Dye Removal from Aqueous Solution into Alternative Low Cost Adsorbent: -A Review

Anil V. Shinde [a], Bharat N. Patil [a*]
[a] Nano Chemistry Research Laboratory G. T. P. College Nandurbar. (M.S.).
shindepa12345@gmail.com

Abstract

This review article provides extensive literature information about dyes, its classification, sources, toxicity, various treatment methods, dye adsorption and characteristics by various adsorbents. The one of the objective of this review article is to organize the scattered available information on various aspects on a wide range of potentially effective adsorbents in the removal of dyes. Therefore, an extensive list of various adsorbents such as natural materials, waste materials from industry, agricultural by-products, and biomass based activated carbon in the removal of various dyes has been compiled here. Dye bearing waste treatment by adsorption using low cost alternative adsorbent is a demanding are double benefits i.e. water treatment and waste management. Further, activated carbon from biomass has the advantage of offering an effected low cost replacement form on-renewable coal based granular activated carbon provided that they have similar or better adsorption on efficiency .The effectiveness of various adsorbents under different physio-chemical process parameters and their comparative adsorption capacity towards dye adsorption has also been presented. This review paper also includes the factors affective adsorption of dye such as solution pH, initial dye concentration, adsorbent dosage, and temperature.

Keywords: - Adsorption, Biodegradable solid waste, Dye, waste water treatment.

Introduction

Water is very essential to our life, animal life, processing industry, plantation and aquatic system. If the dye effluent wastewater discharges in hydrosphere, because of that water quality degrade and their adverse effect to environment. The greatest environmental concern problem deals with dyes absorption and reflection of sunlight that entered to water which interferes on the growth of bacteria level cannot biologically degradable in the water body. Because color is very high wavelength (200 to 800 nm) in the water so directly effect on absorption of sun light in water body and there also side effect on photosynthesis reaction, when lake of photosynthesis reaction its adverse effect of plankton growth and their adverse effect to fisheries production.[1]. If fish production is low so naturally water purification system effect and there directly impact too environmentally and economically loss due to discharge of effluent dye wastewater in fresh water. This problem can be solved by different engineering method such as physical method, chemical method and biological method.

The Some dye manufacturing institute showed that the basic dyes are generally more toxic than acid or direct dyes. And some commercial dye are harmful to some microorganisms .Many dyes may cause allergic derma tics, dysfunction of kidney, skin irritation, central nervous system, liver, and brain. Organic dyes are harmful to human beings. The need to remove dye from waste water effluents become environmentally significance

The main factor which on the adsorption process are surface area, pore size, chemical composition and dyes properties such as molecular size, molecular polarity. Activated carbon is the most widely used adsorbent for dye removal because of its micro –pore structures, high adsorption capacity, extended surface area and high degree of surface reactivity. However, commercially available activated carbon is very expensive and has high regeneration cost.

Dyeing is a process of coloring the fabric using dyes which are organic compounds. They are widely used for imparting colour to textiles industry and other many industry. They are produced either synthetic or naturally. Dyeing properties depended on two reasons. First, the sizes of the dye molecules are smaller than the size of the pores in the fiber. The second reason is the affinity of the dye to the fiber due to forces of attraction. The dye which has diffused or penetrated into the fiber is held there by the forces of attraction between the dye and the fiber. Dyes could be either obtained from natural and synthetic sources. Dye is naturally occurring in the nature such as wood, leaf of tree, soil, bark of tree, seed, root, minerals, fungi, and insect, clay and microorganism. Sources of dye are two type, naturally and synthetic. Naturally dye source is from clay, bark of tree. Leaf, root .seed, fungi, Minerals and microorganism [2]. Synthetic dyes are obtained from many different industry such as cosmetics industry, printing industry, rubber industry, plastic industry, textiles industry and dye and pigment industry. All the above industry effluent discharge in fresh water source so water quality degradable.

Method of dye removal.

Basically there are three methods Such as Physical Methods, chemical Methods & Biological Methods

Physical method

Physical method includes as membrane filtration process, reverse osmosis, electrolysis, sedimentation, and adsorption. Adsorption treatment method is an effective alternative method used to remove dye from waste water. The adsorption treatment has many advantages such as low cost; easily change, less susceptibility to toxic chemicals, greater flexibility in design and operation. Generally two type adsorbent uses **a).** Natural adsorbents **b)** Prepared activated carbon.

Natural adsorbents used for dye removal such as clay, siliceous materials, zeolites etc.

Prepared agricultural waste materials used as low cost adsorbent such as orange peel, banana peel, rice husk, almond shell, soybeans husk and coconut shell. There adsorption capacity various factors affecting are adsorbent dosage, contact time, PH value, agitation speed, Ionic strength, temperature and initial dye concentration etc.

Chemical method

Chemical method includes coagulation/flocculants, oxidation, ion-exchange, and neutralization. It involves the addition of substances such as aluminium, calcium and ferric ions in to the effluent, as such flocculation. [3].Generally, a chemical treatment has feasibility, economic and efficiency, but major drawback is that, the costs of chemical are expensive.

