Removal of COD and color using Coconut shell activated carbon

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***Abstract*—Industrial effluent contains high level of Chemical Oxygen Demand (COD) which are the threat to eco-system and health. This study investigates the alternative options for removal of Chemical Oxygen Demand (COD) and color by investigating the adsorption process using Coconut shell activated carbon (CSAC) which is also a sustainable and efficient adsorbent. Adsorbent (CSAC) was evaluated under different operational parameters such as pH, Contact time, adsorbent dosage and initial pollutant concentration. Results illustrate that Coconut shell activated carbon (CSAC) in adsorption process as adsorbent contains high adsorption capacity, achieving upto 75 % removal of COD and 99% removal of color. This thesis was carried out to reduce the load in biological treatment. This study concludes the potential of coconut shell activated carbon as cost effective, ecofriendly and efficient adsorbent, supporting its application in sustainable wastewater treatment technologies. The findings support the potential of adsorption as an efficient, economical, and scalable approach for wastewater treatment, contributing to sustainable environmental management practices.**

Keywords—COD reduction, Adsorption, Color removal, Coconut shell activated carbon.

I. INTRODUCTION

Wastewater treatment is the process of removing contaminants from water to make it safe for discharge into the environment or reuse. It is essential for protecting public health, maintaining ecological balance, and ensuring sustainable water management. Wastewater originates from domestic, industrial, and agricultural activities and contains various pollutants such as organic matter, heavy metals, pathogens, and nutrients.

Chemical Oxygen Demand (COD) is a key parameter used to assess the organic pollution level in wastewater. It measures the amount of oxygen required to oxidize organic and inorganic matter in water. High COD levels indicate significant pollution, which can have severe environmental consequences, including oxygen depletion in aquatic ecosystems and toxicity to aquatic life. COD (chemical oxygen demand) removal is essential for wastewater treatment to reduce organic pollution and improve water quality. The primary methods for COD removal include physical, chemical, and biological processes. These methods can be used individually or in combination for enhanced efficiency.

One of the most effective methods for COD removal is adsorption using activated carbon. Activated carbon is a highly porous material with a large surface area, making it an excellent adsorbent for removing organic and inorganic pollutants. The adsorption process works through physical and chemical interactions between the activated carbon and the contaminants in the wastewater.

Adsorbents are materials used to remove contaminants from liquids or gases by adsorption, a surface phenomenon where molecules adhere to the adsorbent's surface. Adsorption plays a crucial role in various industries, including water treatment, air purification, and chemical processing.

II. IMPORTANCE FOR REMOVAL OF COD AND COLOR

Chemical Oxygen Demand (COD) is a critical parameter in wastewater treatment, reflecting the total quantity of oxygen required to chemically oxidize both biodegradable and non-biodegradable organic compounds present in water. High COD levels are commonly associated with industrial discharges, domestic sewage, and agricultural runoff, and can severely impact aquatic ecosystems by reducing the availability of dissolved oxygen, leading to hypoxic conditions and harming aquatic life.

The removal of COD from wastewater is essential to meet environmental discharge regulations, prevent

water pollution, and enable water reuse in industrial, agricultural, or even potable applications. Since COD comprises a broad spectrum of organic and inorganic pollutants, its removal is complex and often requires a multi-stage treatment approach. The choice of method depends on factors such as the nature of the pollutants, concentration of COD, biodegradability, treatment cost, space availability, and end-use of treated water.
Color in wastewater is not just an aesthetic concern—it often indicates the presence of harmful pollutants, particularly from industrial sources such as textiles, pulp and paper, leather tanning, dye manufacturing, food processing, and petrochemical industries. Colored effluents can reduce light penetration in water bodies, disturbing aquatic life and photosynthesis, and some colorants are toxic, carcinogenic, or resistant to degradation. Removing color from wastewater is both an environmental necessity and a regulatory requirement. Due to the complex nature of color-causing compounds—especially synthetic dyes—color removal is a challenging task. These compounds are often highly soluble, stable, and resistant to biodegradation, requiring specialized treatment processes. Color removal technologies can be broadly categorized into physical, chemical, biological, and advanced methods. In most cases, an integrated or hybrid treatment approach is employed to achieve effective decolorization and meet discharge or reuse standards.

