EFFICACY OF LOW-COST CARBON ADSORBENTS IN THE REMOVAL OF MALACHITE GREEN DYE

By

KRISHNAKUMARI.K

REG NO: 16PCH009

A Dissertation submitted to

Avinashilingam Institute for Home science and Higher Education
for Women University,Ciombatore-641 043.

In partial fulfillment of the requirement for the

Master's Degree in Chemistry

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N. Renugadevi

Signature of the Guide

10/4/18

Signature of Head of the Department

Acknowledgement

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KRISHNAKUMARI.K

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INTRODUCTION

POLLUTION

Pollution is the introduction of contaminants in to the natural environment that cause adverse change. Pollution can take the form of chemical substances or energy such as noise, heat or light.

TYPES OF POLLUTION

1. Air pollution
2. Soil pollution
3. Biological pollution
4. Nuclear pollution
5. Water pollution

AIR POLLUTION

Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth atmosphere.

CAUSES OF AIR POLLUTION

- Carbon dioxide released into air by deforestation and fossil fuel burning.
- Burning ofsulphur containing fossil fuel releases sulphurdioxide into the atmosphere
- Burning of plastic materials, leakage of refrigerator, air condition equipments, spray cans releases chlorofluorocarbons (CFCS) in the environment, chlorofluorocarbons causes depletion of ozone layer.
- Hydrocarbons, oxides of nitrogen from burningof fossil fuels, suspended particulate matter by diesel engines also cause air pollution.

