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Analytical study of agricultural waste as non-conventional low cost adsorbent removal of dyes from aqueous solutions

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Abstract
Dyes are an important class of pollutants, and can even be identified by the human eye. Disposal of dyes in precious water resources must be avoided, however, and for that various treatment technologies are in use. Among various methods adsorption occupies a prominent place in dye removal. Adsorption techniques are widely used to remove certain classes of pollutants from waters, especially those that are not easily biodegradable.
There have been attempts by researchers to explore the adsorption potential of non-conventional, naturally-occurring agricultural residues in dye removal from effluents. In India alone more than 400 million tonnes of agricultural residue is generated annually, which includes rice husk, bagasse, stalk, coir pith etc. Exploring application of the agricultural residues for use as adsorbents can provide suitable alternatives for the removal of spent dyes from industrial effluents. Dyes represent one of the problematic groups. Currently, a combination of biological treatment and adsorption on activated carbon is becoming more common for removal of dyes from wastewater. Although commercial activated carbon is a preferred sorbent for color removal, its widespread use is restricted due to high cost.

Keywords: Adsorption characteristics, Dye removal, Low cost adsorbents, Activated carbon.

1. Introduction
Agricultural wastes as adsorbents the disposal of waste materials is increasingly becoming a cause for concern 52,166,167 because these wastes represent unused resources. A large amount of solid wastes are produced in the agricultural sector in most countries of the world. A major part of this waste is normally used as a domestic fuel. However, for better utilization of this cheap and abundant agricultural waste, it can be explored as a low cost alternative adsorbent owing to relatively high fixed carbon content and presence of porous structure.
Among the various known forms of pollution, water pollution is of great concern since water is the prime necessity of life and extremely essential for the survival of all living organisms. Indeed, it is a part of life itself, since the protoplasm of most living cells contains about 80% of water. It is worth noting that only 0.02% of the total available water on the earth is immediately available for use in the form of rivers, lakes and streams. However, years of increased industrial, agricultural and domestic activities have resulted in the generation of large amount of wastewater containing a number of toxic pollutants, which are polluting the available fresh water continuously. With the realization that pollutants present in water adversely affect human and animal life, domestic and industrial activities, pollution control and management is now a high priority area. The availability of clean water for various activities is becoming the most challenging task for researchers and practitioners worldwide.
Dyes are coloured substances that can be applied to various substrates (textile materials, leather, paper, hair) from a liquid in which they are completely, or at least partly, soluble. Man has made use of dyes since prehistoric times, and in fact, the demand and the usage of dyes have continuously increased. However, the presence of dyes even in trace quantities is very undesirable in aqueous environment as they are generally stable to light and oxidizing agents, and are resistant to aerobic digestion.
Some of the conventional methods of color removal from industrial effluents include ion exchange, activated carbon adsorption, membrane technology and coagulation. Amongst all, the sorption process by activated carbon has been shown to be one of the most efficient methods to remove dyes from effluents.

1. Activated carbon is the most widely used adsorbent in the industries due to its capability to adsorbing many types of dyes with high adsorption capacity. However, it remains as an expensive adsorbent and has high regeneration cost while being exhausted.
2. Thus, there is a need to search for new and economical process that could remove dyes that are commonly used in the industry.
   Generally, a low-cost sorbent can be defined as one which requires little processing and is abundant in nature. In this context, agricultural by-products and industrial waste can be seen as having a great potential to be developed as a low cost sorbent. The feasibility of using these materials could be beneficial not only to the environment in solving the solid waste disposal problem, but also the economy. Literature survey revealed that numerous biological materials have been utilized as adsorbents.

2. Review of Different type Adsorbents

2.1 Sugarcane Bagasse

Azhar *et al.* (2005) studied the removal of Methyl red dye using treated sugarcane bagasse and compared the results with those obtained using powered activated carbon. As per the study, one portion of ground bagasse with particle size between -80 to +230 mesh was treated with 1% formaldehyde in w/v ration of 1:5 at 50 °C for 4 hours followed by activation at 80 °C for 24 hours. The other portion of the bagasse was treated with sulfuric acid and heated in a muffle furnace for 24 hours at 150 °C, followed by soaking in 1% sodium bicarbonate solution overnight. The study reported adsorption efficiencies of the different adsorbents in the order of powdered activated carbon > bagasse treated with formaldehyde > bagasse treated with sulfuric acid. Untreated, formaldehyde-treated and sulfuric acid-treated sugarcane bagasse powders were used for removal of Ethylene red dye from aqueous solution. The adsorbents were used for treating Reactive blue 171, Reactive yellow 84 and Reactive red 141 dyes. The study reported that, among the above four adsorbents, bagasse had a slightly higher efficiency with 20-26% dye removal.