Biological method

Biological method includes such as activated sludge, anaerobic digestion and aerobic digestion adsorption by (living order) microbial biomass, fungal decolonization, and microbial degradation. Microorganism such as fungi, yeast, bacteria and algae are able to accumulate dye and degrade different pollution [4]. Biological treatment may be aerobic and anaerobic. But the major drawback is that required large land area and high construction cost.Table1gives advantage end disadvantage of dye removal methods

Table1: Advantages and Disadvantage of Dye Removal Methods [1].

No.	Methods	Advantages	Disadvantages
1.	Adsorption by activated carbon (physical treatments)	Good removal capacity of different Varity of dyes	Very costly
2.	Membrane filtration	Removal all types dye	Concentrated sludge production, blocking problems, maintenances cost very high.
3.	Ozonation (chemical treatments)	Ozone can be applied in its gaseous state and does not increase the sludge and volume of waste water.	Very costly and short half-life(20)min
4.	Electro chemical destruction	No sludge formation and does not use chemical component	Relatively high flower at esca use a direct decrease in dye removal
5.	Microbial cultures (mixed bacterial) biological treatments	Decolorizedin24-30hr	Under the aerobic condition azo dyes are not readily metabolized
6.	Adsorption by living/dead microbial biomass	Certain dyes have a particular affinity for binding with microbial species	Not effective for all dyes
7.	Prepared activated carbon sample(bark of vachellianilotica)	Good removal capacity of different dyes	Low cost

Classification of Dye

Mainly dyes are two types

1. Natural Dye
2. Synthetic Dye.

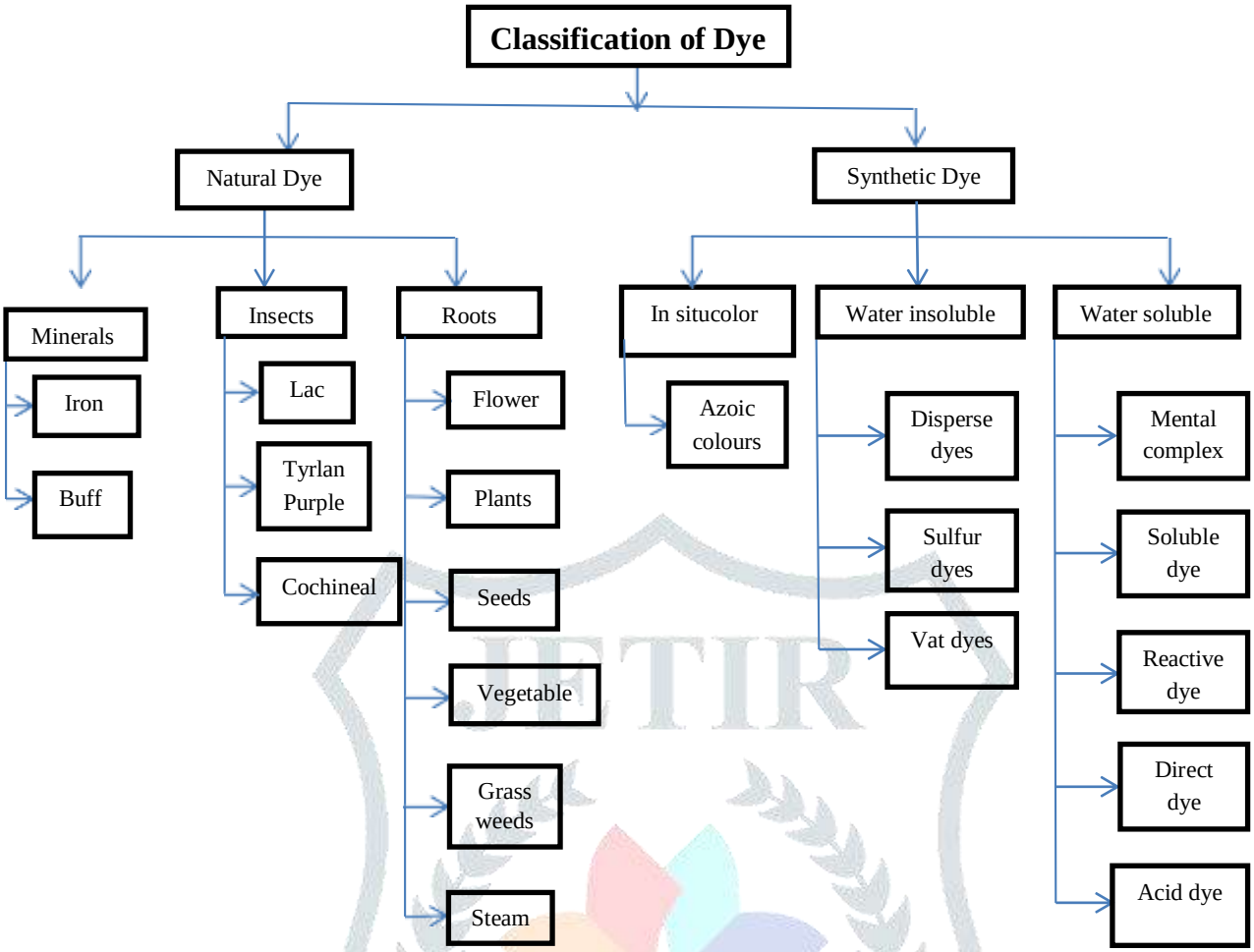
Natural Dye

Natural dyes are organic compounds used to colour various products. In Prior to the year of 1856, natural dyes are extracted from plants, animals, insects and minerals sources. Natural dyes are such as Turmeric, Weld, Onion, Jackfruit, henna, eucalyptus are used in the early textile industry. Due to the increase in population and industrial activities, natural dyes do not meet the industrial demand and their applications have

