International Journal of Engineering Research and General Science Volume 4, Issue 2, March- April, 2016
ISSN 2091-2730

COLOUR REMOVAL OF TEXTILE DYEING EFFLUENT USING LOW COST ADSORBENTS

Ms.A.Kavitha[1], Ms.G.Sai Pooja[2], Ms.M.Kaaviyavarshini[3]

[1]ASSISTANT PROFESSOR, DEPARTMENT OF CIVIL ENGINEERING, SRIGURU INSTITUTE OF TECHNOLOGY, COIMBATORE.

[2,3]STUDENT, DEPARTMENT OF CIVIL ENGINEERING, SRIGURU INSTITUTE OF TECHNOLOGY, COIMBATORE.

[1]corresponding author E-mail id:kavitha.civil@sriguru.ac.in

Abstract - Many industries like dye industries, textile, paper and plastics use dyes in order to colour their products and also consume substantial volumes of water. As a result they generate a considerable amount of coloured wastewater. The presence of small amount of dyes (less than 1 ppm) is highly visible and undesirable. For the present study the sample effluent is collected from yarn dyeing industry, Coimbatore. The physico-chemical characteristics of the dyeing effluent is carried out according to the standard methods. The characteristics of adsorbents were studied and the selection of natural adsorbents for the colour removal in dyeing effluent is carried out. Experiments were performed to investigate the adsorption capacities of locally available low cost bio-adsorbents like cotton seeds, coconut coir pith, groundnut shell, cotton shell powders to remove colour in a textile industry wastewater. Experimental investigation was carried out to identify the effect of adsorbent dosage, contact time, agitator speed, pH, temperature by using Bach adsorption method. From the experimental investigations, the maximum colour from the textile industry wastewater was obtained at an optimum adsorbent dosage of 300 mg, an optimum contact time of 75 min., an optimum temperature of 330 K and an optimum agitator speed of 600 rpm and optimum pH of 7. Further, from the validation experiments, it was found that the maximum colour removal percentage in textile industry wastewater is about 75.25, 79.9, 86.75 and 81.7 % respectively for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell. This result was higher than the results obtained by different process parameters for various bio adsorbents. Finally, from the results of adsorption study, it was concluded that bioadsorbents used as a coagulant for removing the colour from textile industry wastewater especially peanut hulls powder because of its higher adsorptive capacity than other bio-adsorbents used in this study. The experimental data for the adsorption process were well fitted by the Langmuir adsorption isotherm model relative to the fit of the Freundlich adsorption model.

Keywords— Decolourisation, Natural Adsorbents, Cotton Seeds, Coconut coir pith, Groundnut shell, Bioadsorents, Peanut hulls, Efficiency of adsorbents

1. INTRODUCTION

Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a molecular or atomic film (the adsorbate). It is different from *absorption*, in which a substance diffuses into a liquid or solid to form a solution. The term sorption encompasses both processes, while desorption is the reverse process. Adsorption is operative in most natural physical, biological, and chemical systems, and is widely used in industrial applications such as activated charcoal, synthetic resins and water purification. Similar to surface tension, adsorption is a consequence of surface energy. This chapter explains the methods and materials involved for the colour removal. Activated carbon (AC) as many known as a solid, porous, black carbonaceous material and tasteless. Marsh (1989) defined AC as a porous carbon material, usually chars, which have been subjected to reaction with gases during or after carbonization in order to increase porosity. AC is distinguished from elemental carbon by the removal of all non-carbon impurities and the oxidation of the carbon surface.

2. EXPERIMENTAL SECTION

AC manufactured by the pyrolysis of carbonaceous materials of vegetable origin, such as wood, coal, peat, fruit stones, and shell or synthetic polymer followed by activation of the chars obtained from them (Manocha,2003). The pyrolysis of any carbonaceous material in absence of air involves decomposition of organic molecules, evolution of tarry and gaseous products, and finally in a solid porous carbon mass. An adsorbent with highly developed porosity and correspondingly large surface area is obtained only by activating the carbonized material either by physical or chemical activation. The processing of AC basically involves selection of parameters that effecting the activated carbon production, carbonization process and types of activation. The low cost bio-absorbents like cotton shells, cotton seeds, ground nut shell and coconut coir pith were collected from the local areas and washed repeatedly with distilled water to remove dust and soluble impurities. Initially all bio-adsorbents were kept for drying at room temperature in a shade for 10 h and then heating in an air oven at 473 K for 24 h. Then they crushed and passed through 15-20 mesh. Then, the prepared cotton shells, cotton seeds, ground nut shell and coconut coir pith powders were kept in a refrigerator at a temperature of 278 K. This method used to avoid the decomposition, because cotton shells, cotton seeds, ground nut shell and coconut coir pith are agro-based products.

2.1 PHYSIO-CHEMICAL ANALYSIS OF DYEING EFFLUENT SAMPLE

The physio-chemical analysis of the effluent is essential for the treatment technique. For the present study, collected a textile industry wastewater samples from yarn dyeing industry, Coimbatore city, Tamil Nadu, with the help of airtight sterilized bottles. Then, took the wastewater samples to the Environmental Laboratory and then they were stored in refrigerator at 278 K for analyzing colour intensity.

TABLE 2.1 Physico-Chemical Characteristics of Effluent

S.NO	CHARACTERISTICS	VALUE
1	Chlorides	513.31 mg/l
2	PH	10.5
3	Temperature	30^0C
4	Colour	Dark green
5	Odour	Pungent
6	Turbidity	250 NTU
7	Sulphates	660 mg/l
8	Total hardness as $CaCo_3$	459 mg/l
9	BOD	220 mg/l
10	COD	500 mg/l

TABLE 2.2 Proximate analysis of selected adsorbents

CHARACTERISTICS	COTTON SEEDS	COCONUT COIR PITH	GROUND NUT SHELL	COTTON SHELL
Ph	5.5	5.8	6.2	6
Bulk density	2.11	2.16	2.22	2.18
Attrition	13	15	22	19
Moisture content	8.5%	9.2%	9.7%	9.5%
Ash content	8.2%	7.56%	7%	7.23%
Surface area	1188m^2/g	1127.6 m^2/g	1263.6 m^2/g	1242 m^2/g
Iodine removal	660mg/g	682mg/g	702mg/g	690mg/g
Methylene blue number	18g/100g	20.5g/100g	24.6g/100g	22.30g/100g

3. RESULTS AND DISCUSSION

The parameter such as pH, time, temperature, agitation speed, adsorbent dosage for various are discussed. The colour removal in a textile industry wastewater is to be achieved by using bio-adsorbents like Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell.

