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Application of Activated Carbon in the Treatment of Domestic Effluent: A Comparative Analysis

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Abstract: *The lives of humans and animals are affected straight by the amount of harmful substances in water streams. Municipal wastewaters contains dissolved pollutant can therefore contaminate water resources and causes grave water/ environmental problem. In the current study, sorption capacities of Coconut Shell, Corn Cobs, Rice husk and Sugarcane Bagasse were examined for the treatment of domestic wastewater. The percent removal of Biochemical Oxygen Demand, Chemical Oxygen Demand and Turbidity increases with increase in impregnation ration and temperature. Freundlich and Langmuir isotherms were employed to the obtained data to check for fitness of the models. The percentage removal for Biochemical Oxygen Demand, Chemical Oxygen Demand and Turbidity for Rice Husk are 89%, 100% and 100%, Sugarcane Bagasse: 89%, 100% and 100%, Coconut Shell: 78%, 97% and 70% and Corn Cobs: 78%, 97% and 63% respectively. A Langmuir and Freundlich model adequately fits the adsorption data with coefficient of determination (R^2) near unity. The present data confirms that activated carbon from Rice Husk, Sugarcane Bagasse, Coconut Shell and Corn Cobs may be used as effective adsorbent for treatment pollutant from aqueous solutions.*

Keywords: *Comparison, Activated Carbon, Domestic wastewater, Sorption.*

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1. Introduction

One of nature's best gifts to mankind is water. The deterioration of this best gift due to pollution as result of release of toxic chemicals is a matter of serious concern. Advanced industrialization and weak of regulations have collectively compounded the problem. Palatable and high quality water is necessary for human life and satisfactorily clean water is required for domestic, agricultural, commercial as well as industrial activities [1].

In the recent past decades, water quality is deteriorating basically as result of human interference, unchecked urbanization, population explosion, increased industrialization and improper use of natural water resources. Additionally, enlightenment as regards the devastating effect of water pollution and waste generation on the environment has re-align the research community towards the development of stable, economically appealing and environmentally friendly techniques which can remove pollutants from water streams as well as protecting the well-being of affected populations [2].

So research into new extraction methods and purification techniques for wastewater treatment has become essential. Some of these techniques have been successful, but with high cost implication and at the expense of the environment. The release of harmful substance into water has become a significant problem to environmental engineers today due to the pollution of water and environment.

Different treatment methods are available with efficiencies in controlling and minimizing water pollution. Methods like Ion exchange, membrane filtration, coagulation, solvent extraction, and Chemical precipitation were widely used, but these methods has shortcoming is large sludge production and concentrated residual contaminants. Subsequently, most of these methods have high cost operation and maintenance and cumbersome method involved in the treatment. This has led to the development of new adsorption techniques [3]. Relatively, adsorption method is preferred as better option in water and wastewater treatment due to simplicity of design, convenience, ease of operation and affordability [4].

In wastewater treatment plants (WWTPs), for the removal of dissolved contaminants adsorption processes are applied. Today, the most commonly adopted adsorbent is the activated carbon. It is popularly utilized for treatment of heavy metals, dyes and various pollutants [3],[5]. However, its use in treatment plant is carefully controlled because its prohibitive cost [6] added to issues such as the adsorbent regeneration capacity or the disposal of the end-of-life sorbent following different strategies than disposal [7].

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The efficiency of Activated Carbons as adsorbents for variety of pollutants is well documented [8],[9]. It is widely recognized for efficient removal organic compounds than metals and other inorganic pollutants. Several researches are on course to enhance the effectiveness of the carbon surface by using variety of chemicals or appropriate treatment procedures [10] which will enable AC to improve its potential for the removal of certain pollutant in solutions [11].

The major purpose of this research is to investigate and contrast the efficiency of Coconut Shell, Corn Cobs, Rice Husk and Sugar Cane bagasse powder based carbon for the treatment of domestic wastewater. The choices of these materials are based on their availability and low cost.