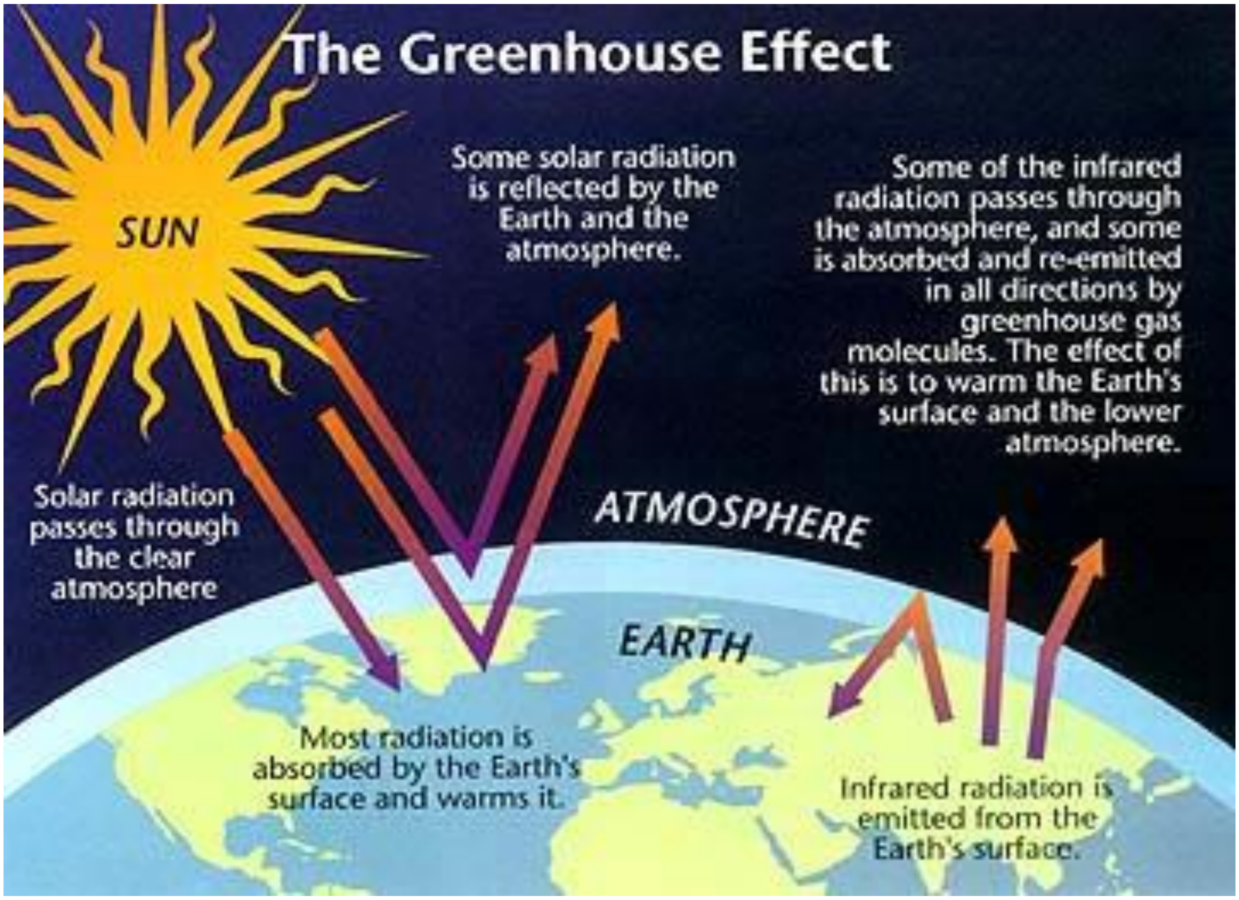
NATURAL AIR POLLUTANTS

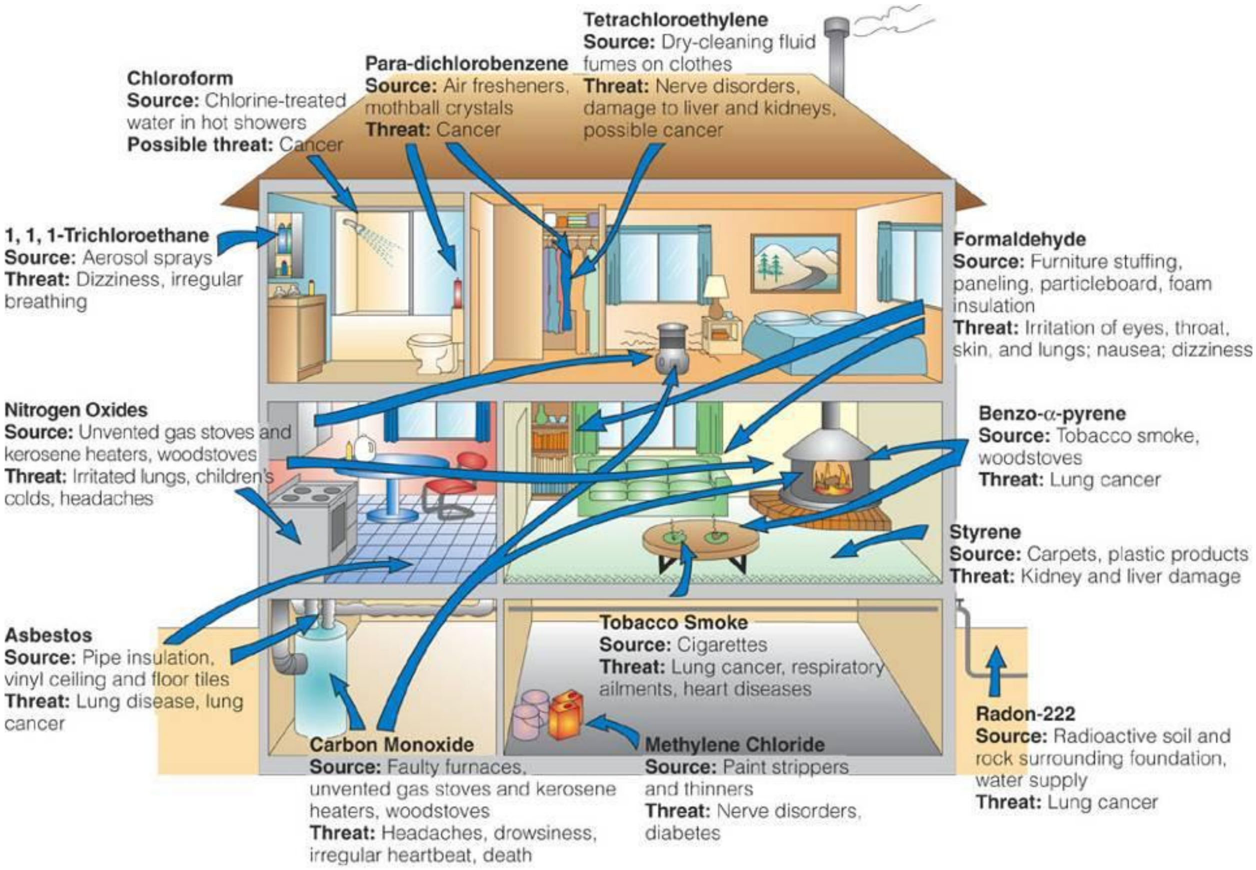
- Smoke form wild fires
- Methane released from live stock
- Volcanic eruptions**(Ratnashelka*e*t al.,2010).**

AIR POLLUTION

GREEN HOUSE EFFECT

CO_2 is a good transmitter of sunlight, but it also partially restricts infrared radiation going back form the earth into space, which produces the so called greenhouse effect, that prevents a drastic cooling of the earth during the night. Increaseinthe amount of CO_2 in the atmosphere reinforces this effect and is expected to result in a warming of the earth surface.





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SOIL POLLUTION

- Contamination of soil system by considerable quantity of chemicals or other substances results in reduction of its fertility.
- Construction waste, agriculture waste, domestic waste, industrial waste etc cause soil pollution.

CAUSES OF SOIL POLLUTION

Textile, dye, soap, and detergent, drug, cement, rubber, paper& pulp, leather, industries release pollutants in to the natural resources. Agro chemicals, fertilizers, pesticides, insecticides, rodenticides, fumigants release toxic pollutants like Pb, AS, Cd, Hg, CO etc. Thus it cause soil pollution by polluting the soil and water **(Baskaran*et* al.,2010).**

RADIOLOGICAL AND NUCLEAR POLLUTION

Radioactivity is a property of certain elements like Ra,Th,U etc. which spontaneously emit alpha,beta,gamma rays by disintegration of atomic nuclei.

The causes of nuclear pollution are nuclear explosions, nuclear weapons,radioactionnuclear fission, fusion and mining etc.