3.1 ADSORPTION EXPERIMENTS

Conducted batch adsorption experiments by shaking a series of five glass bottles containing 250 ml textile industry wastewater with different adsorbent dosage (100, 200, 300, 400 and 500 mg), different pH value (4, 5, 6, 7, 8, 9, 10) different contact time (25, 50, 75, 100 and 125 min.), different temperature (300, 310, 320, 330 and 340 K) and different agitator speed (200, 400, 600, 800 and 1000 rpm) . The bottles were tightly fixed in the shaker. The shaking proceeded for 3 hrs to establish equilibrium, after which the mixture was left to settle for 1 h. The filtrate's absorbance was determined by means of the UV-VIS spectrophotometer. By referring to the calibration curve of the absorbance, the percentage reduction of colour from a textile industry wastewater could be obtained. From Fig.2.1, it may be observed that upto some wavelength absorbance increased with wavelength increased, beyond which, the absorbance decreased. The point at which the absorbance decreased is called point of deflection and the wavelength corresponding to the point of deflection is called maximum wave length. The observed maximum wavelength from Fig is 495 nm.

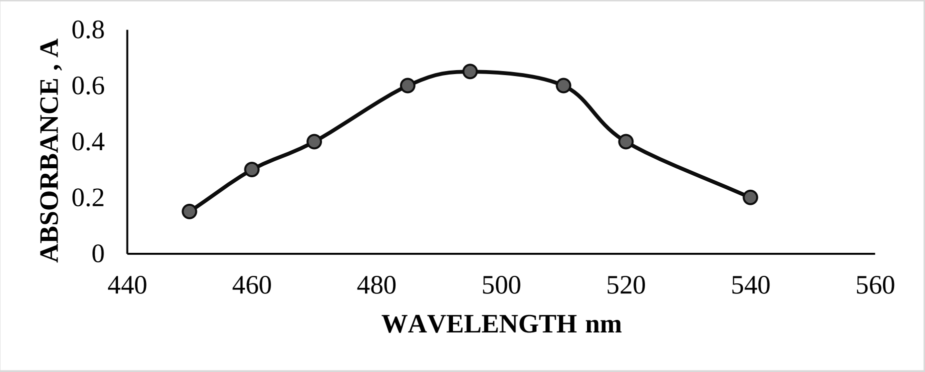


Fig-3.1 Absorbance curve for the textile effluent sample

3.2 EFFECT OF ADSORBENT DOSAGE

The percentage reduction of colour in a textile industry wastewater with pH of 7 against absorbent dosage from 100 to 500 mg with an increment of 100 mg by different bio-adsorbents at contact time of 60 min., temperature 300 K and agitator speed of 400 rpm. The results revealed that colour removal percentage was low at the beginning and then increased with adsorbent dosage increased. This is because, the active sites in the bio-adsorbents could not be effectively utilized when the dosage was low and thereafter bio-adsorbents could be effectively utilized. When the bio-adsorbent dosages are higher, it is more likely that a significant portion of the available active sites remain uncovered, leading to lower specific uptake. From the fig no.2.2 it may be found that an optimum adsorbent dosage at which maximum colour removal is 300 mg and the colour reduction percentage is 75, 78.0, 83.5 and 79.5 % respectively for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell.

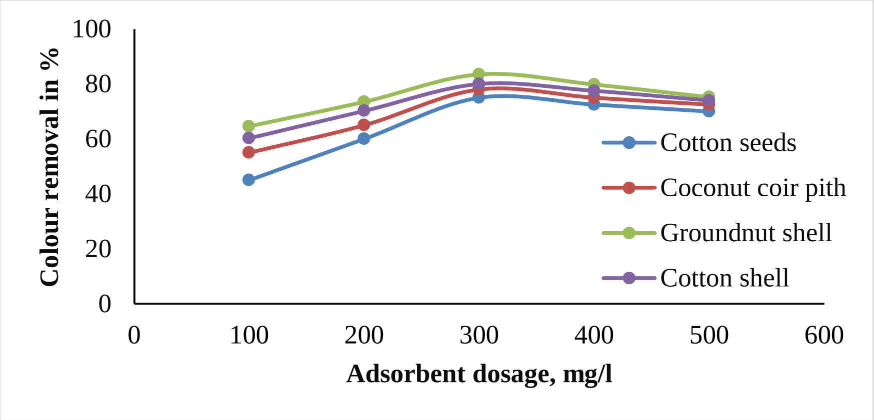


Fig-3.2 Effect of adsorbent dosage on colour removal

3.3 EFFECT OF CONTACT TIME

The percentage reduction of colour in a textile industry wastewater with pH of 7 against contact time from 25 to 125 min. with an increment of 25 min. by different bio-adsorbents at an optimum adsorbent dosage of 300 mg, temperature of 300 K and agitator speed of 400 rpm. The results revealed that the rates of percent colour removal are lower at the beginning of the experiment is probably due to the larger surface area of bioadsorbents was not contacted properly with the textile industry wastewater. Further, as contact time increased, the colour removal percentage also increased, is due to larger surface area of bio-adsorbents was contacted properly with a textile industry wastewater. As surface adsorption sites become exhausted, uptake rate is controlled and transported the adsorbate from the exterior to interior sites of bio-adsorbents. From Fig.2.3, it may be found that an optimum contact time at which maximum colour removal is 75 min. and colour reduction percentage is 72.5, 75, 80.67 and 76.67 % for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell respectively.

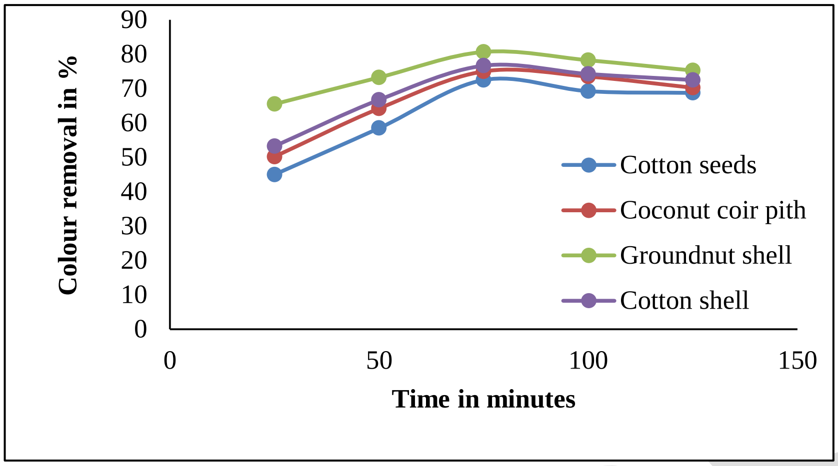


Fig-3.3 Effect of time on colour removal

3.4 EFFECT OF TEMPERATURE

The effect of temperature onto colour removal in a textile industry wastewater with pH of 7 by different bio-adsorbents was investigated at a temperature from 300 to 340 K. with an increment of 10 K and at an optimum adsorbent dosage of 300 mg, an optimum contact time of 75 min and agitator speed of 400 rpm. The percentage of colour removal continuously increased as temperature increased. However, maximum colour removal was obtained at a temperature of 330 K and thereafter equilibrium was attained. Increasing the temperature is known to increase the rate of diffusion of the adsorbate molecules across the external boundary layer and in the internal pores of the adsorbents particle, owing to the decrease in the viscosity of the solution. Thus, a change in temperature will change the equilibrium capacity of the adsorbents for a particular adsorbate. From Fig.2.4, it may be found that an optimum temperature at which maximum colour removal is 330 K and colour reduction percentage is 72.8, 76.2, 81.5 and 77.25% for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell respectively.