2. Materials and Methods

2.1 Materials

Materials employed for this research constitute Coconut Shell, Corn Cobs, Rice husk and Sugarcane Bagasse; Wastewater samples were obtained from the campus of M.M. University-Mullana, Others materials were: muffle furnace (electronic furnace), electronic weighing balance, sieves of 1.0mm-1.7mm, Concentrated hydrochloric acid, distilled water, crucibles, pipette, filter papers with several funnels, beakers, glass wool, air oven, desiccators, moisture cans, spatula, conical flasks, sample bottles, measuring cylinders, density bottle, crusher, and pH meter, COD digester, BOD incubator and laboratory shaker etc.

2.2 Methods

2.2.1 Preparation of Activated Carbon

The precursors, after collection was sun dried, crushed and grinded. Sieve size 1.0 – 1.5 mm was used to sieve the grinded material to obtain a uniform size. Raw material of about 500 g was weighed and then put into a muffle furnace. There after the precursor was carbonize.

They were pyrolysed at 300-400°C for 1 hour, distillate formed while carbonizations were collected to prevent air pollution. The pyrolysed precursor (charcoal or char) was allowed to cool prior to transferring into a crucible. It was thereafter grounded into powder by using pestle and mortar and sieved through of 0.150mm sieve-size to get uniform particles. Precursor of about 100 g was impregnated with different chemicals Zinc Chloride $ZnCl_2$ (rice husk and bagasse) [12], Sodium hydroxide NaOH (coconut shell), and Potassium hydroxide KOH (Corn cobs) [13]. 100g was transferred into a beaker mixed with 50% $ZnCl_2$, 1N NaOH, 1N KOH, at different impregnation ratio (1.0, 1.5, 2.0) until thoroughly mixed. Thereafter the paste was then poured into a container, dried at 105°C overnight and thereafter placed into the muffle furnace and heated at different temperatures 500°C, 550°C and 600°C for 1 hour to increase the surface area of the sample and make it a better adsorbent. After it has cooled, it was then washed with mineral free water and the residual filtrate was ensured neutral pH. Further, it was oven-dried at 105°C overnight. Subsequently the Activated Carbon was stored in polyethylene bag, ready for use. Exact process was repeated for the other precursors [14].

2.2.2 Yield

Activated carbon yield can be considered as a parameter of the process efficiency for the chemical activation process. The yield of Activated Carbon showed as the percentage weight of the resultant activated carbon divided by weight of dried precursor [15].

$$\text{(Yield (\%)} = \frac{weight\ of\ activated\ carbon}{weight\ of\ raw\ material} x100$$

2.2.3 Bulk density

For bulk density, a glass cylinder (25 ml) was filled to a known volume activated carbon and dried. The cylinder was tapped to compact the carbon and the bulk density calculated and presented as g ml^{-1} following the formula [16].

$$\frac{(Weight\ of\ dry\ material\ (g))}{(Volume\ of\ Packed\ dry\ materials\ (ml))} \times 100$$

2.2.4 Chemical Oxygen Demand (COD)

COD is widely used as indirect measure of the quantity of organic compound in wastewater. Chemical Oxygen Demand is an important parameter of the quality of water. Denoted in milligrams per liter (mg/L), it shows the mass of oxygen utilized in a liter of solution. The test was conducted as per **IS: 3025 (Part 58) – Reaffirmed 2006.**

Three COD vials with stopper were used. 2.5ml of sample was added to the two vials and the other vial was for blank (distilled water). 1.5ml potassium dichromate reagent was added. 3.5ml sulfuric acid reagent was also added to the vials. The cap tubes were tightly placed and the COD digester was adjusted to 150°c and set for 2 hrs. The COD vials was placed the block digester and heated for 2 hrs. Ferrous ammonium sulfate was transferred into burette and filled to zero. After the COD vials has been removed and cooled to room temperature, the content was poured in a conical flask. Few drops of Ferroin indicator was added, the solution turns bluish green. The content was titrated against ferrous ammonium sulfate until the appearance of reddish brown color. The volumes of ferrous ammonium sulfate used were recorded and COD was determined.

2.3 Batch equilibrium studies

The primarily adsorption test was carried out on Coconut Shell, Corn Cobs, Rice husk and Sugarcane Bagasse to compare their effectiveness in the treatment of domestic wastewater. A known quantity of each adsorbent (1.0 g) was transferred into 250 mL Erlenmeyer flasks containing 100 mL of domestic effluent and then placed in a shaking incubator at 120 rpm for 3 h at 25°C.