2.2 Fruit Peels

Parvathi and Maruthavanan (2010) performed adsorption studies using tapioca peel for removal of Megeta MB dye. They found that higher percentage removals were observed at solution pH 7 and the equilibrium was reached within 120 minutes of contact time. Jackfruit peel (0.84 mm in size) was used as adsorbent by Jayarajan *et al.* (2011) to remove Rhodamine dye. They reported a maximum colour removal of 25.3% at an adsorbent dose of 3.0 g/L and dye concentration of 100 mg/L. The study established that durian peel is a potentially useful and attractive adsorbent for removed of Methylene blue from aqueous solution. They reported that a flow rate of 15 mL/min showed an early breakthrough time.

2.3 Husk

Ong *et al.* (2007) ground rice hull to pass through a 1 mm sieve and used it as natural rice hull (NRH). Ethylenediamine (EDA) modified rice hull was also prepared by treating natural rice hull with ethylenediamine in a ratio of 1.0 g rice hull to 0.02 mole of EDA in a well-stirred water bath at 80 °C for 2 hours to enable it to function as a sorbent for removal of Basic blue 3 and Reactive orange 16 dyes. They observed adsorption capacities, calculated from the Langmuir isotherm, of 14.68 mg/g and 6.24 mg/g for Basic blue 3 dye and Reactive orange 16 dye respectively. Sharma and Janveja (2008) conducted a study on the removal of Congo red dye from the effluent of a textile industry using rice husk carbon activated by steam. The study reported that a dose of 0.08 g/L of rice husk carbon removed 10 to 99% of dye from aqueous solution with an initial dye concentration of 25 ppm within contact times from 20 to 200 minutes.

2.4 Sawdust

Experiments for removal of Ethylene blue dye using saw dust (420-85 µm) were performed by Gong *et al.* (2008). The activation process included treating sawdust with 240 mL of dioxane, 24 mL of 20% NaOH and 40 ml of epichlorohydrin for 5 hours at 65 °C. The reaction product was filtered, washed and dried. They observed Langmuir adsorption capacities of untreated and treated sawdust as 87.7 mg/g and 188.7 mg/g, respectively. The sawdust was treated with 0.1N NaOH solution and immobilized on alginate biopolymer for use as an adsorbent. The study revealed an adsorption capacity of sawdust of 38.46 mg/g. The kinetics followed closely a Pseudo-second order model.

2.5 Sludge

Activated sludge was dried at 105 °C to a constant weight and sieved to < 205 µm for use as an adsorbent in a study for removal of Rhodamine-B dye (Ju *et al.*, 2006). The results indicated that the adsorption capacity of activated sludge increased with decreasing initial pH and temperature. The Langmuir monolayer adsorption capacities were 5.121 mg/g, 4.847 mg/g, 4.456 mg/g and 3.725 mg/g at temperature of 5 °C, 15 °C, 25 °C, and 45 °C, respectively. Reddy *et al.* (2006) conducted a study of reactive dye removal from dyeing unit effluent using sewage sludge-derived activated carbons by pyrolysis. The adsorption potential of granular sludge (from a pilot scale reactor treating waste water) with Acid orange 7 dye was investigated by Mendez-Paz *et al.* (2005). A dye removal efficiency of 92% was achieved in continuous treatment mode with dye loading rate of 590 mg/L.day.

2.6 Organisms

Kim *et al.* (2004) studied the adsorption of Reactive orange 16 dye using dead cell of brewery yeast. The yeast was washed with deionized water and dried at 80 °C. The dried biomass was ground to an average size of 112.5 µm. An adsorption capacity of 0.604 mg/g, 0.090 mg/g and 0.50 mg/g were observed at solution pHs of 3, 7 and 10, respectively. They observed an increase in the adsorption capacity with temperature, indicating that the adsorption process is endothermic. Fu and Viraghavan (2003) studied the dye removal potential of immobilized fungal biomass (*Aspergillusniger*) with four dyes, namely Acid blue 29, Basic blue 9, Congo red and Disperse red 1. The adsorption capacities observed were 64.7 mg/g for Acid blue 29 dye, 8.9 mg/g for Basic blue 9 dye, 1.1 mg/g for Congo red dye and 0.1 mg/g for Disperse red 1 dye.