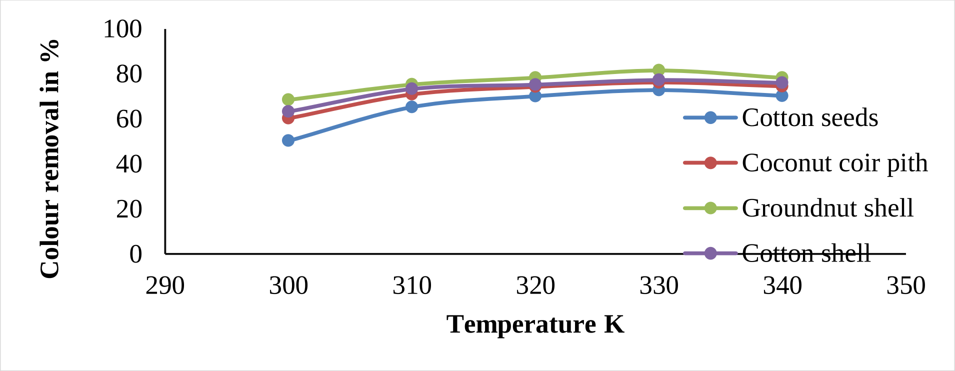


Fig-3.4 Effect of temperature on colour removal

3.5 EFFECT OF AGITATOR SPEED

The influence of agitator speed onto colour removal in a textile industry wastewater with pH of 7 by different bio-adsorbents is to be examined at agitator speed from 200 to 1000 rpm with an increment of 200 rpm and at an optimum adsorbent dosage of 300 mg, contact time of 75 min, and temperature of 330 K. It can be seen that continuous Increment in percentage removal with increasing agitator speed upto 600 rpm, beyond which colour removal attained the equilibrium. From Fig.2.5, it may be found that an optimum agitator speed at which maximum colour removal is 600 rpm and colour reduction percentage is 73.8, 76.9, 82.3 and 78.4 % for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell respectively.

3.6 EFFECT OF PH

The influence of effect of pH in colour removal in a textile industry wastewater with different bio-adsorbents is to be examined at pH varies from 4 to 10 at an optimum adsorbent dosage of 300 mg, contact time of 75 min, and temperature of 330 K, agitator speed of 400 rpm. It can be seen that continuous increment in percentage removal with increasing pH value upto 7, beyond which colour removal attained the equilibrium. From Fig.2.6, it may be found that an optimum pH value at which maximum colour removal is 7 and colour reduction percentage is 72.75, 75.75, 81.25 and 78.25 % for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell respectively.

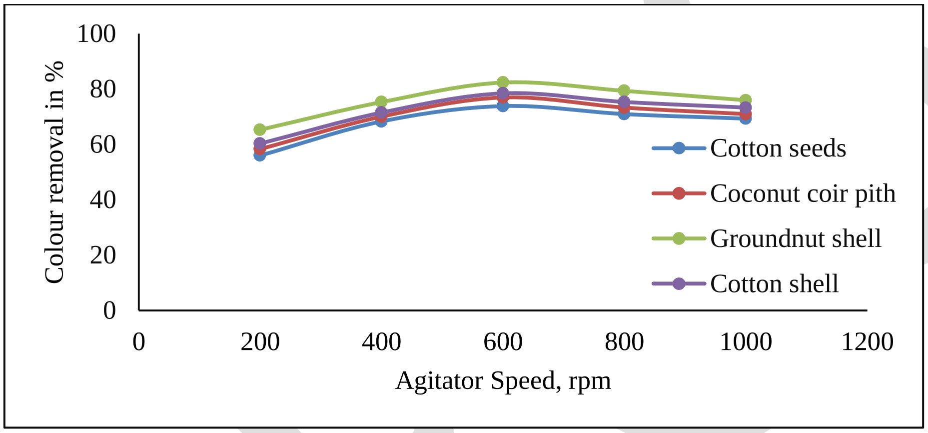


Fig-2.5 Effect of Agitator Speed on Colour Removal

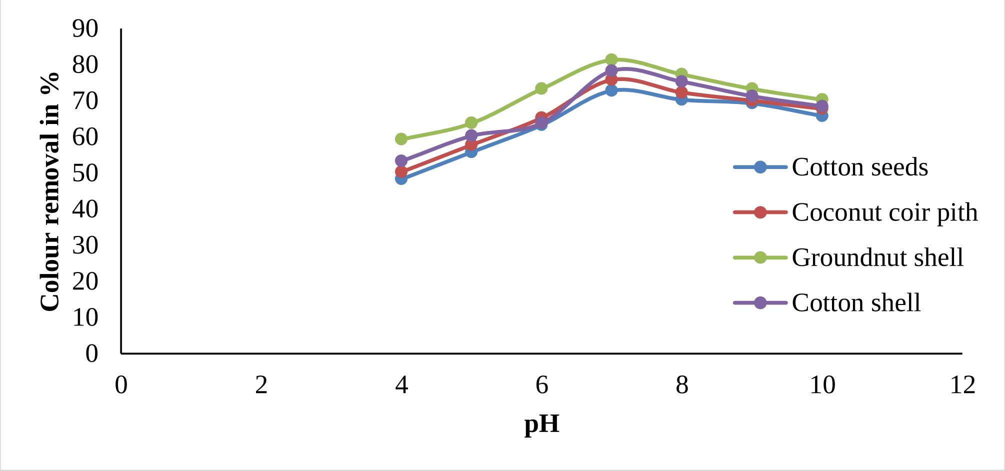


Fig – 3.6 Effect of pH on colour removal

3.7 VERIFICATION EXPERIMENT

In order to validate the above experiments in reducing the colour from textile industry wastewater, a separate experiment has been performed with an optimum adsorbent dosage of 300 mg, an optimum contact time of 75 min, an optimum temperature of 330 K and an optimum agitator speed of 600 rpm and optimum pH value of 7. The maximum colour removal percentage by different bio adsorbents in a textile industry wastewater is shown in Figure 2.7. The results showed that maximum colour removal percentage in a textile industry wastewater is about 75.25, 79.9, 86.75 and 81.7 % respectively for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell. Furthermore, it may also be found from that the maximum colour removal percentage in a textile industry wastewater was higher than each selected process parameters of different bio-adsorbents. Based on the results, it was concluded that bio-adsorbents may be used for removing the colour in a textile industry wastewater. Furthermore, over all experimental results at different process parameters have shown that maximum adsorption capacity of bio-adsorbents in the order of colour removing from textile industry wastewater is Groundnut shell followed by cotton shell, coconut coir pith and cotton seeds.