Batch adsorption studies were conducted by adding certain amount of activated carbon (Coconut Shell, Corn Cobs, Rice husk and Sugarcane Bagasse) (1.0 g) into 250 mL Erlenmeyer flasks containing 100 mL of different impregnation ratio and temperature. The conical flasks then were placed in a shaking incubator at 120 rpm for 3 h.

There after the effluent was filtered with a filter paper and the residual filtrate was analyzed. The amount of sorption at time t and the percentage removal were calculated according to previous study [17].

3. Results and Discussions

The activated carbon were produced successfully, however, analysis of the data and tests conducted comprising adsorption process by fixed batch mechanism and sample analysis before and after adsorption in the wastewater stream are discussed below.

***Table 1**: Characteristics of domestic wastewater before treatment with activated carbon*

Sr. No.	Parameter	Value
1	Turbidity	76 NTU
3	COD	288 mg/l
4	BOD	77.5 mg/l

The physico-chemical properties of the domestic wastewater obtained from the inlet WWTP at MMU-Mullana was presented in the table above.

***Table 2:** Characteristics of treated wastewater parameters using Activated Carbon prepared at temperature of 500°C with different impregnation ratios showing percentage removal*

Sample	BOD (mg/l)	COD (mg/l)	Turbidity (NTU)
CS1	100	22	28
CS1.5	97	22	42
CS2	100	22	50
CC1	97	44	47
CC1.5	90	67	51
CC2	100	33	54
RH1	90	44	72
RH1.5	97	56	74
RH2	97	67	75
SB1	97	44	75
SB1.5	84	44	75
SB2	84	44	76

***Key**: CS: Coconut shell, CC: Corn Cobs, RH: Rice Husk, SB: sugarcane Bagasse. Various impregnation ratios are indicated by subscripts 1, 1.5 and 2 respectively.*

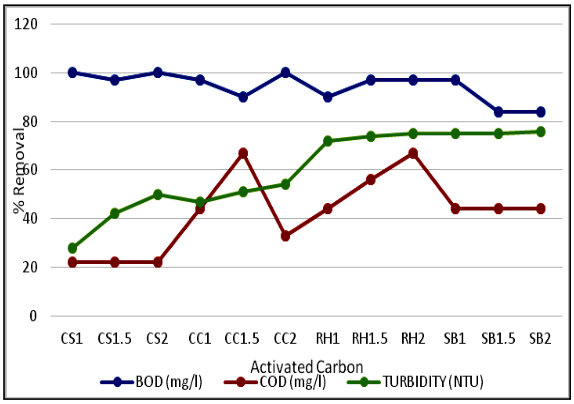

***Figure 1:** Chart showing percentage removal*

The study of batch adsorption of domestic wastewater using activated carbon (CS, CC, RH and SB) which are activated at a temperature of 500°C were presented above. The effects of impregnation ratio and activation temperature were prominent for the fact that impregnation ratio activation temperature were among the most important parameter which determines the adsorption properties of activated carbon [18].

It can be seen from the obtained data of the physico-chemical parameters of the domestic effluent that Coconut Shell Activated Carbon (CSAC) has improved capacity of BOD removal than COD and turbidity. The removal of BOD was 100% at impregnation of 2, while COD is far less with 22% and Turbidity 50%. The effectiveness of Corn Cobs Activated Carbon (CCAC) is appreciable with BOD removal 100% while COD and Turbidity has 67% and 54% respectively.

Rice Husk Activated Carbon (RHAC) was also examined in the studies; it has a BOD removal capacity of 97% while COD was 67% and Turbidity 75%. Similarly Sugarcane Bagasse Activated Carbon (SBAC) activated at a temperature of 500°C has an overall performance of BOD, COD and Turbidity of 97%, 44% and 76% respectively.

From the studies, it can be deduced that the removal efficiency was average, which might be due to the temperature of the activation being moderate mean while the activated carbon with the impregnation ratio of 2 showed improved performance.