EFFECT OF NUCLEAR POLLUTION

The effect of nuclear pollution vary from organism to organism and from level of radioactivity of nuclear isotopes.The radiations destroy the normal cells in human body and causes cancer.A longer exposure to radioactive radiations can damage the DNA cells that results in cancers,genetic defects for the generations to come and even death,killfoetus in the womb andaffects animals also **(Albbanis*et* al.,2000).**

BIO POLLUTION

Disturbance of the ecological balance by the accidental or deliberate introduction of the foreign organism,animal or plant species in to the environment. Bio pollution cause decline in naturalness of nature conservation areas **(Amanyyousself*et* al.,2008).**

WATER POLLUTION

Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater) .This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful pollutants.

SOURCES OF WATER POLLUTION

Industrial effluents discharged from textile, leather, paper and pulp, cosmetic, food, plastic, electroplating and pharmaceutical industries, sewage system, power plants, underground coal mines and oil wells are the major sources of water pollution. Thus water pollution has become an environmental problem in world wide

WASTE WATER TREATMENT

Various techniques are used for removal of pollutants from waste water like adsorption, nanofiltration, electro kinetics, coagulation, coagulation and precipitation, flocculation, sedimentation, flotation, filtration, reverse osmosis, oxidation, electro dialysis, ion- exchange etc. Adsorption is one of the most efficient method to remove pollutants from effluents. Commercially activated carbon or charcoal is considered to be the most suitable adsorbing media. Due to the high cost of the commercial activated carbon some low-cost, eco-friendly activated carbon adsorbents are prepared from agriculture or industrial waste products and used as the adsorbents for the removal of pollutants from waste water.**(Rajeshkannan*et* al.,2009).**

ADSORPTION

The accumulation of molecular species at the surface rather than the bulk of a solid or liquid is known as adsorption.

In other works the surface of a solid has a tendency to attract and to retain molecules of other species (gases or liquids)with which such surfaces comes in contact. This phenomenon is termed as adsorption.

ADSORBATE

The molecular species or substance ,which concentrates or accumulates at the surface of a solid is termed as adsorbate.

Examples of adsorbate :

Various gases like He, Ne, O_2, SO_2, NH_3, etc……

ADSORBENT

The material on the surface of which the adsorption takes place is called adsorbent.

Example of adsorbent :

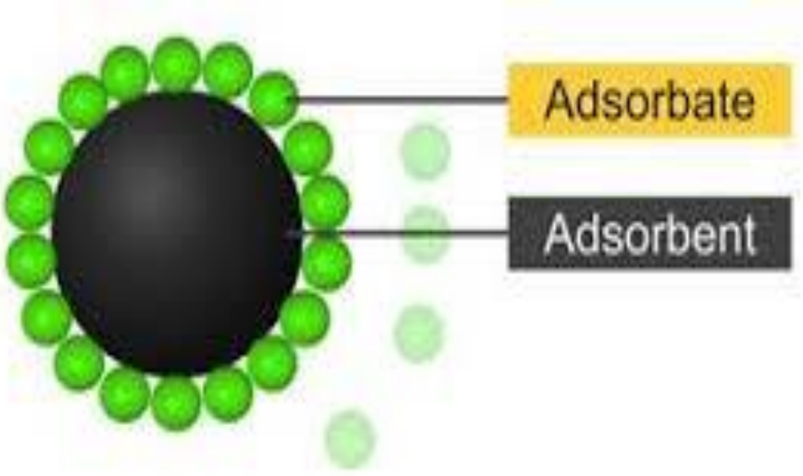
(1) Silica gel:

It acts as a good adsorbent and is prepared by mixing sodium silicate with 10% HCl at 50℃

(2) Metals acts as good adsorbents and are being used for contact analysis.These are prepared by the reduction of their oxides or of the salts under suitable experimental conditions.

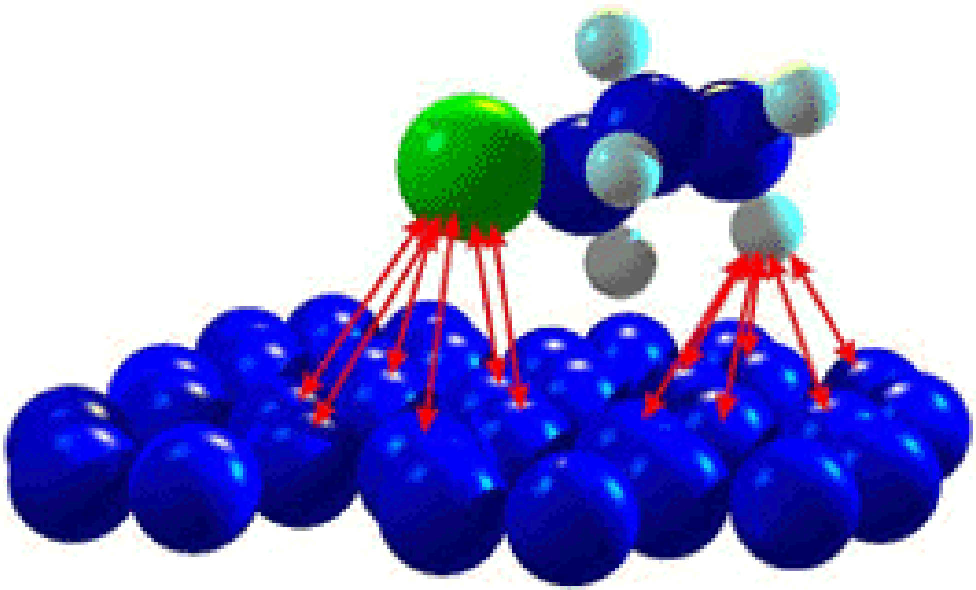
For example : Ni, Cu, Ag ,Pt, and Pdetc are acts as good adsorbents.