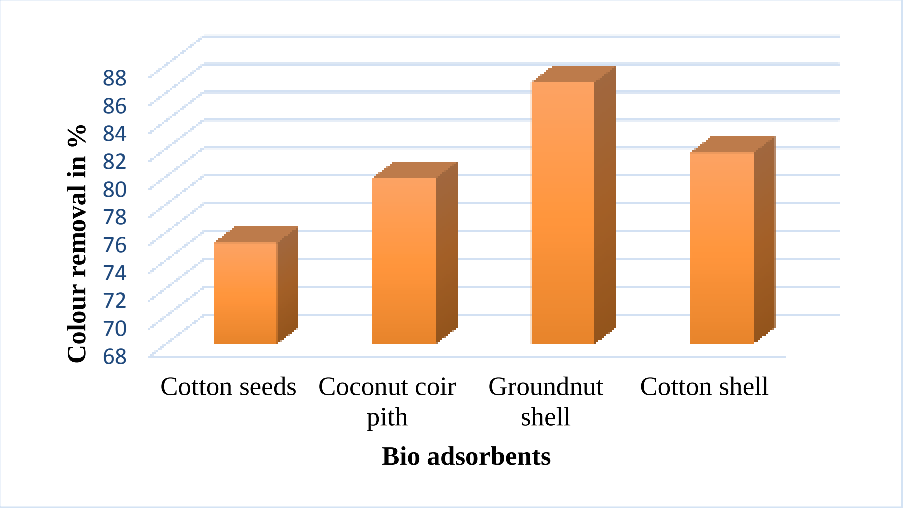


Fig -3.7 Maximum Colour Removal Percentage by Different Bio-Adsorbents

3.8 Adsorption isotherm

Adsorption isotherms, which are the presentations of the amount of solute adsorbed per unit of adsorbent, as a function of equilibrium concentration in bulk solution at constant temperature were studied. If a quantity, q of adsorbate is adsorbed by a porous solid adsorbent at constant temperature and the steady state equilibrium concentration, then the function q describes the adsorption isotherm. It shows the adsorption isotherm for the dye adsorption on groundnut shell, cotton shell, coconut coir pith and cotton seeds. The isotherm rises in the initial stages with higher slope at low Ce and qe values. This indicates that, initially there are numerous readily accessible sites and confirms the monolayer coverage of dye. A variety of isotherm equations have been in use, some of which have a theoretical foundation and some being of mere empirical nature. In the present work, Langmuir and Freundlich isotherm has been tested.

Table 3.8.1 Adsorption isotherm for dye adsorption on Cotton seeds

S.NO	Ce (mg/l)	q (mg/g)
1	24	7.6
2	30.6	8.94
3	37.6	10.24
4	46	11.4
5	56.3	12.37
6	67	13.3

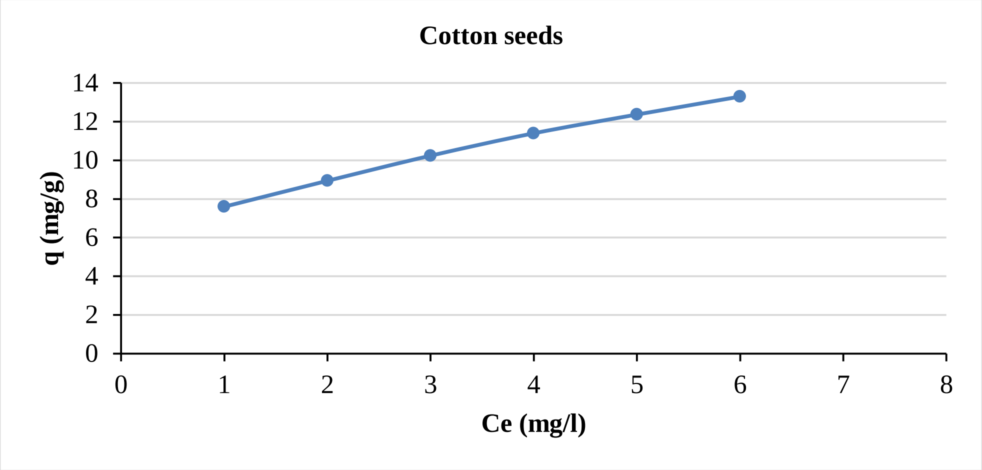


Fig -3.8.1 Adsorption isotherm for dye adsorption on Cotton seeds

Table 3.8.2 Adsorption isotherm for dye adsorption on Coconut coir pith

S.NO	Ce (mg/l)	q (mg/g)
1	20.3	7.97
2	27.3	9.27
3	35	10.5
4	42	11.8
5	54	12.6
6	61.5	13.85

