68.05	65.01
	1000	20.5	6.84	66.63	
	1500	20.5	7.02	65.76	
	2000	20.5	7.04	65.66	
	2500	20.5	7.62	62.83	
	3000	20.5	7.54	63.22	
	3500	20.5	7.6	62.93	
	4000	20.5	7.29	64.44	
	4500	20.5	7.25	64.63	
	5000	20.5	6.98	65.95	
300 ml/min	500	20.5	7.63	62.78	59.59
	1000	20.5	7.82	61.85	
	1500	20.5	7.7	62.44	
	2000	20.5	7.97	61.12	
	2500	20.5	8.21	59.95	
	3000	20.5	9.8	52.20	
	3500	20.5	8.22	59.90	
	4000	20.5	8.5	58.54	
	4500	20.5	8.57	58.20	
	5000	20.5	8.42	58.93	
350 ml/min	500	20.5	8.6	58.05	57.32
	1000	20.5	8.57	58.20	
	1500	20.5	8.64	57.85	
	2000	20.5	8.83	56.93	
	2500	20.5	9.03	55.95	
	3000	20.5	9.03	55.95	
	3500	20.5	8.83	56.93	
	4000	20.5	8.81	57.02	
	4500	20.5	8.6	58.05	
	5000	20.5	8.56	58.24	



% REMOVAL IN TOTAL SUSPENDED SOLIDS

CONSTANT FLOW RATE ml/min	PASSED VOLUME IN ml	TOTAL VOLUME TAKEN FOR TSS	RAW TOTAL SUSPENDED SOLIDS	TREATEDTOTAL SUSPENDED SOLIDS	% REMOVAL IN TOTAL SUSPENDED SOLIDS	% AVERAGEREMOVAL IN TSS
5 ml/min	**1000 ml**	**50**	**3.88**	**1.07**	**72.42**	**70.30**
10 ml/min	**1000 ml**	**50**	**3.88**	**1.07**	**72.42**	
15ml/min	**1000 ml**	**50**	**3.88**	**0.94**	**75.77**	
25 ml/min	**1000 ml**	**50**	**3.88**	**0.94**	**75.77**	
30 ml/min	**1000 ml**	**50**	**3.88**	**1.02**	**73.71**	
50 ml/min	**1000 ml**	**50**	**3.88**	**0.95**	**75.52**	
70 ml/min	**1000 ml**	**50**	**3.88**	**0.99**	**74.48**	
100 ml/min	**1000 ml**	**50**	**3.88**	**1.30**	**66.49**	
150 ml/min	**1000 ml**	**50**	**3.88**	**1.25**	**67.78**	
200 ml/min	**1000 ml**	**50**	**3.88**	**1.30**	**66.49**	
250 ml/min	**1000 ml**	**50**	**3.88**	**1.30**	**66.49**	
300 ml/min	**1000 ml**	**50**	**3.88**	**1.39**	**64.18**	
350 ml/min	**1000 ml**	**50**	**3.88**	**1.46**	**62.37**	



Conclusion:

The present study investigated the adsorption performance of walnut crust for the tertiary treatment of secondary sewage effluent, focusing on the removal of color, turbidity, and suspended solids. The experimental results demonstrated that walnut crust is a promising adsorbent for enhancing the quality of treated sewage effluents. The adsorption experiments conducted at various flow rates revealed that walnut crust exhibited significant removal efficiencies for color, turbidity, and suspended solids. The highest color removal efficiency of 93.85% was achieved at a flow rate of 10 ml/min, while the maximum turbidity removal efficiency of 79.31% was observed at a flow rate of 5 ml/min. The suspended solids removal efficiency reached 75.77% at a flow rate of 15 ml/min. These results highlight the effectiveness of walnut crust in simultaneously removing multiple contaminants from secondary treated sewage. The experimental data also indicated that the adsorption performance of walnut crust was influenced by the flow rate. Lower flow rates generally resulted in higher removal efficiencies, which can be attributed to the increased contact time between the adsorbent and the contaminants. However, it is important to consider the practical implications of operating at low flow rates, as it may affect the overall treatment capacity and throughput of the system.

The adsorption mechanism of walnut crust can be attributed to its unique structural and chemical properties. The presence of functional groups, such as carboxyl, hydroxyl, and phenolic groups, on the surface of walnut crust facilitates the binding of contaminants through various interactions, including electrostatic attraction, complexation, and hydrogen bonding. The porous nature of walnut crust also contributes to its adsorptive capacity by providing a large surface area for contaminant adsorption. The findings of this study have significant implications for the development of sustainable and cost-effective tertiary treatment technologies for sewage effluents. Walnut crust, being an agricultural waste material, offers several advantages over conventional adsorbents like activated carbon. It is readily available, renewable, and requires minimal processing, making it an economically viable option for wastewater treatment. Furthermore, the use of walnut crust as an adsorbent aligns with the principles of circular economy and waste valorization. By utilizing agricultural waste for wastewater treatment, this approach not only addresses the issue of waste management but also provides a value-added application for walnut crust, which would otherwise be discarded.

However, it is important to acknowledge the limitations of the present study and the need for further research. The experiments were conducted at a laboratory scale, and the scalability and long-term performance of walnut crust in real-world wastewater treatment plants need to be evaluated. Additionally, the regeneration and disposal of spent walnut crust adsorbent should be investigated to ensure the sustainability and environmental safety of the process. Future research should also focus on optimizing the adsorption process parameters, such as particle size, bed depth, and regeneration methods, to enhance the efficiency and longevity of the walnut crust adsorbent. The economic feasibility and life cycle assessment of the walnut crust-based adsorption system should be conducted to determine its practicality and environmental impact. In conclusion, this study demonstrates the potential of walnut crust as a sustainable and effective adsorbent for the tertiary treatment of secondary sewage effluent. The high removal efficiencies achieved for color, turbidity, and suspended solids highlight the adsorptive capabilities of walnut crust and its potential to enhance the quality of treated sewage effluents. The utilization of agricultural waste materials, such as walnut crust, for wastewater treatment offers a promising approach towards developing eco-friendly and economically viable solutions for water pollution control. Further research and pilot-scale studies are recommended to validate the findings of this study and pave the way for the implementation of walnut crust-based adsorption systems in real-world wastewater treatment applications.

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