Synthetic Dye

The first synthesis dye was discovered by William Henry Per-kin in 1856. Dye effluents are produced because dyes do not have a complete degree of fixation to fiber during dyeing and finishing processes[5].Dye based effluents can cause a serious hazards to the water stream and environment due to their synthetic origin and complex moleculear structures which decrease their ability to biodegrade. There are various types of dyes used in various industries such as acid dyes, reactive dyes, basic dyes, azo dyes, direct dyes, vat dyes and disperse dyes [6]. All dyes are water soluble except disperse dyes and vat dyes .All dyes contain traces of metals such as copper, zinc, lead, chromium and cobalt in their aqueous solution except vat and disperse dyes. Dye bearing effluents from these industries are characterized by its high colour, organic content and hazardous as well. It is estimated that more than100, 000 commercial dyes are known with an annual production of more than 7 x 105 tonnes per year [2].Dyes are broadly classified into cationic, anionic and non-ionic dyes.

Anionic dyes include various dyes 'groups such as acid dyes, reactive dyes, azo dyes Figure -1 shows the classification of dyes.



Desiccation & Result

Factors Affecting Adsorption of Dye

There are many factors affecting dye adsorption such as solution pH, temperature, initial dye concentration, etc. Thus, the effects of these parameters are to be taken into account. Optimization of such conditions will greatly help in the development of industrial-scale dye removal treatment process. In this section, some of the factors affecting adsorption of dyes are discussed below:

Effect of solution pH

One of the most important factors affecting the capacity of adsorbent in wastewater treatment is solution pH. The efficiency of adsorptions dependent on the solution pH, since variation in pH leads to the variation in the degree of ionization of the adsorptive molecule and the surface properties of adsorbent [7].[8] studied the effect of solution pH on the adsorption of Basic Green4dye by An anscomosus leaf powder and they noticed that at a pH range from 2 to 10, the dye removal ratio was maximum at a pH 10.[9] studied the effect of solution pH on the adsorption of Congo red by pine cone and they noticed that the adsorption was maximum at pH of 3.5.[10] studied the adsorption of RB4 dye by modified barley straw and they found that RB4 gives a complete removal of 100% at pH of 3 and decreased value below 50% as the pH was increased.[11] reported that adsorption of cationic dye MB onto raw pine leaves biomass was increased with increase In solution pH (Figure1). Table 4 reported the compilation of different studies on the effect of solution pH on dye adsorption.

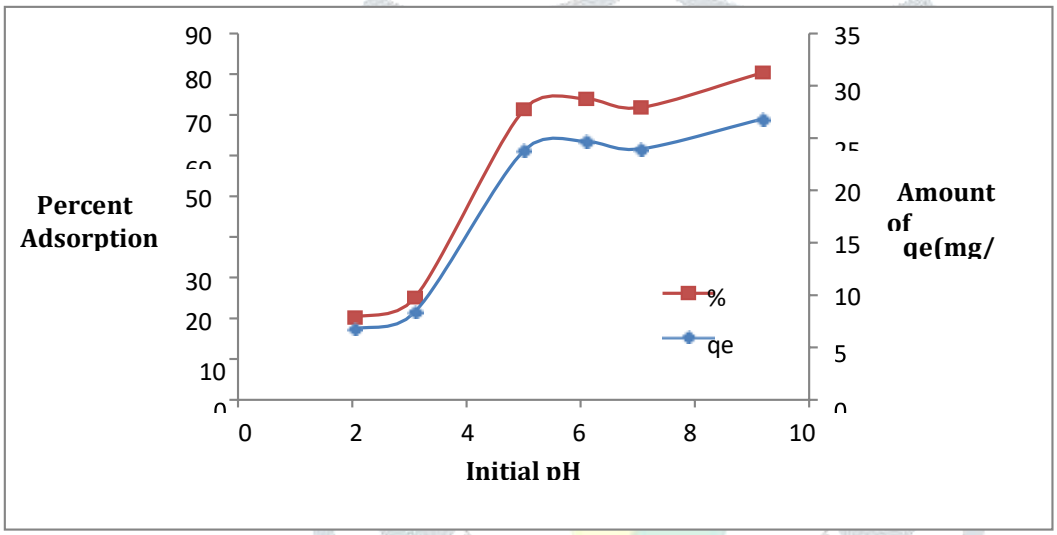


Fig.1 Effect of initial solution pH on the adsorption of Methylene Blue (MB) on pine leaves [11]

The adsorption ability of the surface and the type of surface active centers are indicated by the significant factor that is the point of zero charge (pH_{pzc}) [12]. The pH at which the surface charge is zero is called the point of zero charge (pzc) and is typically used to quantify or define the electro kinetic properties of a surface. The value of pH is used to describe pzc only for systems in which H^+/OH^- are the potential determining ions. Many researchers studied the point of zero charge (pH_{pzc}) of various adsorbents prepared from agricultural solid wastes; in order to underset and the adsorption mechanism. Due to presence of functional group such as OH^- group, cationic dye adsorption Is favoured at pH> pH_{pzc}, whereas, anionic dye adsorption is favoured at pH<$pH_{pzc\ where}$ the surface becomes positively charged [12].