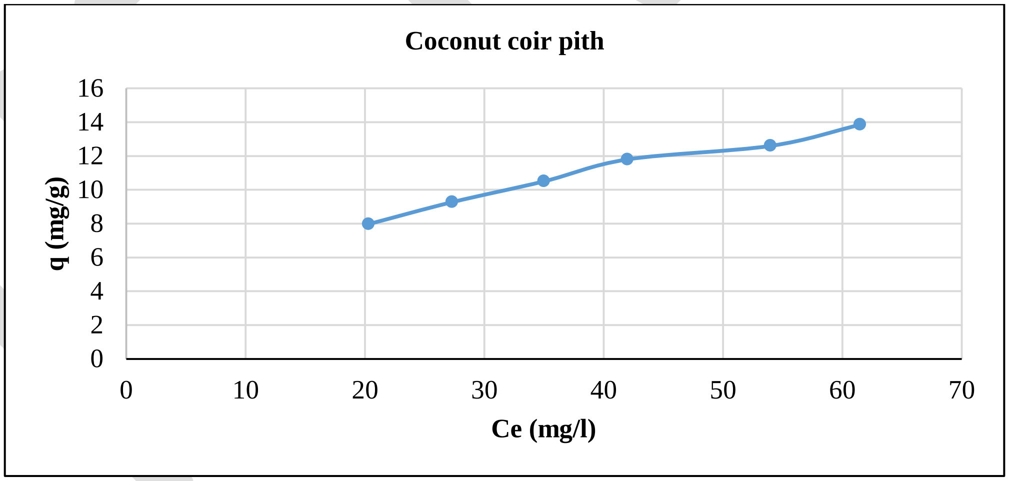


Fig-3.8.2 Adsorption isotherm for dye adsorption on Coconut coir pith

Table 3.8.3 Adsorption isotherm for dye adsorption on Groundnut shell

S.NO	Ce (mg/l)	q (mg/g)
1	13.7	8.63
2	18	10.2
3	23.4	11.66

4	29.3	13.07
5	37.3	14.27
6	43.8	15.62

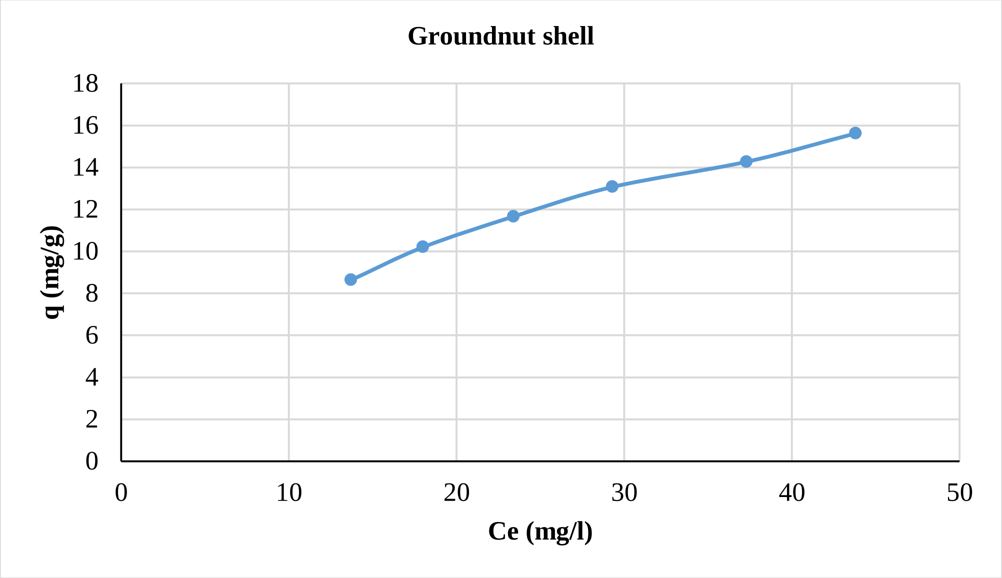


Fig- 3.8.3 Adsorption isotherm for dye adsorption on Groundnut shell

Table 3.8.4 Adsorption isotherm for dye adsorption on Cotton shell

S.NO	Ce (mg/l)	q (mg/g)
1	19.8	8.02
2	25.1	9.49
3	31	10.90
4	39	12.10
5	47.2	13.28
6	57.5	14.25

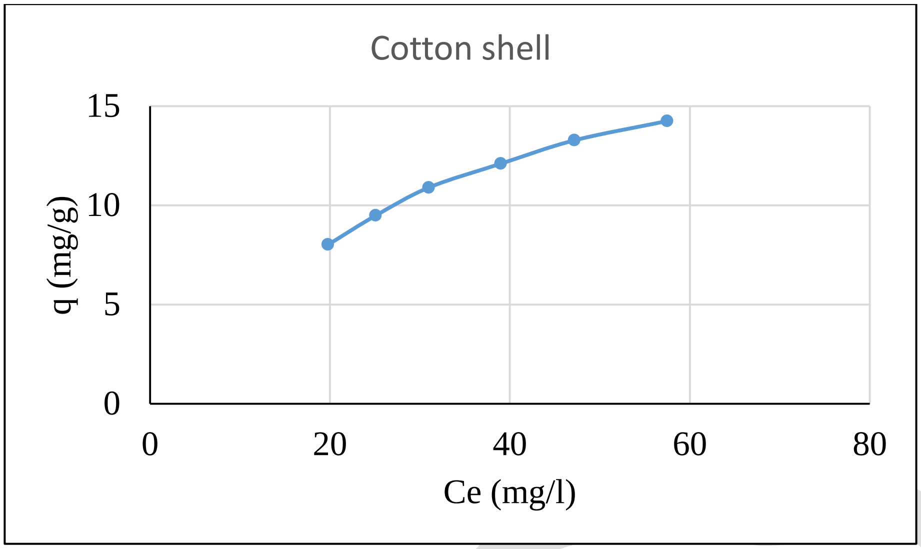


Fig- 3.8.4 Adsorption isotherm for dye adsorption on Cotton shell

3.9 Langmuir isotherm

According to Langmuir model, adsorption occurs uniformly on the active sites of the adsorbent, and once an adsorbate occupies a site, no further adsorption can take place at the site. The Langmuir model is given by following Eq (1),

Ce / qe = 1/qm KL + Ce/ qm ---------------- (1)

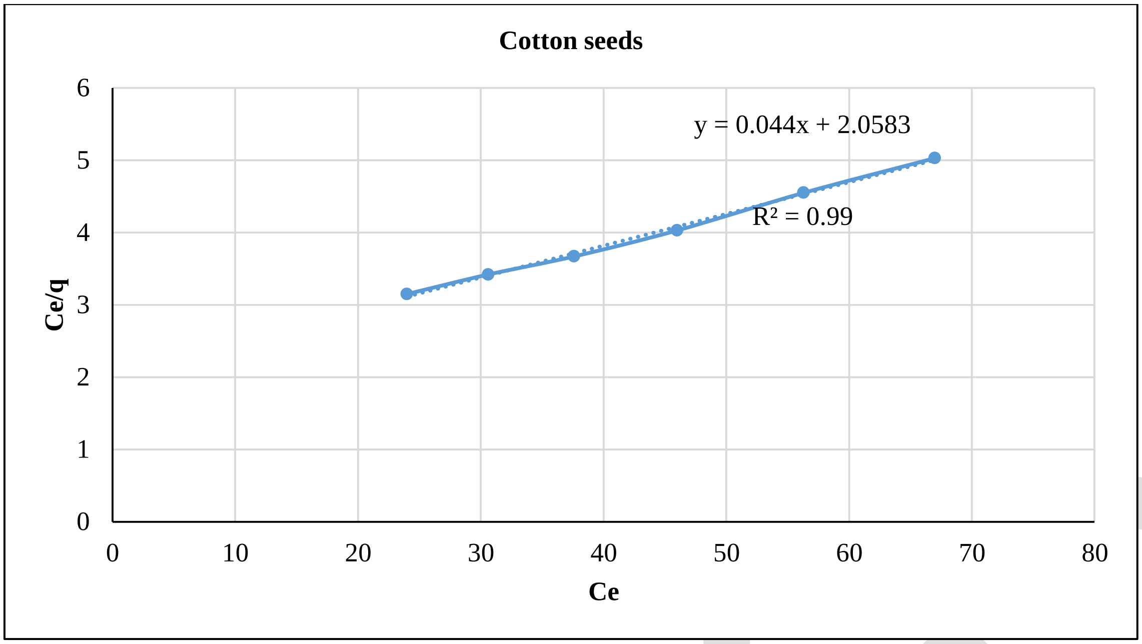
Where, Ce is the equilibrium concentration mg/L, qe is the amount of dye adsorbed at equilibrium (mg/g) and qm is qe for a complete monolayer (mg/g); KL is sorption equilibrium constant (L/mg). A plot of Ce/qe versus Ce (Fig. 6, Table 6) should indicate a straight line of slope 1/qm and an intercept of 1/KLqm [40-41]. The Langmuir parameters can be used to predict the affinity between the adsorbate and adsorbent using the dimensionless separation factor, RL, defined by Eq. (2)

RL=1 / (1+KLCe) ------------------------ (2)

The value of RL lies between 0 and 1 for favorable adsorption, while RL> 1 represents unfavourable adsorption, and RL= 1 represents linear adsorption while the adsorption process is irreversible if RL = 0. The adsorption of dye on ABC follows the Langmuir isotherm model for metal adsorption. The dimensionless parameter RL values lies between 0.09623 to 0.4128 is consistent with the requirement for favorable adsorption. The high value of correlation coefficient R^2 indicates a good agreement between the parameters and confirms the monolayer adsorption of dye onto the adsorbent surface.