III. CHARACTERISTICS OF ADSORBENT

Component	Typical Content (%)	Remarks
Cellulose	30–35%	Provides structural strength
Hemicellulose	20–25%	Decomposes at lower temperatures
Lignin	30–35%	Important for carbon yield during pyrolysis
Extractives (oils, resins)	5–10%	Removed during pre-treatment sometimes
Ash (Minerals)	0.5–2%	Mainly silica (SiO_2), minor K, Ca, Mg, Na
Moisture Content	5–10%	Depends on drying/preparation

Element	Content (%)
Carbon (C)	45–50%
Hydrogen (H)	6–7%
Oxygen (O)	42–49%
Nitrogen (N)	<1%
Ash (minerals)	~1%

IV. LITERATURE REVIEW

(Hadid Sukmana et al, 2019) theory suggest that adsorption and coagulation are the most commonly used methods and have the most advantage due to low costing, it nature of practice and efficiency compare to other methods. They effectively remove pollutants and can achieve good standard of waste water quality. Other part suggests that despite of its most commonly used method, area of exploration of new research can be done in terms of natural resources for adsorption. This paper also suggested that agricultural waste is the best natural resource which can be used as natural adsorbent and due to its availability is vast it creates the opportunity to use with various different methods. It can be used in various wastewaters and multiple examinations can be used with natural adsorbent either by making it a composite or by single use. It can also become sustainable to environment. This paper suggests to open a wide investigation on application of natural adsorbent in industrial wastewater to obtain the appropriate efficiency of the adsorbent.[1]

(Nagireddi Jagadeesh et al,2023) suggests that biochar is a functional material prepared under controlled thermal decomposition of organic feedstock from crops, forestry residue, sewage sludge, algae biomass and poultry manure. Due to its property biochar has been widely used as an adsorbent to remove wide range of pollutant such as organic, microplastic, heavy metals, and nutrient from different types of wastewaters. This paper has suggested few scopes work such as, to commercialization of the biochar and it quality requirement. Environment risk assessment should be done while employing the biochar for environment rehabilitation.[2]

(Sunil Valand et al, 2019) proposed a new convention flow of waste water treatment. Study was done to check the adsorbent efficiency of two adsorbent, one is Earth fuller and the other is Activated carbon. This study concludes that the reduction is achieved more in acidic effluent rather than neutral or basic for both the adsorbent. Also, it was also observed that the more time and quantity of the adsorbent is used, reduction is more in COD, Mean the decrease in the COD is directly proportion to the time and quantity of the adsorbent. Further it was also observed that fuller earth adsorbent are very cost effective and efficient as compared to activated carbon. [3]

(Sherif Alsherbenya et al, 2021) carried out study for removal of 10 different pesticides (viz., chlorfenvinphos, profenofos, atrazine, malathion, chlorpyrifos, cyprodinil, dimethoate, diuron, ethion, and diazinon) from aqueous solution. Isotherms and kinetics of adsorption mixture was carried out. Adsorption equilibrium was achieved at 60 mins of the trial. pH has played a major role in pesticide removal as the adsorption capacity of the Corn cob biochar was increased at 3 pH. This adsorption also is also dependent on the hydorphobocity of each pesticide. This study sugges that adsorption kinetics of pseudo-first order model were better compare to other models. Also, Adsorption equilibrium data were compares with different models where result indicated that it match with Langmuir model for rate of adsorption. This study concluded that this biochar is an eco-friendly and economic sorbent in the removal of pesticides mixture from water.[4]

Thamiris Ferreira de Souza (et al, 2024) suggested that combination of biochar adsorbent can be more effective if, combined with other wastewater treatment, can be effective in removing pesticides. The adsorption capacity depends both on adsorbent and pesticide. Material modifications can result in achieving the highly restricted norms. Artificial intelligence can be very useful in processing data and decision making.[5]

Liming Zhang(et al, 2020) say that mango peels were pyrolyzed on different temperature to check the efficiency of the pyrolysis process on each adsorbent. Mango peel has been efficient in removing Cd(II) from wastewater. Pseudo-second-order model and Langmuir adsorption isotherm model were well fitted. Also, at 2 g/litre of mango peel, pH around 6-8 mostly neutral and time about 480 mins were the optimum dosing and result were satisfactory. It is a good alternative adsorbent for removal of Cd(II) from heavy metal wastewater. EDS analysis and FT-IR and XRD result of before and after Cd(II) adsorption shows that cation exchange, complexation reaction with oxygen containing functional groups and surface precipitation of Cd carbonates were the important and main mechanism of adsorption.[6]

Flávia Rhuana Pereira Sales (et al, 2018) suggest the adsorbent substrate proved effective in reducing key physicochemical parameters, particularly chloride hardness, acidity, and pH. This indicates strong potential for reusing the treated effluent in irrigated agriculture, especially in water-scarce regions. The adsorption technique enhanced the water quality of effluent from the Gramame ETA, aligning with CONAMA Resolution No. 357/2005 standards. While unsuitable for human consumption, the treated effluent can significantly contribute to agricultural water availability. Given the scarcity of water in Brazil's Northeast, this method offers a practical and sustainable reuse solution. Continuous-flow column adsorption is thus validated as a viable technology for water reuse in real wastewater treatment scenarios. [7]