Effect of initial dye concentration

The amount of adsorption for dye removals highly dependent on the initial dye concentration. The effect of initial dye concentration depends on the immediate relation between the concentration of the dye and the available sites on an adsorbent surface. In General, the percentage of dye removal decreases with an increase in the initial dye concentration, which may be due to the saturation of adsorption sites on the adsorbent surface. On the other hand the increase in initial dye concentration will cause an increase in the capacity of the adsorbent and this may be due to the high driving force for mass transfer at a high initial dye concentration [13-14] studied the adsorption of Methyl Orange by Chitosan/Alumina interface and it was found that when the Methyl Orange concentration increased from 20 mg/L to 400mg/L, the percentage of dye removal decreased from 99.53% to 83.55% with the same MB concentration range. [11] studied the effect of initial dye concentration on the adsorption of methylene blue (MB) by pine leaves and they noticed that as the initial dye concentration increase from10 to 90 mg/L ,the percentage removal of dye decreased from 96.5 to 40.9% on increasing the initial dye concentration from 10 to 90 mg/L after 240 minutes. Fig 2 showed that the amount of CR dye adsorption increased with increase initial dye concentration.

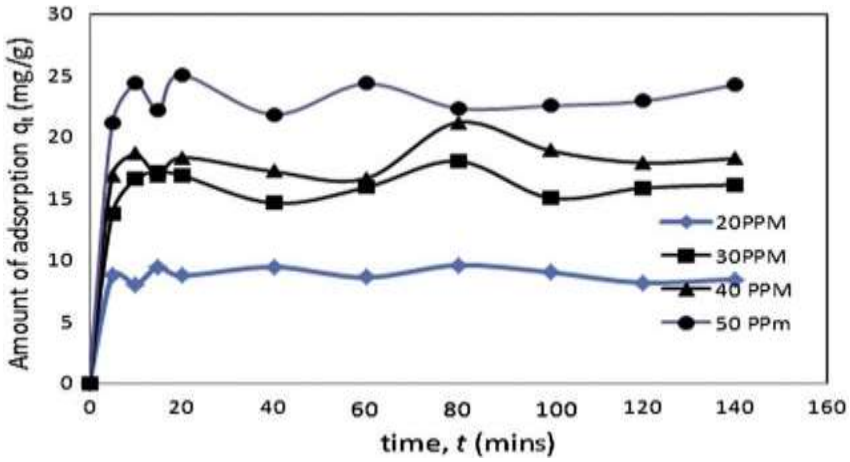


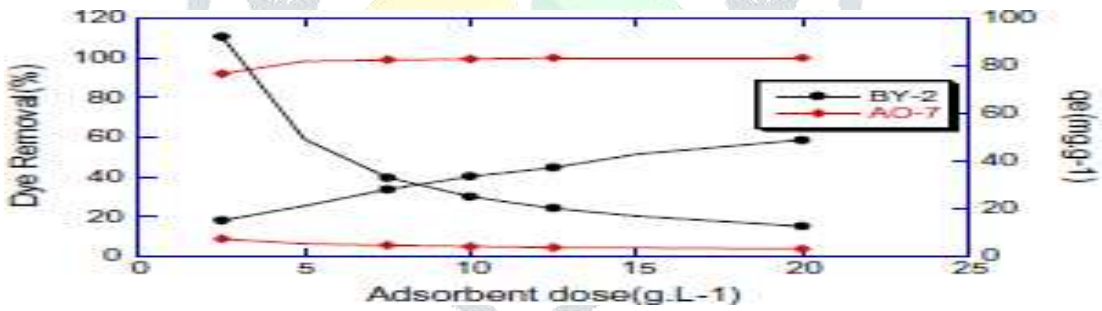
Fig.1 Effect of Initial Dye concertation (amount of CR dye adsorption increased with increase initial dye concentration.)

Effect of Temperature

Effect of temperature is another significant physio-chemical process parameter because temperature will change the adsorption capacity of the adsorbent [15]. If the amount of adsorption increases with increasing temperature then the adsorption Is an endothermic process. This may be due to increasing mobility of the dye molecules and an increase in the number of active sites for the adsorption with increasing temperature. Whereas the decrease of adsorption capacity with increasing temperature indicates that the adsorption is an exothermic process. This may be due to increasing temperature decrease the adsorptive forces between the dye species and the active sites on the adsorbent surface as a result of decreasing the amount of adsorption [1].