***Table 3**: Characteristics of treated wastewater parameters using Activated Carbon prepared at temperature of 550°C with different impregnation ratios showing percentage removal*

Sample	BOD (*mg/l*)	COD (*mg/l*)	Turbidity (*NTU*)
CS1	100	67	71
CS1.5	97	67	72
CS2	100	67	76
CC1	77	56	72
CC1.5	81	67	75

CC2	94	56	76
RH1	90	67	63
RH1.5	93	67	59
RH2	97	67	59
SB1	100	56	59
SB1.5	100	89	54
SB2	97	56	47

***Key**: CS: Coconut shell, CC: Corn Cobs, RH: Rice Husk, SB: sugarcane Bagasse. Various impregnation ratios are indicated by subscripts 1, 1.5 and 2 respectively.*

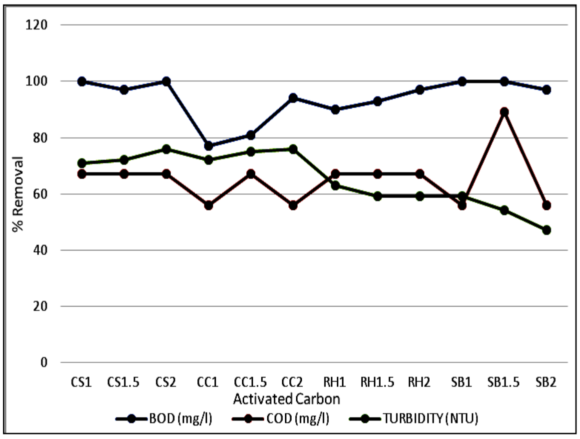

***Figure 2:** Chart showing percentage removal*

Similarly the same activated carbon (CSAC, CCAC, RHAC and SBAC) examined at temperature of 500^{o}C was also tried at a higher temperature 550^{o}C. At this moment the improvements in the adsorptive capacity was visible and have relatively increased.

Checking for the adsorption capacity of Coconut Shell Activated Carbon (CSAC), it can be seen from the data (Table 3) that BOD removal was 100%, COD removal was 67% while Turbidity removal was 76%. Corn cobs AC (CCAC) also showed improved capacity due to the increase in the activation temperature. Its BOD removal was 94%, COD was 67% while turbidity was 76%.

The effect of increase in the activation temperature was also visible in the RHAC and SBAC. The adsorption capacity of RHAC was 97% for BOD, 76% for Cod while Turbidity recorded 63%. Likewise for SBAC the removal efficiency for BOD, COD and Turbidity were 100%, 89% and 59% respectively.

Obviously, there is an increase in adsorptive performance from 500oC to 550oC temperature of activation. Further, the impregnation ratio also showed visible improvement with impregnation ratio 2 showing better performance than 1 and 1.5 respectively (Fig.2).

***Table 4:** Characteristics of treated wastewater parameters using Activated Carbon prepared at temperature of 600^{o}C with different impregnation ratios showing percentage removal*

Sample	BOD (mg/l)	COD (mg/l)	Turbidity (NTU)
CS1	93	67	68
CS1.5	97	67	70
CS2	97	78	63
CC1	93	56	62
CC1.5	93	56	62
CC2	97	78	64
RH1	100	89	78
RH1.5	100	89	78
RH2	100	78	79
SB1	100	78	78
SB1.5	100	78	78
SB2	100	67	79

***Key**: CS: Coconut shell, CC: Corn Cobs, RH: Rice Husk, SB: sugarcane Bagasse. Various impregnation ratios are indicated by subscripts 1, 1.5 and 2 respectively.*

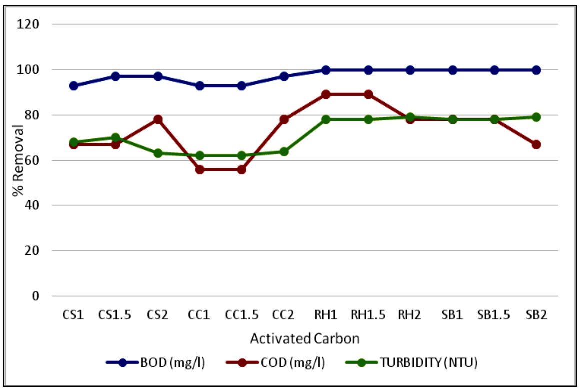

***Figure 3:** Chart showing percentage removal*

Subsequently, the effects of impregnation ratio and activation temperature were further experimented at 600^{o}C temperature. In this case it was clearly seen that the performance were much better than has been recorded at 500^{o}C and 550^{o}c.