2.7 Grains

Jaikumar and Ramamurthi (2009) studied the adsorption of Acid yellow 17 dye by an adsorbent prepared from spent brewery grains. The spent brewery grains were suspended in 0.13 M sulphuric acid solution (20 g of grain per 100 mL of solution) for one hour. The grains were washed, dried and ground for use as adsorbent. They observed the highest adsorption capacity at pH 2 with an initial dye concentration of 150 mg/L, dose of adsorbent 0.5 g/L and contact time of 40 minutes.

2.8 Coconut

Theivarasu and Mylsamy (2010) conducted an adsorption study of Rhodamine-B dye on char prepared by treating the coconut shell with concentrated sulfuric acid at ratio of 1:1 (w/v). The activation was performed by heating in a muffle furnace at 550 °C for 7 hours, followed by washing and drying. The adsorption capacity of the treated coconut shell char was reported as 41.67 mg/g. For removal of Coomassie brilliant blue dye on coir pith as adsorbent, The study reported a maximum adsorption capacity of 31.84 mg/g and the adsorption capacity for the system was 6.43 mg/g.

2.9 Palm Shell

Rajavel *et al.* (2003)[4] evaluated the removal efficiency of Dark green PLS dye from textile industry wastewater using carbons prepared from palm nut shell, cashew nut shell and broom stick. The carbons were prepared by treating 4 parts of each material with 2 parts of concentrated sulfuric acid and heating at 140-170 °C for 24 hours. They observed that, upon increasing adsorbent dose and agitation, the efficiency of dye removal increased.

2.10 Leaves

Gulmohor leaves were ground, washed and dried to use as adsorbent in an adsorption study by Ponnusami *et al.* (2009). The results indicated that the equilibrium dye removal capacity of gulmohar leaves with Methylene blue dye varies from 132.40 mg/g to 34.76 mg/g with adsorbent dose of 0.5 g to 2.5 g/L and a dye concentration of 100 mg/l. The monolayer adsorption capacities of gulmohar leaf powder were observed 120 mg/g, 178 mg/g and 253 mg/g at temperature of 293 K, 303 K and 313K, respectively.The adsorption data fitted well the Langmuir isotherm with monolayer adsorption capacities of 444.44 mg/g and 454.5 mg/g for Malachite green dye and Methylene blue dye, respectively at 25 °C. The column study indicated break through capacities of 300 mg/g and 275 mg/g for Malachite green dye and Methylene blue dye respectively.

2.11 Tree Bark

Patil *et al.* (2011) carried out adsorption studies of Methylene blue dye using teak tree bark with various process parameters. The maximum adsorption of Methylene blue dye was 333.33 mg/g. The study revealed an increase in dye adsorption efficiency with increasing pH, increasing temperature and decreased particle size of adsorbent.

2.12 Straw

Abdualhamid and Asil (2011) conducted adsorption studies for removal of Methylene blue dye using barley, wheat and oat straws as adsorbents. The straws were cut into pieces of 1 cm size, washed and dried at 65 °C overnight. One portion of each straw was subjected to soaking by immersing in water at room temperature for 20 days and then dried at 60 °C overnight for use as adsorbent. In the study, the maximum dye adsorption capacity for the straws before soaking followed the order: barley > oat > wheat, with values of 27.72 mg/g, 17.54 mg/g and 8.34 mg/g, respectively. The maximum dye removal capacity of straws after soaking in water was found in the order of oat > barley > wheat, with values of 50.00 mg/g, 22.22 mg/g and 11.11 mg/g.

2.13 Seeds

Esterified natural papaya seeds were used by Nasuha *et al.* (2011) for adsorption of Methylene blue and Congo red dyes from effluent. Esterification was carried out by treating the adsorbent with methanol and HCl followed by washing and drying. Data for adsorption of Methylene blue dye fit well to the Langmuir isotherm and maximum adsorption capacities of 250.0 mg/g and 200 mg/g were observed for esterified adsorbent and natural adsorbent, respectively. Santhi *et al.* (2010) studied the adsorption potential of *Annonasquamosa* seed with adsorbates, namely Methylene blue dye, Methylene red dye and Malachite green dye. Carbon was prepared by treating the mass with H2SO4 for 12 hours. The studies indicated that the equilibrium adsorption of Acid orange 7 dye was higher for charcoal carbonized at higher temperatures.