Effect of Amount of Adsorbent

Adsorbent dosage is an important process parameter to determine the capacity of an adsorbent for a given amount of the adsorbent at the operating conditions. Generally the percentage of dye removal increases with increasing adsorbent dosage, where the quantity of sorption sites at the surface of adsorbent will increase by increasing the amount of the adsorbent. The effect of adsorbent dosage gives an idea for ability of a dye adsorption to be adsorbed with a smallest amount of adsorbent, so as to recognize the capability of a dye from an economical point of view [1] Fig 3 presented the effect of doses on the removal of acidic and basic dye by tea waste [16].



. Fig 3 presented the effect of doses on the removal of acidic and basic dye by tea waste.

Various Adsorbents in the removal of Dyes from aqueous Solution

Activated carbon

Activated carbon is the most popular for the removal of pollutants from wastewater among allthe sorbent materials proposed [17, 18]. In particular, the effectiveness of adsorption on activated carbons for removal of a large variety of dyes from waste water such as made it an ideal alternative to the expensive treatment options[17].However, activated carbon possess several disadvantages, it is quite expensive ,problem in regeneration, non-selective and ineffective against disperse and vat dyes [18]. The use of carbons based on relatively expensive starting materials is also unjustified for most pollution control applications [19].This has led many researcher to search for alternative low cost adsorbents.

Low Cost Adsorbents for Dyes Removal

Selection of the precursor for the development of low cost adsorbents depends on many factors. The precursor should be freely available, in-expensive and non-hazardous in nature. In recent times, attention has been focused on different natural solid, which are able to remove pollutants from contaminated water at low cost. Cost is an important parameter for comparing the sorbent materials. In general, a sorbent can be assumed to be “low cost” if It requires little

processing and is abundant in nature, or waste material from another industry, which has lost its economic or is a by-product or further processing values. There are many low cost adsorbents that have been used for the removal of dyes. Also certain waste products from industrial and agricultural operations, natural materials and biosorbents represent potentially economical alternative sorbents. Many of them have been tested and proposed for dye removal. Waste treatment by adsorption using low cost adsorbent is a demanding area as it has double benefits i.e. water treatment and west management. Given below table shows example of absorption for removal of dye The use of agricultural waste helps tore duce the waste and produce a better waste minimization plan. Various cost effective adsorbents have been successfully used in the removal of textile dyes from.

Adsorbents	Dyes	Adsorption capacity (mg/g)	Reference
Raw coffee residue	Basic blue3G	251	[21]
Coffee waste	Toluidine Blue	142.5	[22]
Raw coffee residue	Remazol Blue	232	[21]
Pinecone	Congo red	19.18	[24]
Acid treated pinecone	Congo red	40.19	[24]
Palm shell	Reactivered141	14	[29]
Palm shell	Reactiveblue21	24.7	[29]
Pinecone	Methylene blue	109.9	[28]
Pine tree leave	Methylene Blue	126.6	[27]
Pinecone	AcidBlack26	62.9	[25]
Pinecone	AcidGreen25	43.3	[25]
Pinecone	AcidBlue7	37.4	[25]
Pine tree leaves	Basicred46	71.9	[23]
Organ attapulgite	Congo red	189.4	[31]
Rice husk	Indigo Carmine	65.9	[30]
Rice husk	Methylene blue	40.6	[26]
Pine saw dust	Acid yellow132	398.8	[30]
Pine saw dust	Acidblue256	280.3	[30]
Coffee residues	BasicBlue3G	179	[32]
Poplar leaf	Methylene Blue	135.35	[61]
Swede rape straw	Methylene Blue	246.4	[33]
Grape fruit peel	Crystal violet	254.16	[34]
Wheat bran	Crystal violet	80.37	[35]
Japonica	Crystal violet	82.83	[35]
Coniferous pinus bark	Crystal violet	32.78	[36]
Citrus sinensis Bagasse	Methylene Blue	96.4	[37]
Peanut hull	Methylene Blue	68.06	[38]
Banana peel	Methylene Blue	20.8	[39]
Pine apple stem	Methylene Blue	119.05	[40]
Pine sawdust	Acid yellow132	398.8	[30]
Garlic peel	Methylene Blue	82.64	[41]
Coconut bunch waste	Methylene Blue	70.92	[42]
Coffee husk	Methylene Blue	90.1	[43]
Rubber seed shell	Methylene Blue	82.64	[44]
Ground hazel nutshells	Methylene Blue	76.9	[60]
Walnut sawdust	Methylene Blue	59.17	[60]
Yellow passion fruit waste	Methylene Blue	44.7	[46]
Rice husk	Methylene Blue	40.59	[47]
Cherry sawdust	Methylene Blue	39.84	[60]
Coconut coir	Methylene Blue	15.59	[48]
Neem leaf powder	Methylene Blue	3.67	[49]
Pine apple leaf powder	Crystal violet	78.22	[50]
Sawdust	Crystal violet	37.83	[51]
Rice husk	Crystal violet	44.87	[52]
Orange Peel	Methylene Blue	18.6	[39]
Mango seed kernel	Methylene Blue	142.86	[53]