Table 3.9.1 Langmuir adsorption isotherm for dye adsorption on Cotton seeds

S.NO	Ce	Ce/q
1	24	3.15
2	30.6	3.42
3	37.6	3.67
4	46	4.03
5	56.3	4.55
6	67	5.03



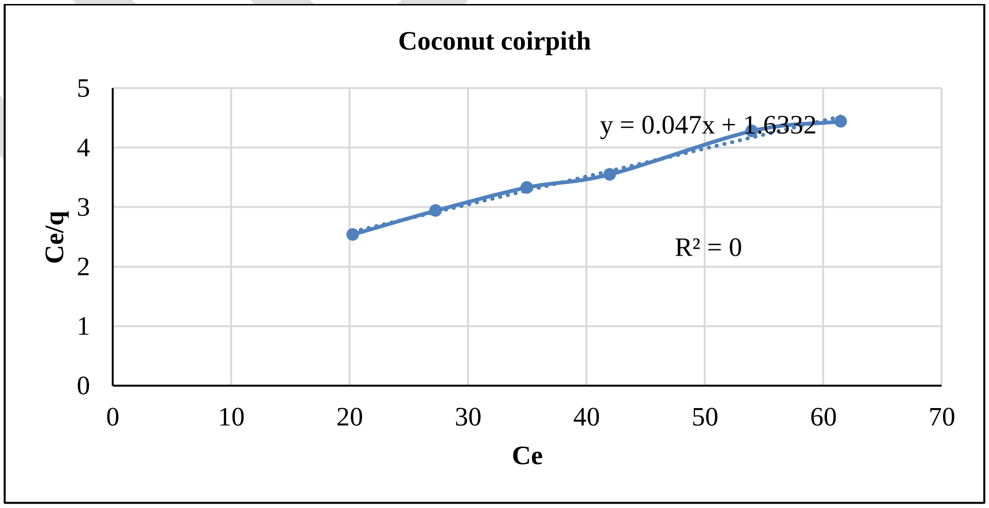
Slope of the curve = 1/qm= 0.044, Intercept of the curve = 1/KL qm = 2.0583

qm = 22.72 mg/g, KL= 0.021 and R^2= 0.9973

Fig 3.9.1 Langmuir adsorption isotherm for dye adsorption on Cotton seeds

Table 3.9.2 Langmuir Adsorption isotherm for dye adsorption on Coconut coir pith

S.NO	Ce	Ce/q
1	20.3	2.54
2	27.3	2.94
3	35	3.33
4	42	3.55
5	54	4.28
6	61.5	4.44



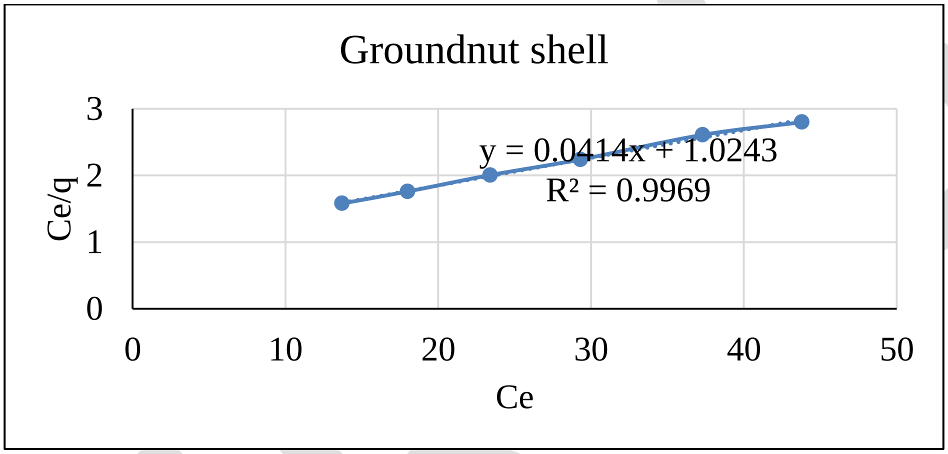
Slope of the curve = 1/qm= 0.047, Intercept of the curve = 1/KL qm = 1.6332

qm = 21.27 mg/g, KL= 0.028 and R^2= 0.99

Fig 3.9.2 Langmuir Adsorption isotherm for dye adsorption on Coconut coir pith

Table 3.9.3 Langmuir Adsorption isotherm for dye adsorption on Groundnut shell

S.NO	Ce	Ce/q
1	13.7	1.58
2	18	1.76
3	23.4	2.006
4	29.3	2.24
5	37.3	2.61
6	43.8	2.80



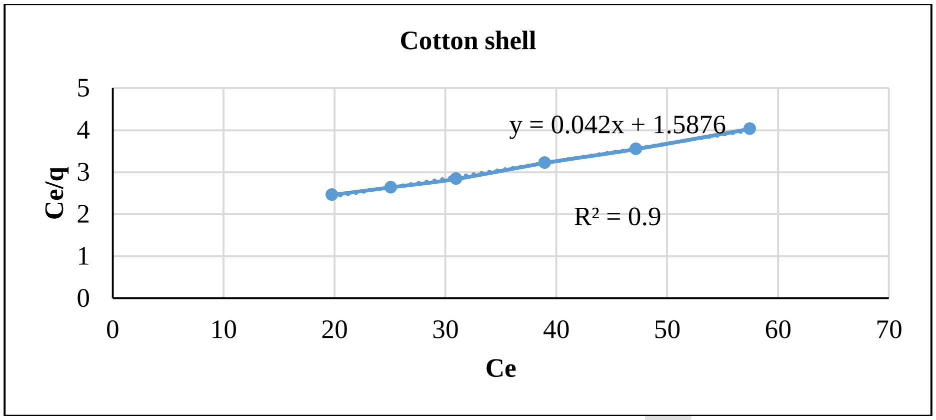
Slope of the curve = 1/qm= 0.0414, Intercept of the curve = 1/KL qm = 1.0243

qm = 24.15 mg/g, KL= 0.04 and R2= 0.9969

Fig – 3.9.3 Langmuir Adsorption isotherm for dye adsorption on Groundnut shell

Table 3.9.4 Adsorption isotherm for dye adsorption on Cotton shell

S.NO	Ce	Ce/q
1	19.8	2.46
2	25.1	2.64
3	31	2.84
4	39	3.22
5	47.2	3.55
6	57.5	4.03



Slope of the curve = 1/qm= 0.042, Intercept of the curve = 1/KL qm = 1.5876

qm = 23.80 mg/g, KL= 0.026 and R^2= 0.997

Fig – 3.9.4 Adsorption isotherm for dye adsorption on Cotton shell

3.10 Freundlich isotherm

Freundlich isotherm model was also used to explain the observed phenomenon (Freundlich, 1906)[43]. The Freundlich isotherm is represented by log qe = log Kf + 1/n log Ce