The recorded performance for Coconut Shell Activated Carbon (CSAC) were 97% BOD removal at an impregnation ratio of 2 while 93% and 97% are recorded for impregnation ratios of 1 and 1.5 respectively. The COD removal for CSAC with impregnation ratio of 2 was 78% while 1 and 1.5 recorded 67% both. Turbidity readings were 68%, 70% and 63% for impregnation ratios 1, 1.5 and 2 respectively. Performance of CCAC at 600^{o}C were recorded as follows, BOD removal for impregnation of 2 was 97% and 97% for both 1 and 1.5. The best removal of COD was at impregnation ratio (I.R) of 2 with 78% and turbidity recorded 64%.

Rice Husk Activated Carbon (RHAC) and Sugarcane Bagasse Activated Carbon (SBAC) showed very much increase in the adsorptive behaviors with performance as follows, RHAC recorded 100% for all impregnation ratios BOD removal, COD removal 89% for I.R 1 and 1.5 while for I.R 2 was 78%. Turbidity removal RHAC recorded 78% for I.R 1 and 1.5 while 79% was recorded for I.R 2. SBAC also showed 100% flat BOD removal, 78% COD removal while 79% was recorded for Turbidity removal.

From the studied data, it can be deduced that impregnation ratio and activation temperature can greatly affect the adsorptive capacity of activated carbon (CSAC, CCAC, RHAC and SBAC). Subsequent increase in the temperature and impregnation ratio showed and enhancement in the performance of the activated carbon [19].

4. Adsorption mechanism

The adsorption of a substance in aqueous state to the surface of a solid substance causes a thermodynamic process to take place between the two phases when the system reaches equilibrium, in other words, at equilibrium the rate of adsorption and desorption are the same.

Therefore, there is no further net adsorption occurs. A different numerical relationship have been reported to illustrate the equilibrium distribution of solute between the solid and the liquid phases at a fixed temperature and thus helps in the explanation of the adsorption processes. The most common isotherms are Freundlich and Langmuir models. They are applicable for interpretation the adsorption capacity of adsorbents [20].

4.1 Langmuir isotherm

The Langmuir isotherm is derived on the assumption of monolayer adsorption on a homogenous surface. It is expressed by [21]:

$$q_e = \frac{bq_{0}C_e}{1+bC_e} \quad (1)$$

Where q_e is the equilibrium adsorption capacity (mg/g), C_e is the equilibrium concentration (mg/L), b is the Langmuir adsorption constant (L/mg), and q0 is the maximum adsorption capacity (mg/g) [18].

For Langmuir adsorption isotherm, one of the most important parameters is dimensionless constant referred to as equilibrium parameter, RL [22]:

$$R_L = \frac{1}{1+bC_0} \quad (2)$$

Where C_0 is the highest initial solute concentration, b is the Langmuir adsorption constant (L/mg). The value of R_L indicates the type of isotherm to be irreversible ($R_L = 0$), favorable ($0 < R_L < 1$), linear ($R_L = 1$) or unfavorable ($R_L > 1$).

4.2 Freundlich isotherm

The Freundlich isotherm believes heterogeneous surface energies, which is appropriate for the description of multilayer adsorption with interaction between adsorbed molecules. It is expressed by the following empirical equation [23]:

$$q_e = (K_F C_e)^{1/n} \quad (3)$$

Where K_F (L/mg) is the Freundlich adsorption constant and 1/n is the heterogeneity factor.

Langmuir and Freundlich models were applied in this study. The various plots obtained with their coefficient of determination (R^2) were presented below.