Pine Tree Leaves	Basic Red 46	71.94	[62]
Pinecone	Basic Red 46	73.53	[54]
Canola hull	Basic Red 46	49.00	[55]
Princess tree leaf	Basic Red 46	43.1	[56]
Rice husk	Direct Red 23	4.35	[57]
Rhizophoraapiculata bark	Direct Red 23	21.55	[58]
Pea nut hull	Reactive Black 5	55.55	[59]

Conclusion:-

A review of various type of activated carbon as adsorbent has been presented. The use of thsese activated carbon as adsorbent is recommended since they show a good potential in eliminating dyes from industrial wastewater, easily available, low cost and renewable. This paper presented the potential of adsorption process using activated carbon from agricultural waste to remove dye from textile wastewater. The factors effecting dye adsorption such as contact time, adsorbent dosage, pH and initial dye concentration has been discussed. Solution of pH turn to be the most important condition in adsorption process as for anionic dye, a low pH value are preferable in contrast for cationic dye where the suitable pH value is high. For the adsorbent dose, that the adsorption capacity increase along with the increment of adsorbent dosage due to the increase of available amount of sorption site. Is was also highlighted that the contact time between adsorbent and dye affecting the efficiency of dye removal where strong attraction force will shortened the time. As for the effect of dye initial concentration, increasing the initial concentration, enhance The increment of adsorbent surface area to adsorb dyes. Extensive studies in literature show that industrial waste and biosorbent activated carbon are among the less selective compound in removing dye. Furthermore, agricultural waste activated carbon showed effectiveness in removing dye such as basic dye and direct dye yet often being test for other pollutant such as copper II, fluoride and phenol. However, the raw material of activated carbon to be used are depends on the local sources available at low cost. According to the literature reviewed, these adsorption method using agricultural waste activated carbon have potential to be applied at full-scale wastewater treatment. These low cost adsorbent can used to replace the expensive adsorbents in the market nowadays.

References

[1] Salleh, Mohamad Amran Mohd, Dalia Khalid Mahmoud, Wan Azlina Wan Abdul Karim, and AzniIdris." Cationic and anionic dye adsorption by agricultural solid wastes: A comprehensive review." Desalinatio n280, no.1-3(2011):1-13.

[2] Gupta, V. K. "Application of low-cost adsorbents for dye removal–a review." Journal of environmental management 90.8(2009):2313-2342.

[3] Muhammad Tahir Amin, Abdulrahman Ali Alazba and Muhammad Shafiq, Adsorptive removal of reactive black 5 from waste water using Bentonite Clay: Isotherms, kinetics and thermodynamics, sustainability2015,ISSN2071-1050

[4] Yagub, Mustafa T, T. K sen, Sharmeen A froge, H, M Ang. "Dye and its removal from aqueous solution by adsorption: a review." Advances in colloid and interface science 209(2014):172-184.

[5] Pang Y L , Abdullah A Z. Current Status of Textile Industry Wastewater Management and Research Progress in Malaysia: A Re-view. Clean (Weinh) (2013)41:751–764.

[6] Demirbas A (2009) Agricultural based activated carbons for there moval of dyes from aqueous solutions: a review. J Hazard Mater removal of dyes from aqueous solutions: a review. J Hazard Mater167:1-9.

[7] Nandi, B., A. Goswami, and M. Purkait, Removal of cationic dyes from aqueous solutions by kaolin: Kinetic and equilibrium studies .Applied Clay Science, 2009.42(3-4):p.583-590.

[8] Chowdhury, S., S. Chakraborty, and P. Saha, Biosorption of Basic Green 4 from aqueous solution by Ananas comosus (pineapple) leaf powder. Colloids and Surfaces B: Bio interfaces, 2011.84(2): p.520-527.

[9] Dawood, S. and T.K. Sen, Removal of anionic dye Congo red from aqueous solution by raw pine and acid-treated pine cone powder as adsorbent: Equilibrium, thermodynamic, kinetics, mechanism and process design. Water Research, 2012. 46(6):p.1933-1946.

[10] Ibrahim, S., et al., Adsorption of anionic dyes in aqueous solution using chemically modified barley straw. Water science and technology: a journal of the International Association on Water Pollution Research, 2010.62(5): p.1177.

[11] Yagub, M.T., T.K. Sen, and H. Ang, Equilibrium, Kinetics, and Thermodynamics of Methylene Blue Adsorption by Pine Tree Leaves. Water, Air, & Soil Pollution, 2012.223(8):p.5267-5282.

[12] Liu, W., et al., Kinetics and thermodynamics characteristics of cationic yellow X-GL adsorption on at tapulgite /rice hull-based activated carbon nanocomposites. Environmental Progress &Sustainable Energy, 2012.32(3):p.655-662.

[13] Bulut, Y. and H. Aydın, A kinetics and thermodynamics study of methylene blue adsorption on wheat shells. Desalination, 2006.194(1):p.259-267.

[14] Zhang, J., Q. Zhou, and L. Ou, Kinetic, Isotherm, and Thermodynamic Studies of the Adsorption of Methyl Orange

from Aqueous Solution by Chitosan /Alumina Composite. Journal of Chemical & Engineering Data, 2012. 67:p.412-419.