Where, Ce is the equilibrium concentration (mg/L), Kf and n are constant incorporating all factors affecting the adsorption process such as adsorption capacity and intensity, respectively. A plot of log qe vs log Ce from values in Table gives a linear trace with a slope of 1/n and intercept of log Kf. Kf and n calculated from the intercept and slope of the plots were found to be 5.899 and 4.038 respectively. The Kf value is related to the adsorption capacity; while the *1/n* value is related to the adsorption intensity. 1/n values indicate the type of isotherm to be irreversible (1/n = 0), favourable (0 < 1/n < 1) and unfavorable (1/n >1). Therefore ABC which has n value of 0.2476 implies effective adsorption. The value of the correlation coefficient, R^2, obtained in this case indicates that the Freundlich model gave a poorer fit to the experimental data than the Langmuir isotherm model.

Table 3.10.1 Freundlich adsorption isotherm for dye adsorption on Cotton seeds

S.NO	log Ce	log qe
1	1.38	0.88
2	1.48	0.95
3	1.57	1.01
4	1.66	1.05
5	1.75	1.09
6	1.82	1.12

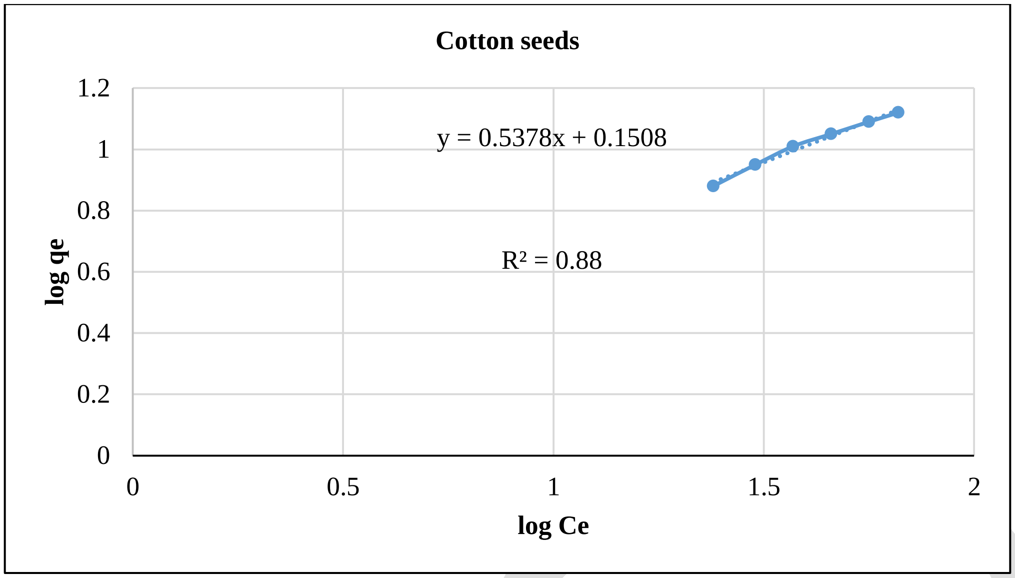


Fig 3.10.1 - Freundlich adsorption isotherm for dye adsorption on Cotton seeds

Slope = 1/n = 0.5378, Intercept = log Kf = 0.1508, R^2 = 0.8876

Table 3.10.2 Freundlich Adsorption isotherm for dye adsorption on Coconut coir pith

S.NO	log Ce	log qe
1	1.30	0.90
2	1.43	0.96
3	1.54	1.02
4	1.62	1.07
5	1.73	1.10
6	1.78	1.14

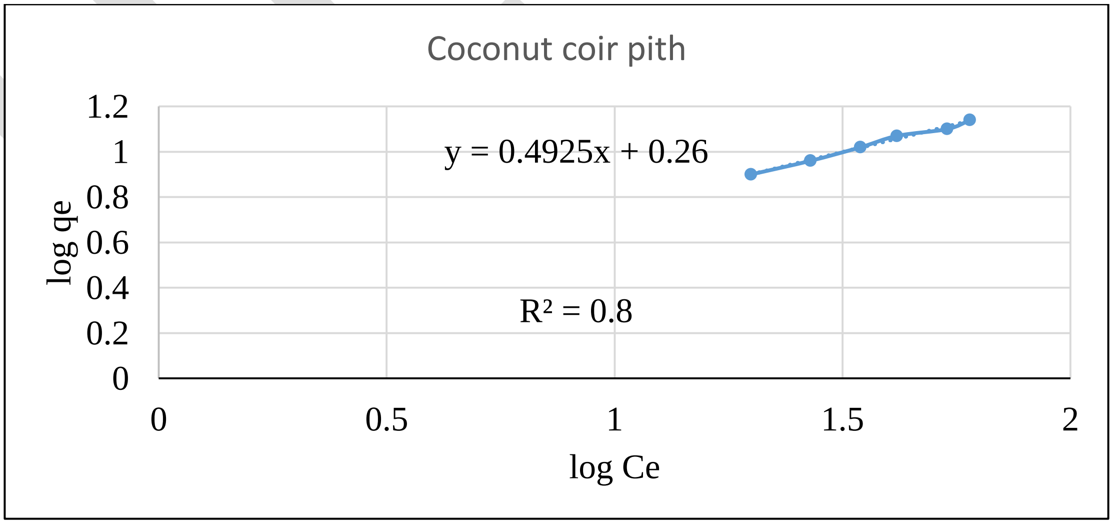


Fig 3.10.2 - Freundlich Adsorption isotherm for dye adsorption on Coconut coir pith

Slope = 1/n = 0.4925, Intercept = log Kf = 0.26, R^2 = 0.882

Table 3.10.3 Freundlich Adsorption isotherm for dye adsorption on Groundnut shell

S.NO	log Ce	log qe
1	1.136	0.93
2	1.25	1.008
3	1.36	1.06
4	1.46	1.11
5	1.57	1.15
6	1.64	1.19