2.14 Other Biomasses

Habib *et al.* (2006) performed adsorption studies using tuberose sticks as adsorbent for removal of Methylene blue dye. The dried tuberose sticks were cut into small pieces, powdered and then sieved with a 425 μm sieve for use as adsorbent. The maximum dye removal of 80% was achieved at pH 11, adsorbent dose of 1 g/L and dye concentration in solution of 40 mg/L. In another study, flame tree (Delonixregia) pods were used for preparing adsorbents. The flame tree pods were crushed into smaller pieces and soaked with concentrated sulfuric acid in a 1:1 ratio (weight of material to volume of acid) for 48 hours and activated at 160 °C for 6 hours. The adsorption studies were conducted to obtain isotherm and kinetic data under different experimental conditions. They observed maximum dye removal at a pH of 2 and temperature of 30 °C. The equilibrium data were reasonably described by the Langmuir and Freundlich isotherms. The authors reported that the adsorption capacity of activated carbon was 140.14 mg/g. The kinetics followed closely a Pseudo-second order model. Table 1 show different agricultural residues used to prepare the adsorbents, along with adsorption capacities for removal of different dyes from effluents.

3. Low Cost Adsorbents and Activation Methods

Among the various methods available for removing dyes from effluents, adsorption by commercial activated carbon is the most effective. The efficiency of activated carbon in adsorption is due to its structural characteristics, porous texture and chemical nature. The use of activated carbons derived from expensive starting materials is not satisfactory for most pollution control applications. This has led research towards economic adsorbents. A convenient alternative treatment for the discoloration of wastewaters from the textile industry is the usage of non-conventional adsorbents with lower cost and higher colour removal efficiency

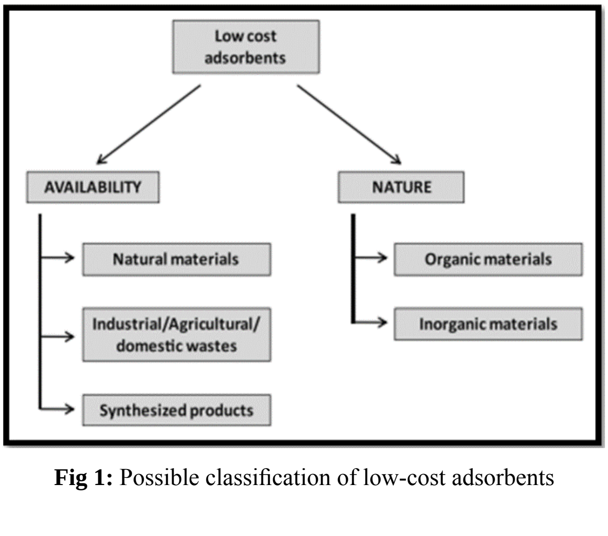

Fig 1: Possible classification of low-cost adsorbents

The basic components of the agricultural waste materials include hemicellulose, lignin, lipids, proteins, simple sugars, water, hydrocarbons, and starch, containing a variety of functional groups. In particular agricultural materials containing cellulose show a potential sorption capacity for various pollutants. If these wastes could be used as low-cost adsorbents, it will provide a two-fold advantage to environmental pollution. Firstly, the volume of waste materials could be partly reduced and secondly the low-cost adsorbent, if developed, can reduce the treatment of wastewaters at a reasonable cost. Agricultural waste is a rich source for activated carbon production due to its low ash content and reasonable hardness.

The agricultural waste materials have been used in their natural form or after some physical or chemical modification. Pretreatment methods using different kinds of modifying agents such as base solutions (sodium hydroxide, calcium hydroxide, sodium carbonate) mineral and organic acid solutions (hydrochloric acid, nitric acid, sulfuric acid, tartaric acid, citric acid), organic compounds (ethylenediamine, formaldehyde, epichlorohydrin, methanol), oxidizing agent (hydrogen peroxide), and dyes for the purpose of removing soluble organic compounds, color and metal from the aqueous solutions have been performed.

Materials and Method

Agriculture Based Adsorbents and Non-Conventional Low Cost Adsorbent in the Removal of Reactive Dyes

Analysis:

In spite of prolific use of activated carbon in wastewater treatment, its use is sometimes restricted because of its higher cost. To replace the expensive activated carbon, a wide range of inexpensive adsorbents have been investigated utilizing naturally occurring materials and waste products of different industries. Some of them were found to be quite satisfactory. However, still, there is a strong need to conduct extensive research on the following points: (i) To improve the removal efficiencies/adsorption of Agriculture based adsorbents. (ii) Cost factor is also an important point that should be considered before selecting such developed adsorbents. (iii) Last but not the least, it is very important to dispose of the spent adsorbents in an environmental friendly way.