[15] Argun, M.E., et al., Activation of pine cone using Fenton oxidation for Cd (II) and Pb (II) removal. Bio resource technology, 2008.99(18): p.8691-8698.

[16] Khosla, E., S. Kaur, and P.N. Dave, Tea waste as adsorbent for ionic dyes. Desalination and Water Treatment, 2013.13(ahead-of-print): p.1-10.

[17] Rama krishna, K.R. and T. Viraraghavan, Dye removal using low cost adsorbents. Water science and technology, 1997.36(2): p.189-196.

[18] Babel, S. and T.A .Kurniawan, Low-cost adsorbents for heavy metals uptake from contaminated water: a review. Journal of hazardous materials, 2003. 97(1):p.219-243.

[19] Banat, I. M.et. al. Microbial decolorization of textile-dye containing effluents: a review .Bio resource technology, 1996.58(3):p.217-227.

[20] Kyzas G Z, Lazaridis N K, Mitropoulos A C Removal of dyes from aqueous solutions with untreated coffee residues as poten-tial low-cost adsorbents: Equilibrium, reuse and thermodynamic ap-proach. Chem. EngJ.2012.189–190:148–159.

[21] Lafir, Fradj A B, Hafiane A, Hameed B H Coffee waste as potential adsorbent for there moval of basic dyes from aqueous solu-tion .KoreanJChemEng1.2014.-9.

[22] Deniz F, Karaman S Removal of Basic Red 46 dye from aqueous solution by pine tree leaves. ChemEngJ.2011. 170:67–74.

[23] Dawood S, Sen T K Removal of anionic dye Congo red from aqueous solution by raw pine and acid-treated pine cone pow-der as adsorbent: equilibrium, thermodynamic, kinetics, mechanism and process design. Water Res.2012.46:1933-1946.

[24] Slejko, F.L Adsorption technology: A step-by-step approach top rocess evaluation and application Vol. chemical industries series/19. 1985: Tall Oaks Publishing, Inc.223.

[25] Vadivelan V, Kumar K V Equilibrium, kinetics, mecha-nism, and process design for the sorption of methylene blue on to rice husk. J Colloid Interface Sci. 2005.286:90-100.

[26] Sen TK, Afroze S, Ang H M Equilibrium, kinetics and mechanism of removal of methylene blue from aqueous solution by adsorption on to pine cone biomass of Pinusradiata. Water, Air, & Soil Pollution 2011. 218:499-515.

[27] G Sreelatha, V Ageetha, J Parmar P Padmaja Equilibrium and kinetic studies on reactive dye adsorption using palm shell pow-der and chitosan. J. Chem. Eng Data 2011.56:35-42.

[28] Lakshmi U R, Srivastava V C, Mall I D, Lataye D H Rice husk as has an effective adsorbent: Evaluation of adsorptive characteristics for Indigo Carmine dye. J. Environ Manage 2009.90:710-720.

[29] Chen H, Zhao J (2009) Adsorption study for removal of Congo red anionic dye using organo attapulgite. Adsorption.2009. 15:381-389.

[30] Ozacar, M. and I.A. Sengil, Adsorption of metal complex dyes from aqueous solutions by pine saw dust. Bio resource technology, 2005.96(7): p.791-795.

[31] Ho, Y. S. and G. M c Kay, Sorption of dyes and copper ions on to biosorbents. Process Biochemistry, 2003.38(7):p.1047-1061.

[32] Kyzas, G.Z., N.K. Lazaridis, and A.C. Mitropoulos, Removal of dyes from aqueous solution swith untreated coffee residues as potential low-cost adsorbents: Equilibrium, reuse and thermodynamic approach. Chemical Engineering Journal, 2012.

[33] Feng, Y., et al., Methylene blue adsorption onto swede rape straw (Brassica napus) modified by tartaric acid: equilibrium, kinetic and adsorption mechanisms. Bio resource technology, 2012.125:p.138-144.

[34] Saeed, A., M. Sharif, and M. Iqbal, Application potential of grapefruit peel as dye sorbent: Kinetics, equilibrium and mechanism of crystal violet adsorption. Journal of hazardous materials, 2010.179(1):p.564-572.

[35] Wang, X.S., et al., Comparison of basic dye crystal violet removal from aqueous solution by low-cost biosorbents. Separation Science and Technology, 2008.43(14):p.3712-3731.

[36] Ahmad, R., Studies on adsorption of crystal violet dye from aqueous solution on to coniferous pinus bark powder (CPBP).Journal of hazardous materials, 2009. 171(1):p.767-773.

[37] Bhatti, H.N., N. Akhtar, and N. Saleem, Adsorptive Removal of Methylene Blue by Low-Cost Citrus sinensis Bagasse: Equilibrium, Kinetic and Thermodynamic Characterization. Arabian Journal for Science and Engineering, 2012:p.1-10.

[38] Gong, R., et al., Utilization of powdered peanut hull as biosorbent for removal of anionic dyes from aqueous solution. Dyes and pigments, 2005.64(3):p.187-192.