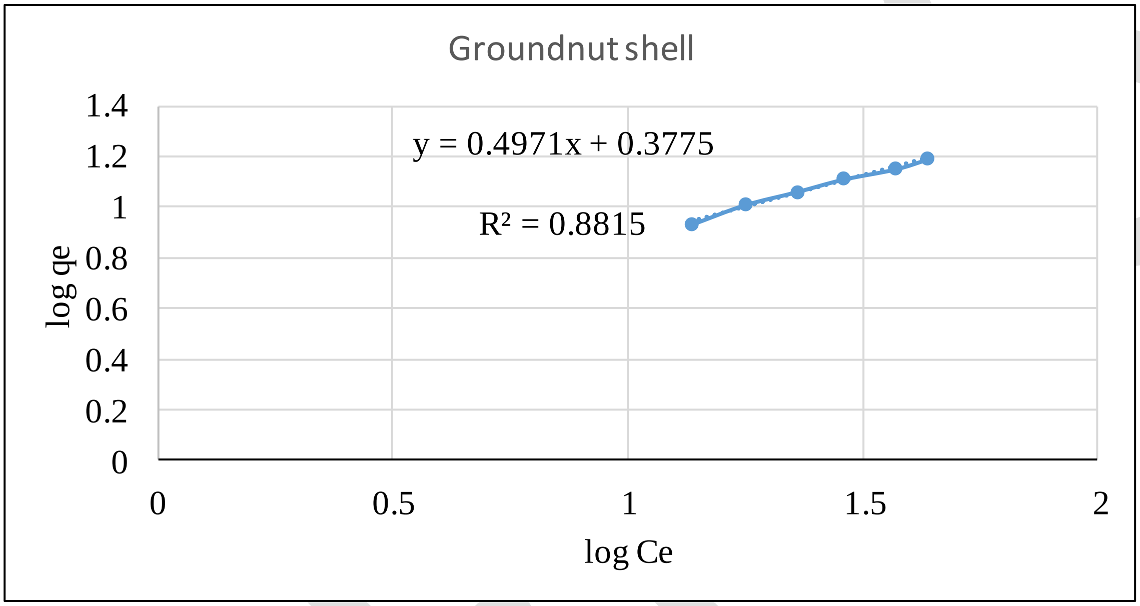


Fig 3.10.3 - Freundlich Adsorption isotherm for dye adsorption on Groundnut shell

Slope = 1/n = 0.4971, Intercept = log Kf = 0.3775, R^2 = 0.8815

Table 3.10.4 Adsorption isotherm for dye adsorption on Cotton shell

S.NO	log Ce	log qe
1	1.29	0.39
2	1.39	0.42
3	1.49	0.45
4	1.59	0.50
5	1.67	0.55
6	1.75	0.60

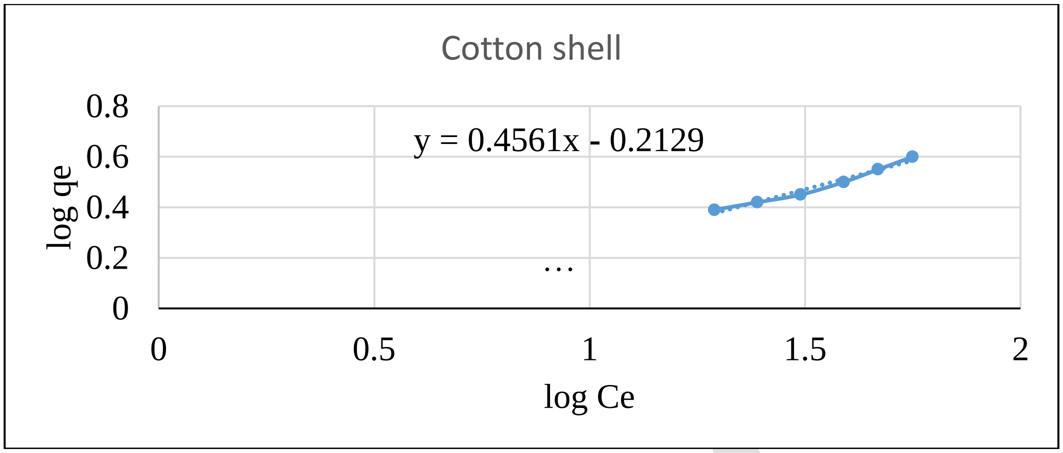


Fig 3.10.4 - Adsorption isotherm for dye adsorption on Cotton shell

Slope = 1/n = 0.4561, Intercept = log Kf = 0.2129, R^2 = 0.8732

3.11 SUMMARY

The effect of using various parameters have been analysed through this study. The experimental investigation of varying such parameters and their optimum values will be analysed in next phase of the project. The colour removal efficiency of using such adsorbents is expected to be 70-80%. In the present study, the batch adsorption study was conducted to find out suitability of bio-adsorbents for removing colour in a textile industry wastewater. The ability of bio-adsorbents for removing colour in a textile industry wastewater with different dosage, different contact time, different temperature and different agitator speed were monitored for this present study. The maximum percentage reduction of colour in a textile industry wastewater by different bio-absorbent were obtained at an optimum adsorbent dosage of 300 mg, an optimum contact time of 75 min., an optimum temperature of 330 K and an optimum agitator speed of 600 rpm. From the validation experiments, it found that maximum colour removal percentage in a textile industry wastewater is about 74.2, 79.3, 85.6 and 80.7 % respectively for neem leaves, orange peels, peanut hulls and coconut coir pith powders. These results of validation experiment were higher than the results obtained by different process parameters. Furthermore, over all experimental results have shown that maximum adsorption capacity of bio-adsorbents in the order of colour removing from a textile industry wastewater is peanut hulls powder followed by coconut coil pith powder, orange peels powder and neem leaves powder. Finally, from the results of adsorption study, it was concluded that bioadsorbents may be used as a coagulant for removing colour from a textile industry wastewater especially peanut hulls powder because of its higher adsorptive capacity than other bio adsorbents used in this study.

4. ACKNOWLEDGEMENT

We take this opportunity to express our thanks to department of Civil Engineering, Sriguru Institute of technology to undertake this work and allow us to present our findings as our contribution to the development of knowledge in the field of Environmental Engineering and also wish to express my sincere thanks to my parents and all my friends for their support

5. CONCLUSION

In the present study, the batch adsorption study was conducted to find out suitability of bio-adsorbents for removing colour in a textile industry wastewater. The maximum percentage reduction of colour in a textile industry wastewater by different bio-adsorbent were obtained at an optimum adsorbent dosage of 300 mg, an optimum contact time of 75 min., an optimum temperature of 330 K and an optimum agitator speed of 600 rpm and pH 7. From the validation experiments, it found that maximum colour removal percentage in a textile industry wastewater is about 75.25, 79.9, 86.75 and 81.7 % respectively for Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell. These results of validation experiment were higher than the results obtained by different process parameters.

Furthermore, over all experimental results have shown that maximum adsorption capacity of bio-adsorbents in the order of colour removing from a textile industry wastewater is groundnut shell followed by cotton shell, Coconut coir pith and cotton seeds. Finally, from the results of adsorption study, it was concluded that bio adsorbents may be used as a coagulant for removing colour from a textile industry wastewater especially groundnut shell powder because of its higher adsorptive capacity than other bio-adsorbents used in this study. The experimental data for the adsorption process were well fitted by the Langmuir adsorption isotherm model relative to the fit of the Freundlich adsorption model. The Langmuir adsorption capacity was determined as 22.72 mg/g, 21.27 mg/g, 24.15 mg/g, 23.80 mg/g, for adsorption on Cotton seeds, Coconut coir pith, Groundnut shell, Cotton shell.

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