Adsorbent	Dye	Maximum adsorption capacity (mg/g
Coir pith	Congo red	2.6
Orange peel	Aid violet	19.88
Banana peel	Basic blue 9	20.8
Rice husk	Acid yellow 36	86.9
Straw	Basic blue 9	19.82
Date pit	Basic blue 9	17.3
Oil palm fiber: activated carbon	Malachite green	149.35
Durian shell: based activated carbon	Methylene blue	289.26
Guava (*Psidium guajava*) leaf Powder	Methylene blue	185.2
Almond shell	Direct red 80	90.09
Pomelo (*Citrus grandis* peel)	Methylene blue	344.83
Broad bean peel	Methylene blue	192.7
Peanut hull	Reactive dye	55.5
Citrullus lanatus rind	Crystal violet	11.9

Table 1: Reported adsorption capacities q_m(mg/g) of different agricultural wastes

Only limited information is available in literature about safe disposal of spent adsorbents. More efforts should be made in this direction. If it is possible to develop such adsorbents having all the above-mentioned characteristics, then these adsorbents may offer significant advantages over currently available commercially expensive activated carbons and, in addition contribute to an overall waste minimization strategy.

Results and Discussion

Table 2: Adsorption capacities of some agricultural residue based adsorbents for removal of different dyes from effluents.

Name of Adsorbent	Dye	Adsorption Capacity
Citrus documana	Reactive red 2	0.608 mg/g
Citrus medica	Reactive red 2	0.580 mg/g
Citrus aurantifolia	Reactive red 2	0.566 mg/g
Orange peel (Citrus sinensis L.)	Remazol brilliant blue	11.62 mg/g (20 °C), 10.70 mg/g (30 °C), 8.61 mg/g (40 °C), 6.39 mg/g (50 °C), 5.54 mg/g (60 °C).
Mosambi peel	Erichrome black T	90% (Initial dye concentration 50 mg/L & adsorbent dose 4 g/L)
Palm nut shell carbon	Dark green PLS	0.84 mg/g
Cashew nut shell carbon	Dark green PLS	1 mg/g
Broom stick carbon	Dark green PLS	0.63 mg/g
Coconut shell char	Rhodamine-B	41.67 mg/g
Coir pith char	Coomassie brilliant	31.84 mg/g
Palm shell activated carbon	Reactive red 3 BS	7 mg/g
Palm shell powder	Methylene blue Rhodamine 6G	121.5 mg/g
		105 mg/g
Sugarcane bagasse	Reactive orange	3. 48 mg/g
Sugarcane bagasse ($ZnCl_2$ treated)	Reactive orange	2.83 mg/g
Sugarcane bagasse (H_3PO_4 treated)	Reactive orange	1.8 mg/g
Sugarcane bagasse fly ash	Remazol Black B Remazol brilliant blue R Remazol Brilliant red	16.42 mg/g 32.468 mg/g 18.282 mg/g
Sugarcane bagasse	Basic blue 3 Reactive orange 16	37.59 mg/g 34.48 mg/g
Sugarcane dust	Basic violet 1 Basic violet 10 Basic green 4	50.4 mg/g 13.9 mg/g 20.6 mg/g
Rice hull	Basic blue 3 Reactive orange 16	14.68 mg/g 6.24 mg/g
Rice husk carbon	Congo red	10 to 99% (Initial dye concentration 25 ppm & adsorbent dose 0.08 g/L)
Saw dust	Ethylene blue	87.7 mg/g (natural saw dust). 188.7 mg/g (treated saw dust)
Beech wood saw dust	Direct orange 26 Acid green 20 Aid orange 7	2.78 mg/g 7.81 mg/g 5.06 mg/g
Activated sludge	Rhodamine-B	5.121 mg/g (5 °C), 4.847 mg/g (15 °C), 4.456 mg/g (25 °C), 3.725 mg/g (45 °C)
Sewage sludge activated carbons	Reactive dye	33.5 mg/g
Barley straw	Methylene blue	27.72 mg/g

In this review, a wide range of non-conventional low cost adsorbents has been presented.

Agricultural wastes, being porous and lightweight due to fibrous nature, are non-conventional low cost adsorbents for metal adsorption. Carboxylic and hydroxyl functional groups on surface of agricultural wastes have high affinity for heavy metal ions. Physicochemical modifications of wastes can enlarge surface area, type of adsorbing sites, porosity etc, thus improving sorptive capacity, which may compensate for the cost of additional processing. Regeneration of spent adsorbent has become a cost effective and sound environmental option. Desorption and regeneration can be done to recover valuable metal from spent adsorbent. Hydroxyl and carboxylic groups in agricultural wastes make them amenable to easy desorption and regeneration with basic or acid solutions.