(3) Colloids : As colloids possess high surface per unit mass due to small size. They are acts as good.



Adsorption is mass transfer process which involves the accumulates of substances at the interface of two phases, such as, liquid-liquid, gas-liquid,gas –solid or liquid-solidinterface. Thesubstance being adsorbed is the adsorbate and the adsorbing material**(Rajeshkannan*et* al., 2009).**

ADSORBATIVE FORCES



PHYSISORPTION

The properties of adsorbates and adsorbents are quite specific and depend upon their constituents.If the interaction between the solid surface and the adsorbed molecule as a physical nature. The process is called physisorption. In this case, the attraction interactions are vanderwaals force and, as they are weak the process results arereversible. It occurs lower or close to the critical temperature of the adsorbed substance.

CHEMISORPTION

- The attraction forces between adsorbed molecules and the solid surface are due to chemical bonding, the adsorption process is called chemisorption.
- Chemisorption occurs only as a mono layer .Often very specific in nature.

The rate of chemisorption decrease with increase of pressure.**(Godbole*e*t al.,2006).**

Objectives

- To compare the removal efficiency of two selected low-cost activated carbon adsorbents with commercially available activated carbon.

Review of Literature

REVIEW OF LITERATURE

One can utilize resources of inexpensive waste and little used materials among various ways of treating industrial effluents containing dyes.Human are dependent upon ecosystem services such as air, water and food for survival. Most of the pollutions are due to increase in population, growth of industries, urbanization, lack of environment awareness and use of chemical fertilizers instead of organic manures. Dyes have harmful effects on environment and human health. Most of the dyes are completely resistant to biodegradable process. Coloured waste water cannot be discharged without adequate treatment, due to toxic nature of dyes to plants and microorganisms. By the above study the aim is to use low-cost adsorbent for the removal of dyes from aqueous solution **(Josep Egli2007).**

Waste water Treatment

Various techniques have been employed for the removal of dyes from waste water. They involve the combination of physical, chemical, and biological methods such as chemical coagulation /flocculation, advanced oxidation process, chemical precipitation, ion- exchange, reverse osmosis, sedimentation which may be efficient for the removal of dyes from waste water **(Kumar and Tamilarasan.,2012).**

There are four types of waste water treatment:

- Preliminary treatment process
- Primary treatment process
- Secondary treatment process
- Tertiary treatment process

Preliminary treatment process

- The coarse and readily settle able inorganic solids with the size range of more then 0.01mm, such as sand and grit particles are removed by preliminary treatment and this was carried out using screen and grit chambers**(Shon et al .,2006).**

- Screening process used to remove certain materials like piece of woods, plastic, paper, floatry debris, rags etc. present in the waste water **(Sharma and kaur,1998).**
- By using grit chambers, the heavy inorganic materials like sand, ash and others can be removed. By the method of floatation skimming tanks, grease and oily substance can be removed **(Satyanarayana ,2006).**

Primary treatment process

In this treatment most of the settleable solids are separated or removed from the waste water by physical processes of sedimentation and flotation **(http://www.water.siemens.com).**

They are three ways :

- Sedimentation
- Flotation
- Filtation

Sedimentation

It is a physical phenomenon relating to the settling of solids by gravity. Sedimentation for solid separation is a very common process and is routinely employed at the beginning and end of waste water treatment operation **(http://en.wikipedia.org/wike/sedimentation).**

Flotation

Dissolved air flotation involves the dissolution of air in waste water by pressurizing it in a pressure vessel. When the air saturated waste water is released to the flotation tank, the sudden decrease in pressure causes the air to come out of the solution as micro-bubbles which will attach themselves to solid particles in the waste water and make them float **(Carty *e*t al.,1997).**

Filtation

Waste water is passed through a filter medium to separate solids. An example would be the use of sand filters to further remove entrained solids from treated waste water **(http://en.wikipedia.org/wiki/filtration)**.

Secondary treatment process

The process consists of removing or reducing contaminants that are left in waste water from primary treatment process.

They are two ways :

- Chlorination
- Coagulation

Chlorination

It is commonly used chemical process. Chlorine is a strong oxidizing chemical used to kill bacteria and slow down the rate of decomposition of the waste water **(Shon*et* al.,2006).**

Coagulation

Treatment of waste water with coagulant removes colloidal and coarse dispersed impurities is coagulation **(Kaur,2005).**

Oxidation process

Oxidation process is a one of the method of wastewater treatment by using oxidizing agents. Two methods such as UV assisted oxidation and chemical oxidation using chlorine, hydrogen peroxide, fenton's regent, ozone and potassium permanganate are used for treating the effluents. Hydrogen peroxide are used for the decolourisation of dyes, which has strong oxidizing properties and it is powerful bleaching agent. Chlorine is obtained from calcium hypochlorite and sodium hypochlorite, which is a strong oxidizing agent. Textile industry effluent containing reactive dyes, remazol carbon, remazol gold yellow was decolourisation using fenton's oxidation**(Gupta and suhas, 2009).**