[39] Annadurai, G., R.S. Juang, and D.J. Lee, Use of cellulose-based wastes for adsorption of dyes from aqueous solutions.

Journal of hazardous materials, 2002.92(3):p.263-274.

[40] Hameed, B., R. Krishni, and S. Sata, A novel agricultural waste adsorbent for the removal of cationic dye from aqueous solutions. Journal of hazardous materials, 2009. 162(1): p. 305-311.

[41] Hameed, B. and A. Ahmad, Batch adsorption of methylene blue from aqueous solution by garlic peel, an agricultural waste biomass. Journal of hazardous materials, 2009. 164(2): p.870-875.

[42] Hameed, B., D. Mahmoud, and A. Ahmad, Equilibrium modeling and kinetic studies on the adsorption of basic dye by a low-cost adsorbent: Coconut (Cocos nucifera) bunch waste. Journal of hazardous materials, 2008.158(1):p.65-72.

[43] Oliveira, L.S., et.al., Evaluation of untreated coffee husks as potential biosorbents for treatment of dye contaminated waters. Journal of hazardous materials, 2008. 155(3): p. 507-512.

[44] Oladoja, N. et.al. Studies on castor seed shell as asorbent in basic dye contaminated wastewater remediation. Desalination, 2008. 227(1-3):p.190-203.

[45] Han, R., et al., Biosorption of methylene blue from aqueous solution by fallen phoenix tree's leaves. Journal of hazardous materials, 2007.141(1): p.156-162.

[46] Pavan, F.A., et al., Methylene blue biosorption from aqueous solutions by yellow passion fruit waste .Journal of hazardous materials, 2008.150(3): p.703-712.

[47] Vadivelan, V. and K.V. Kumar, Equilibrium, kinetics, mechanism, and process design for the sorption of methylene blue onto rice husk. Journal of colloid and interface science, 2005.286(1): p.90-100.

[48] Sharma, Y.C. and S.N. Upadhyay, Removal of a cationic dye from wastewaters by adsorption on activated carbon developed from coconut coir. Energy &Fuels, 2009.23(6):p.2983-2988.

[49] Bhattacharyya, K. G. and A. Sharma, Kinetics and thermodynamics of Methylene Blue adsorption on Neem (Azadirachta indica) leaf powder. Dyes and pigments, 2005. 65(1): p.51-59.

[50] Chakraborty, S., S. Chowdhury, and P.D. Saha, Insight into biosorption equilibrium, kinetics and thermodynamics of crystal violet onto Ananas comosus (pineapple) leaf powder. Applied Water Science, 2012:p.1-7.

[51] Parab, H., et. al., Use of Agro-Industrial Wastes or Removal of Basic Dyes from Aqueous Solutions. CLEAN–Soil, Air, Water, 2009.37(12):p.963-969.

[52] Chakraborty, S., S. Chowdhury, and P. Das Saha, Adsorption of Crystal Violet from aqueous solution on to NaOH-modified rice husk .Carbohydrate Polymers, 2011. 86(4):p.1533-1541.

[53] Kumar, K .V. and A. Kumaran, Removal of methylene blue by mango seed kernel powder. Biochemical engineering journal, 2005.27(1):p.83-93.

[54] Deniz, F., S. Karaman, and S.D. Saygideger, Biosorption of a model basic dye onto Pinus brutia Ten.: Evaluating of equilibrium, kinetic and thermodynamic data. Desalination, 2011. 270(1):p.199-205.

[55] Mahmoodi, N.M., et al., Novel biosorbent (< i> Canola</i> hull): Surface characterization and dye removal ability at different cationic dye concentrations. Desalination, 2010. 264(1): p.134-142.

[56] Deniz, F. and S.D. Saygideger, Removal of a hazardous azo dye (Basic Red 46) from aqueous solution by princess tree leaf .Desalination, 2011.268(1):p.6-11.

[57] Abdelwahab, O., et al., Use of Rice Husk for adsorption of direct dyes from aqueous solution: Case Study .J. Aquatic Res, 2005.31: p.1-11.

[58] Tan, L., K. Jain, and C. Rozaini, Adsorption of textile dye from aqueous solution on pretreated mangrove bark, an agricultural waste: equilibrium and kinetic studies. Journal of Applied Sciences in Environmental Sanitation, 2010.5(3):p.283-294.

[59] Tanyildizi, M.Ş., Modeling of adsorption isotherms and kinetics of reactive dye from aqueous solution by peanut hull. Chemical Engineering Journal, 2011.168(3): p.1234-1240.

[60] Ferrero, F., Dye removal by low cost adsorbents: Hazelnut shells in comparison with wood saw dust. Journal of hazardous materials, 2007. 142(1):p.144-152.

[61] Han, X., X. Niu, and X. Ma, Adsorption characteristics of methylene blue on poplar leaf in batch mode Equilibrium, kinetics and thermodynamics. Korean Journal of Chemical Engineering, 2012: p.1-9.

[62] Sen, T.K., Agricultural by-product biomass for removal of pollutants from aqueous solution by adsorption. Journal of Environmental Research and Development Vol, 2012. 6(3): p. 523-533.