The agricultural residues are required to be properly treated. The treatments employed by researchers involve physical and chemical processes such as washing, drying, size reduction, burning to produce ash, burning in the absence of oxygen to obtain char, carbonizing and specific treatment to effect chemical modifications.

In particular, from the recent literature reviewed, chitosan-based sorbents have demonstrated outstanding removal capabilities for certain dyes in comparison to activated carbon. However, despite a number of papers published on low-cost adsorbents, there is as yet little information containing a full study of comparison between sorbents. Although much has been accomplished in the area of low-cost sorbents, much work is necessary (i) to predict the performance of the adsorption processes for dye removal from real industrial effluents under a range of operating conditions, (ii) to better understand adsorption mechanisms and (iii) to demonstrate the use of inexpensive adsorbents at an industrial scale.

Conclusion

Agricultural residues are abundantly available. For using as adsorbents, the agricultural residues are required to be properly treated. The treatments employed by researchers involve physical and chemical processes such as washing, drying, size reduction, burning to produce ash, burning in the absence of oxygen to obtain char, carbonizing and specific treatment to effect chemical modifications. This literature review shows that it is possible to develop agricultural residues for use as adsorbents in colour removal from effluents. The adsorption capacity data reported in the literature indicate that dye removal through the use of agricultural residue is feasible. Although intensive studies have been undertaken on the lab scale with different processes parameters, there is a need to explore the adsorption potential of the agriculture residues through pilot plant studies to establish the treatment process at commercial level.

Reference

1. Ong ST, Keng PS, Lee CK. Basic and reactive dyes sorption enhancement of rice hull through chemical modification, Am. J Applied. Sci.2010; 7:447-452.
2. Amit Bb. Conventional and non-conventional adsorbents for removal of pollutants from water – A review Indian Journal of Chemical Technology. 2006; 13:203-217.
3. Ho YS, Chiu WT, Wang CC. Regression analysis for the sorption of basic dyes on sugarcane dust. Bioresource Technology 2005; 96:285-1291.
4. Ponnusami. Removal of Dark green PLS dye from textile industrial waste through low cost carbons" Indian J Environ. Health. 2009; 45(3):195-202
5. Grag VK, Rakesh Kumar, Renuga Gupta. Removal of malachite green dye from aqueous solution by adsorption using agro industries waste: A case study of Phosopis Ceneraria. Dyes & pigments 2004; 62:1-10.
6. Lorenc–Grabowska E,Gryglewicz G. Adsorption characteristics of Congo red on Coal based mesoporous activated carbon Dyes & Pigments 2007; 74:34-40.
7. Habib. Analysis for the removal of a reactive dye from aqueous solution onto hydrotalcite by adsorption Water Research 2006; 37:3023-3033.
8. Abdualhamid, Asil Non. Conventional low-cost adsorbents for dye removal: areview Bioresource Technology 2011; 97:1061- 1085.
9. Azhar, Kadirvelu K. Coir pith, an agricultural waste byproduct for the treatment of dyeing wastewater. Bioresource Technology 1994; 48:79-81.
10. Nasuha. Removal of basic dye from aqueous solution using treefern as a biosorbent, Process Biochemistry 2011; 40:119-124.
11. Patil. Removal of malachite green dye from aqueous solution by adsorptionusing agro-industrywaste: a case study of Prosopis cineraria, Dyes and Pigments 2011; 62:1-10.
12. Kadirvelu K, Kavipriya M, Karthika C, Radhika M, Vennilamani N, Pattabhi S. Utilization of various agricultural wastes for activated carbon preparation and application for the removal of dyes and metal ions from aqueous solutions, Bioresource Technology 2003; 87:129-132.
13. Jaikumar and Ramamurthi. Degradation of anthraquinone dye C.I. Reactive Blue 19 in aqueous solution by ozonation. Chemosphere. 2011; 77(2):214-21.
14. Parvathi et.al. Color removal from simulated dye water and actual textile wastewater using a composite coagulant prepared by ployferric chloride and ammonium chloride. SEP PURIF TECHNOL. 2007;54(2):157-63
15. Theivarasu and Mylsamy. "Adsorption of anionic dyes in acid solutions using chemically cross-linked chitosan beads", Dyes Pigments, Vol.60, pp. 69-84, 2010.