Ozonation process

Ozonationprocess has been found to be very effective for the removal of dyes from textile effluents. Ozonation can be used to remove the colour completely and chemical oxygen demand to an extent this was suggested by many authors which is sufficient for the reuse of water**(Wu et al ., 2008).**

Tertiary treatment process

Tertiary treatment is the final treatment meantfor polishing the effluents from the secondary treatment process **(www.water.siemens.com).**

Electrochemical process

Electrochemical process is a tertiary treatment used to remove colour. In this process decolourisation can be achieved either by electro oxidation with non -soluble anodes or by electro-coagulation using consumable materials. The main drawbacks of this process are high electricity cost, sludge production and causes pollution due to indirect oxidation **(Gupta and Suhas., 2009).**

Reverse osmosis

It is filtration method where the demineralized water is forced through a semipermeable membrane at high pressure which removes large molecules and ions from the solution. The membrane is better at rejecting salts, non ionized weak acids, bases and smaller organic molecules, generally molecular weight below 200**(Kaur ,2005).**

Ion exchange

It is a reversible chemical reaction where in an ion from solution is exchanged for a similarly charged ion attached to an immobile solid particle. These solid ion exchange particles are either naturally occurring inorganic zeolites or synthetically produced organic resins.**(http://www remco.com/ix.htm).** By far, the largest application of ion exchange process of drinking water treatment is in the area of softening and the removal of hardness producing salts **(Wu et al.,2008).**

Adsorption

The term adsorption refers to the accumulation of a substance at the interface between two phases (liquid-solid interface or gas-solid interface). The substance that accumulates at the interface is called adsorbate and the solid on which adsorption occurs is adsorbent.

Hence adsorption is defined as “the concentration of substance at the interface between two immiscible phase like solid-liquid, solid-gas, liquid-liquid or liquid-solid”. Adsorption is a surface phenomenon, the larger the surface area, greater will be the adsorption.

Adsorption is one of the efficient method to remove dyes from effluents. Activated carbon or charcoal is considered as a most suitable adsorbing media for such purpose. Hydrocarbons , Organic acids, Esters, Ketone and heavy metals get readily adsorbed on activated carbon **(Rajeshkannan*et* al.,2009).**

Commercial adsorbent

A number of materials have been investigated as adsorbent in waste water treatment. Some of the important ones included silica gel, activated alumina, zeolites and activated carbon etc.,

Silica gel

Silica gel is a non-toxic, inert and efficient support and is generated by decrease in the pH value of the alkali silicate solution to less than ten. Kinetic studies shows that the adsorption follows pseudo- second order kinetics and intra particle diffusion model. Oxalic acid and citric acid modified silica gel used for the removal of malachite green dye from aqueous solution **(Atulkumarkushwaha et al.,2010).**

Zeolites

Natural zeolites are abundant low cost resources, which are crystalline hydrated aluminosilicates with a framework structure containing pores occupied by water, alkali and alkaline earth cations. (**Han 2010).**recently used zeolites for the removal of malachite green from aqueous solution.

Activated alumina

The activated alumina comprises a series of non equilibrium forms of partially hydroxylated alumina oxide. Activated alumina is a filter media made by treating aluminium ore so that it becomes porous and highly adsorptive **(Johnson et al., 2005).**

Activated carbon

Activated carbon has undoubtedly been the most popular and widely used adsorbent in treatment of waste water throughout the world. Low cost adsorbents can be prepared from a wide variety of raw materials which are abundant and cheep, having high organic content and low inorganic content and these can be easily activated. The preparation of low cost adsorbents from waste materials has several advantage, mainly of economic and environmental nature.

Low cost adsorbent

Materials which are locally and abundantly available such as agricultural wastes and industrial by-products can be utilized as low cost adsorbent conversion of these materials into adsorbents for waste water treatment would help to reduce the cost of waste disposal and provide an alternative to commercial activated carbon **(Kurniawan*et* al.,2006).**

Agricultural waste as adsorbents

Agricultural waste materials are viable option for waste water treatment due to eco-friendly and economic nature, unique chemical composition, availability in abundance and renewable in nature.

- Ground nut shell activated using $Zncl_2$ was used for malachite green removal. It's adsorption properties was compared with commercially available powered activated carbon. The results of comparative adsorption capacity of both carbons indicated that ground nut shell can be used as low-cost alternative to commercial powered activated carbon in aqueous solution for malachite green removal **(Malik *e*t al.,2006)**
- Activated carbon prepared from tamarind fruit shells by direct carbonization was used for the removal of Rhodamine B and malachite green dyes from aqueous solutions. Increase in pH of the solution resulted in increased adsorption of both the dyes **(Edwin Vasu 2008).**
- The removal of textile dye malachite green was studied by **(Xavier *e*t al., 2011).** By adsorption technique using adsorbents such as rose apple carbon, coconut shell carbon and saw dust carbon. The percentage of dye adsorbed increases with decrease in initial concentration.
- **(Garg*et* al.,2003)** Successfully removed Malachite green from aqueous solution using Prosopis cineraria saw dust. The adsorbent included formaldehyde treated saw dust (PCSD) and sulphuric acid treated saw dust (PCSDC). The adsorption efficiency was compared with commercially available coconut based activated carbon. The experimental

studies indicated that PCSD and PCSDC can be employed as a low- cost alternative in wastewater treatment for the removal of malachite green.