Amro A. El-Baza (et al, 2020) suggest adsorption can reduce the organic compounds that are either soluble or insoluble and can be used for the treatment of organic as well as inorganic contaminants from different polluted water sources. It shows the mechanism and removal of different organic and inorganic removal by different types of adsorbents. Also, different modes of kinetic, isotherms and effect of multiple ions were shown. Adsorption process is a good method for removal of these pollutant. It also showed sweet lemon peel biochar (Cirtus limetta) for removal of Pb^{+2} has the largest adsorption capacity for heavy metals from literature, which has low cost adsorbent and can be used in replacement of activated carbon. It also suggested that presence of two or more than one pollutant could affect the adsorption capacity of the adsorbent. Batch process are effective way to analyse the adsorbent capacity and can not be used for column design. Adsorption capacity can be improved with the help of chemical modification.[8]

Samiksha Gaikwad (et al,2015) suggested that sugar bagasse fly ash can be obtained in large quantities as a waste product and granular activated carbon manufactured from coconut shell is designed to reduce the Odors and dissolved organic chemicals from both municipal and industrial wastewater. In this review both of them individually and composite of both are used as adsorbent to check the efficiency of the adsorbent. This study lead to that reduction in coconut shell activated carbon showed more promising results that sugarcane bagasse and both composite mixture of different proportions. Coconut shell activated carbon gave the maximum efficiency in reduction of COD. [9]

AKA Rathi (et al, 2001) suggested new treatment flow as wastewater---Adsorption---pH adjustment---Physicochemical / Biological treatment---Treated wastewater which previously was wastewater---pH adjustment---Physicochemical / Biological treatment--- Adsorption---Treated water. Also, different model for predicting COD such as Weber and Morri's equation, Lagergren equation and Rathi Puranik equation. Out of all the equation it was found that Rathi Puranik model for predicting COD was easiest and requires two data points, while other models require detail experimentation on a given system. Also, Adsorbent used in adsorption process was activated carbon, bentonite and lignite in the treatment of wastewater. Out of all the adsorbent it was found that lignite shows the best promising results and are also cost effective compared to others. The prediction of COD and COD equilibrium can help design the effective adsorption system. [10]

V. MATERIAL AND METHODOLOGY

Preparation of Raw material

Coconut shells were collected from various anonymous locations and thoroughly cleaned to remove materials such as fibers, soil, and other impurities. The shells were then washed with fresh water for further purification and dried under sunlight for more than a week to eliminate moisture. To ensure complete dryness, the shells were subsequently placed in a hot air oven at 105 °C for 24 hours.

A stainless-steel drum, fabricated from scrap material, was used for carbonization. The cleaned coconut shells were placed inside the drum, which was then sealed. A mild steel (MS) pipe was inserted into the drum to allow smoke to escape during the pyrolysis process. The drum was placed over a stove-like structure on soil and heated using wood and paper as fuel for approximately 3–4 hours. After cooling to room temperature, the charred product was collected.

The char was then activated by heating it at 850 °C. The resulting activated charcoal was collected and ground into a fine powder. A 100-mesh sieve (approximately 150 microns) was used to obtain uniform particle sizes suitable for the adsorption process.

Lab Experiment

Coconut Shell activated carbon was sieved by particle size 150 micron and were used for different sample size and at different pH. Wastewater used for the adsorption process was taken from the Agrochemical industries. Colour removal was also observed during the analysis.

Characteristics of the sample was as follows:

pH	10.1
TDS	1100
COD	3800
Adsorbent Size	150 Micron

Different analysis was done on different dosage such as 1 gm adsorbent was used on pH 2,4,7 & 10. Further for all dosage of 2,3,5,7,10,12 gm of adsorbent was used in different pH of 2,4,7 &10. Total time duration for each experiment were 120 minutes and each 20 minutes, samples were drawn for analysis of COD and color. Adsorption equilibrium was observed within 100 to 120 minutes.

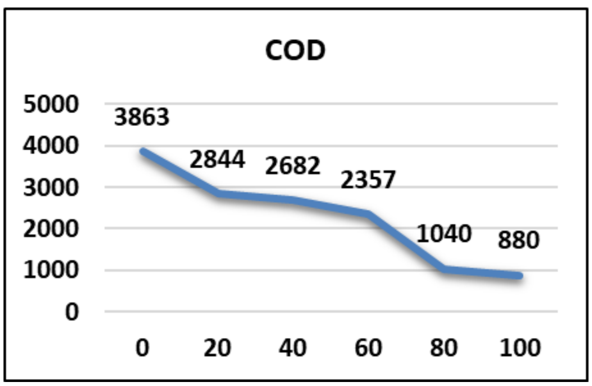
Sample with pH 10 was taken in a 500 ml beaker. Sulphuric Acid of 98% concentration (lab scale) was used to reduce the pH from 10 to 2,4,7,10. Approximately 6, 4.5, & 2 ml of conc. Sulphuric acid was use for the reduction in pH respectively.