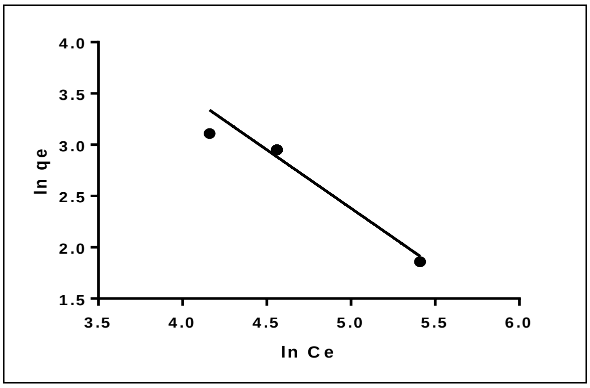

Fig.4: *Freundlich adsorption isotherm of Coconut Shell activated carbon for COD adsorption in domestic wastewater*

The mechanism of adsorption of CSAC corresponds with the Freundlich model more than the Langmuir model. The coefficient of correlation was found to 0.9573. Hence, indicating a favorable adsorption.

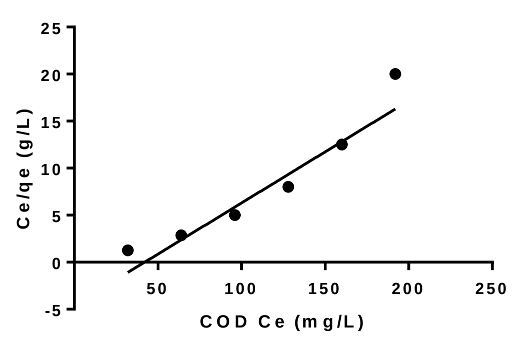

Fig.5: *Langmuir adsorption isotherm of Corn cobs activated carbon for COD adsorption in domestic wastewater*

The CCAC's adsorption model fitted well into Langmuir model more than Freundlich. The Langmuir coefficient of correlation (R^2) was 0.8876 while the separation factor (R_L) value was 0.03098 which is between 0 and 1 indicating a favorable adsorption.

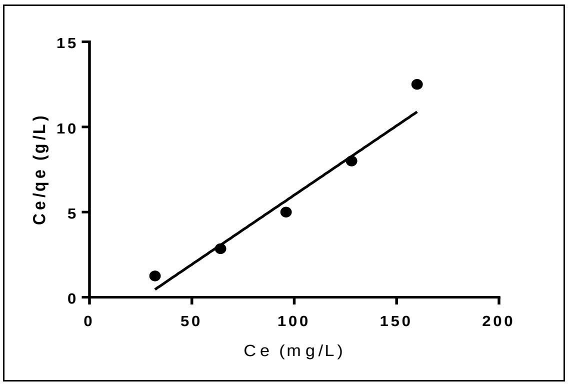

Fig.6: *Langmuir adsorption isotherm of Rice Husk activated carbon for COD adsorption in domestic wastewater*

In the case of RHAC the model of adsorption fitted well with the Langmuir isotherm, having coefficient of correlation (R^2) of 0.9409. The separation factor R_L being a dimensionless number and one of the most important parameter in the Langmuir model was 0.04088 which signifies a favorable adsorption.

Subsequently SBAC's model fitted weakly with both the Freundlich and the Langmuir model with coefficient of correlation (R^2) of 0.7574 and 0.7741 respectively. The separation factor (R_L) in the case of Langmuir was between 0 and 1, hence the adsorption was favorable.

5 Conclusions

The present study showed the adsorptive capacity of activated carbon (Coconut Shell, Corn Cob, Rice Husk and Sugarcane Bagasse) as a promising precursor to be used in the treatment of BOD, COD and Turbidity from municipal wastewater. The study further explain the strong effect of impregnation ratio and temperature on the adsorption strength of activated carbon, which shows the more the temperature and the higher impregnation the better the adsorption capacities. This is the reason in the study that temperature of 600^{o}C and impregnation ratio of 2 were found to be most satisfactory. A Freundlich and Langmuir model adequately explains the characteristics of adsorption by estimating the highest sorption efficiency of sorbent. Equilibrium results are well fitted to Langmuir model with coefficient of determination close to unity.

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