- **(Hameed*et* al.,2008)** studied the adsorption of malachite green on rattan (stems of climbing palm) saw dust at 30°C. The results indicated that rattan saw dust can be used as low –cost adsorbents for the removal of Malachite green fro aqueous solution.
- Maize cob powder used for the adsorption of Malachite green. The results demonstrated that the maize cob powder is a low-cost alternative in wastewater treatment for the dye removal **(Sonawane*et* al., 2009).**
- **(Baskaran*et* al., 2010)** studied the ability of zea mays dust carbon to remove Malachite green from aqueous solution. The results showed that adsorption on zea mays dust carbon followed Langmuir and Freundlich adsorption isotherm.
- Adsorption of malachite green on treated ginger waste was carried out by**(Rais Ahmed *e*t al.,2010).** The effect of various factors such as initial dye concentration , contact tine, pH and temperature were studied. The adsorption of Malachite green was observed at" pH 9.
- **(Hameed*et* al., 2008)** studied the adsorption of Malachite green on activated carbon prepared from bamboo by chemical activation with k_2 Co_3 and physical activation with Co_2. The equilibrium data fitted well with the Langmuir model with maximum adsorption capacity.
- **(Xing *e*t al., 2009)** reported that adsorption capacity of ethylene diamine tetra acidic dianhydride (EDTAD) modified sugarcane baggase for Malachite green showed a significant increase compared with sugarcane baggase. Kinetic studies showed better correlation coefficient for pseudo second order kinetic model confirming that the adsorption rate was controlled by a chemisorptions process.
- Nirgudi leaf powder used for the Malachite green adsorption has been investigated by **(RatnaShelke*et* al.,2010)**. Experimental adsorption kinetic data were fitted to be Lagergren first order. Equilibrium data were well represented by the Freundlich and Langmuir isotherm model for all tested adsorption system.
- **(Nethaji*et* al., 2010)** studied the removal of Malachite green from aqueous solution by batch adsorption on Borassusaethiopum (African fan, palm) flower. The result showed

that the adsorption followed pseudo second order model and the adsorption was both film diffusion and by intra particle diffusion.

- **(Santhi*e*t al., 2010)** investigated the potential use of activated carbon prepared from Annonasqumosa (Custard apple) seed. The experimental results indicated that the Annonasqumosa seed an attractive option for removal made on dyeing waste water. The results showed better removal percentage of Malachite green.
- **(Hema*e*t al., 2009)** examined the ability to remove Malachite green from aqueous solution using an activated carbon prepared from Borassus (palm) bark. The temperature variation study showed that the dye adsorption was endothermic and spontaneous with increased randomness at the solid solution interface.
- The banana pseudo stem fiber was used as an adsorbent for the removal of Malachite green. The adsorption process followed pseudo second order kinetic and intra paticle diffusion rate model. Equilibrium data were fitted to Langmuir and Freundlich isotherm **(Neha Gupta *e*t al.,2011).**
- **(Mendez *e*t al., 2006)** studied the removal of Malachite green in waste water using the carbon based adsorbents obtained from pyrolysis of waste material from paper industry and pine bark. The results showed that percentage of Malachite green removal were higher with the carbon based material prepared from paper industry than from pine bark.
- **(Xiang Liang Pan *e*t al.,2008)** reported that wood fiber of phoenix tree is an effective adsorbent for Malachite green. The results showed that it follows pseudo second order equation. The Freundlich isotherm described the adsorption data.
- **(Santhi*e*t al.,2010)** investigated the potential use of activated carbon prepared from the epicarp of Ricinuscommunis for the removal of Malachite green dye from simulated waste water. The results showed that as the amount of the adsorbent increased, the percentage of dye removal increased accordingly. The maximum removal of Malachite green was obtained at pH 7 as 99.04% for adsorbent dose 1g 50mL(-1) of initial dye concentration at room temperature.
- Batch adsorption experiments were carried out for the removal of Malachite green from aqueous solution using Arundodonax root carbon (ADRC) as adsorbent. The results

showed that the adsorption of Malachite green onto ADRC followed pseudo second order model **(Zhang *e*t al.,2007).**

- Oil palm trunk fiber (OPTF) an agricultural solid waste was used as a low cost adsorbent to remove Malachite green from aqueous solution. Equilibrium adsorption data were analyzed by three isotherm, namely the Freundlich isotherm, the Langmuir isotherm, and the Multilayer adsorption isotherm. It was found that with increasing the initial concentration of Malachite green, the pore –diffusion coefficient increased while the film-diffusion coefficient decreased **(Hameed*e*t al.,2007).**
- Orange peel, banana peel, jack fruit, mango peel, pine apple, and cassava etc have been used as inexpensive adsorbents for the dye removal from wastewater. The effectiveness of orange peel in adsorbing Acid violet 17 ,Direct Blue 86 , Congo Red , Procion Orange and Rhodamine B was studied as a function of agitation time, adsorbent dosage, initial dye concentration and pH . Lemon peel was examined as an adsorbent for the removal of Malachite green **(Kumar 2007).**
- Neam saw dust (Azadirachtaindica) was used as an adsorbent for the removal of Malachite green from an aqueous solution. The studies were carried out by varying agitation time, dye concentration, adsorption dose, pH and temperature to assess the potentially of neem saw dust for the removal of Malachite green dye from waste water. A greater percentage of dye removal was observed with decrease in the initial concentration of dye and increase in amount of adsorbent. The equilibrium isotherm was analysed by the Langmuir model and the monolayer adsorption capacity was found to be 4.354 mg g^{-1}

Industrial by-products as adsorbents

Industrial activities generate huge amount of solid waste materials as by-products. The industrial waste material is available almost free of cost and causes disposal problem. If the solid wastes could be used as adsorbents, the volume of waste materials can be partly reduced as well as the pollution of wastewater can be reduced at reasonable cost. Thus, a number of industrial wastes with or without treatment have been investigated as adsorbents for the removal of pollutants from wastewater.