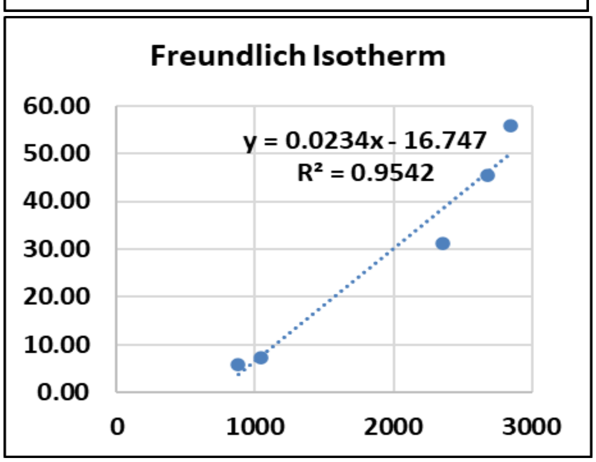
Sample was mixed with 1,2,3,5,7,10,12 gm of adsorbent (CSAC) into 500 ml sample and was kept on magnetic stirred. RPM were set to 350 and mixing was done. Initial pH, TDS and COD were observed. After interval of 20 minutes samples were drawn. Further Sample was filter with Watman filter 42 until all the wastewater completely drawn out from the filter paper. Again pH, TDS, COD, and colour were observed. COD was done using Open flux method. Total time for experiment taken was 120 minutes and mostly at 100 minutes, adsorption equilibrium was achieved.

VI. RESULTS AND DISCUSSION

Below is the analysis result of 10 gm charcoal used in 500 ml waste water sample

10 GM charcoal IN 500 ML sample with filter					
Time	PH	TDS	COD	% reduction	Difference
0	10	1080	3863		
20	10.3	1090	2844	26.38	
40	10.3	1100	2682	30.57	4.19
60	10.5	1120	2357	38.99	8.41
80	10.6	1170	1040	73.08	34.09
100	10.8	1200	880	77.22	4.14





Charcoal is highly effective in reducing COD from wastewater, especially between 60–80 minutes. Optimal contact time appears to be around 80–100 minutes for maximum efficiency. The model supports the idea that adsorption increases with concentration. The positive slope (0.0234) and high R^2 value suggest that the adsorption of COD onto charcoal follows the Freundlich isotherm well. The Freundlich isotherm is appropriate for modeling the adsorption behavior in your experiment. The high R^2 value confirms that charcoal is effective in adsorbing COD from the solution, especially at higher concentrations.

VII. CONCLUSION

The efficacy of Coconut shell activated carbon as an adsorbent for the removal of COD and color from the wastewater using batch adsorption process was investigated. To evaluate the Coconut shell activated as a cost-effective and environmentally sustainable alternative to other commercial activated carbon in removal of COD and color, study was carried out.

Due to high surface area, microporous structure and abundant surface functional group, Coconut shell activated carbon has performed best. Under optimized conditions such as pH 10, Contact time 100 minutes and adsorbent dosage was 10 gm / 500 ml, Coconut shell achieved removal of 75 percent removal of COD and crystal-clear appearance of wastewater after filtration with Watman filter no.42. The particle size of adsorbent CSAC was 150 microns. Further, optimised condition such as pH 7.0, Contact time 100 minutes and dosage around 5 gm / 500 ml, removal of COD was observed around 57 percent and crystal color appearance of wastewater after filtration with Watman filter no.42

These results confirm that coconut shell-derived activated carbon is not only effective but also comparably efficient to commercial activated carbons in treating organic and dye-laden effluents.

The adsorption process was significantly influenced by the physicochemical conditions of the system. Neutral pH values favoured the adsorption of organic compounds, likely due to increased electrostatic interactions between the protonated adsorbent surface and negatively charged pollutants. The dosage of CSAC played a crucial role, as increased surface area and available active sites led to enhanced adsorption. The contact time required for equilibrium further supported that adsorption kinetics are relatively fast, making CSAC suitable for practical applications.

In addition to technical performance, CSAC stands out for its environmental and economic advantages. Being derived from agricultural waste, coconut shell-based carbon supports circular economy principles by transforming biomass waste into a valuable treatment material. The use of CSAC offers a dual benefit: reducing solid waste disposal issues in coconut-producing regions and mitigating water pollution caused by industrial discharges.

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Feel free to personalize the acknowledgment section further based on your experiences and the specific contributions of individuals involved.

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