- **(Hiroshi Kominami*et* al.,2003)** developed a photo catalytic decolourization and mineralization of Malachite green in aqueous solution of titanium (IV) oxide nanoparticals under aerated conditions. Longer irradiation was required for mineralization of Malachite green. Total organic carbon in the suspension with improved crystallinity continuously decreased.
- **(ShamikChowdhury*et* al., 2010)** have reported that alkali treated fly ash is a potential low-cost adsorbent for the removal of Malachite green from aqueous solution. The Langmuir isotherm model showed good fit to the equilibrium adsorption data at all temperatures. The kinetic data were found to follow the pseudo second order kinetic model.
- Removal of some reactive dyes from textile effluents using Sorel's cement. The adsorption isotherms including Langmuir constant and freundlich constant for the dyes decrease with increase of temperature **(Hassan *e*t al.,2009).**
- **(Lugun*et* al.,2009)** investigated the adsorption of Malachite green using Mahua oil cake. The results indicated that Mahua oil cake is an attractive adsorbent for removing basic dye from aqueous solution.
- Perlite was utilized as an adsorbent for the removal of Malachite green from aqueous solution. The negative values of energy of adsorption and positive values of entropy change suggested that the adsorption process is spontaneous and endothermic**(vijayakumar*et* al.,2010).**
- **(Back *e*t al., 2009)** reported the feasibility of employing degreased coffee beans as adsorbent for Malachite green removal in dyeing wastewater. The adsorption reaction well fitted with the Langmuir isotherm and Freundlich models.
- The surfactant – modified alumina (SMA) was used for the removal of Malachite green from aqueous solution. All the studies were carried out in batch mode. SMA was very efficient to remove Malachite green up to 99%. The isotherm studies showed that it follows Langmuir model better than Freundlich model **(Das *e*t al.,2009).**
- **(Suchithra*et* al.,2008)** studied the removal of cationic dyes malachite green methylene blue and crystal violet from aqueous solutions using Humic acid-immobilized amine modified polyacrylamide/bentonite composite. The result shows that more than 99% removal of dyes was detected at pH range 6.0- 8.0. The capacity of HA-Am-PAA-B was

found to decrease in the following order: MG>MB>CV. The kinetic and isotherm data were interpreted by pseudo second order rate equation and freundlich isotherm model respectively.

Bio adsorbent used as an adsorbent

- Pine tree root decayed by brown rot fungi tried for the first time for the removal of malachite green from aqueous solution. The results showed that malachite green adsorption was mainly a spontaneous, endothermic and chemisorptions process**(Hong Zhang *e*t al., 2011).**
- **(Amanyyoussef*e*t al,.2008)** studied the decolourization of malachite green by the local isolate Acremoniumkiliense. Decolourization rate for malachite green dye is shacked culture were found to be more than the static culture and also depends on biomass concentration.
- The adsorption of malachite green on Hydrillaverticillata biomass, a submerged aquatic plant was investigated in a batch system. The Langmuir and freundlich isotherm models were applied to the equilibrium data. The maximum monolayer coverage capacity of Hydrillaverticillata biomass for malachite green was found to be 91.97 mg/g at an initial pH 8.0.It was found that external diffusion as well as intra particle diffusion contributes to the actual adsorption process. The pseudo- second order kinetic model described the malachite green adsorption process with a good fitting**(Rajeshkannan*e*t al., 2010).**
- The removal of a cationic dye Malachite green from aqueous solution using chitosan bead was carried out. Langmuir equation showed higher conformity than freundlich equation. 99% removal of Malachite green was reached at the optimum pH value of 8. From kinetic experiments, it was observed that adsorption process followed the pseudo-second order kinetic model. This study showed that chitosan beads can be excellent adsorbents at high pH values **(Bekci*e*t al.,2007).**

Clay used as an adsorbent

- **(HajiraTahir et al., 2010)** have reported the removal of Malachite green on Mont morillonite clay adsorbent under optimized conditions. The percentage removal data shows that Malachite green Mont morillonite clay system shows about 95% adsorption tendency.

- **(PapitaSaha et al., 2010)** investigated the adsorption potential of clayey soil towards Malachite green from aqueous solution. A negative enthalpy value indicated that the adsorption process was exothermic. The results showed that clayey soil can be used as an effective and low cost adsorbent.

- **(AbdilOzdemir*et* al.,2009)** carried out the adsorption of dye mixtures namely Malachite green and Congo red by bentonite. The result shows that the pH of the dye solution is strongly affected by the chemistry of both the dye molecules and of the adsorbent in an aqueous solution.

Materials

MATERIALS

In the present study nearly hundred low-cost adsorbents prepared from agricultural and industrial waste materials were collected and analyzed for their removal efficiency of malachite green dye from aqueous solution.

Discussion

DISCUSSION

In the present work nearly hundred Eco-friendly, low -cost adsorbents used for the removal of malachite green dye from aqueous solution is analyzed. The experimental conditions at which maximum removal of malachite green dyeobtained using these low- cost adsorbents is listed in the following table.

Adsorbent	Adsorbent Dose	Concentration of the dye solution	Contact Time	Temperature	pH	Maximum Amount of dye Removed
Lentil husk	0.5g	250 mg/L	45 mins	30℃	5	66%
Banana peel	2g	10-40 mg/L	60mins	30℃	7	82.6%
Neem leaf powder	1g	250mg/L	45 mins	30℃	-	90-95%
Pummel peel	2g	300mg/L	30mins	30℃	10	65%
Bio adsorption baggase	0.2g	50mg/L	60 mins	45℃	2	53%
Tio_2/uvphotocatalytic	1.2g	60m g/L	56mins	25℃	4	72%

Adsorbent	Adsorbent Dose	Concentration of the dye solution	Contact Time	Temperature	pH	Maximum Amount of dye Removed
Cucumis Sativa fruit	0.6 g	25 mg/L	50 mins	27℃	2	52%
Ghassoul	0.1g	500 mg /L	10 mins	55℃	8	60%
Gypscum	0.2 g	60mg/L	40 mins	25℃	4	74.27%
Algerian bentonie	1 g	500 mg/L	20 mins	20℃	10	71%
Water hyacinth	0.1g	20 mg/L	77 mins	27℃	8	72%
Sawdust	0.2 g	20 mg/L	30 mins	25℃	10	72%
$CuFeO_4$ Rice bran	0.05 g	50 mg/L	15 mins	25℃	2	60%
Almond shell	0.1 g	20 mg/L	24 hrs	25℃	4	67%

Adsorbent	Adsorbent Dose	Concentration of the dye solution	Contact Time	Temperature	pH	Maximum Amount of dye Removed
Activated carbon shell	0.4 g	300 mg/L	45mins	30℃	6	72.5%
Pine wood	0.2g	300mg/L	55mins	40℃	4	25%
Loess soil nanoparticles	1.2g	100mg/L	150mins	25℃	6	50%
Cane pith carbonized	0.8g	40mg/L	40 mins	32℃	10	52.5%
Cane pith	2g	50mg/L	35mins	32℃	4	74.35%
Yellow passion fruit	1.0g	200mg/L	40mins	25℃	8	70%
Mixture almond shell	0.5g	100mg/L	30mins	20℃	6	32%
Chitosan nanoparticles	0.5g	100mg/L	45mins	28^o C	4.6	78%

Adsorbent	Adsorbent Dose	Concentration of the dye solution	Contact Time	Temperature	pH	Maximum Amount of dye Removed
Wheat stem	0.3g	72mg/L	60mins	35℃	4	62.45%
Mercerized garlic	0.1g	200mg/L	45mins	25℃	4	63%
Mangrove plant leaf powder	0.1g	100mg/L	40mins	30℃	4	50%
Sunflower stalk	1.6g	100mg/L	40mins	21℃	4	66.2 6%
Ash gourd peel powder	0.5g	50mg/L	30mins	20℃	6	69.84%
Rambuttan peel	1.5g	250mg/L	20mins	20℃	4	43%
Halloysite nanotubes	0.5g	200mg/L	30mins	22℃	6.02	54%

Adsorbent	**Adsorbent Dose**	**Concentration of the dye solution**	**Contact Time**	**Temperature**	**pH**	**Maximum Amount of dye Removed**
Mg^{2+}type orange peel adsorbent	0.5g	300mg/L	50mins	25℃	5	73.40%
Mosambi peel	0.2g	200mg/L	20mins	40°C	2	82%
pomegranate peel	1.0g	50mg/L	20mins	25℃	5.5	52%
Muskmelon peel	0.5g	50mg/L	45mins	25℃	4.5	82%
Sun fured orange peel	0.2g	76mg/L	45mins	30℃	4	71.5%
Mercerized garlic	0.1g	200mg/L	45mins	25℃	4	63%
Wheat shell	1.0g	50mg/L	55mins	40℃	6	71.42%
$Zncl_2$ activated grape fruit peel	0.2g	100mg/L	90mins	30℃	2	73.12%

Adsorbent	**Adsorbent Dose**	**Concentration of the dye solution**	**Contact Time**	**Temperature**	**pH**	**Maximum Amount of dye Removed**
Garden grass	0.5g	500mg/L	30mins	29℃	6	58.34%
Nano-porous activated neem bark	0.1g	200mg/L	2 days	45℃	4	67.25%
Olive stone(raw)	1g	50mg/L	60mins	20℃	5.5	56%
Lentil shell	1.0g	25mg/L	45mins	39ºC	6	59%
Sky fruit husk activated carbons	0.8g	25mg/L	55mins	30℃	5.0	61.12%
Fruit juice residue	3.0g	30mg/L	80mins	24℃	6.0	52.28%
Wood derived bio char	1.0g	40mg/L	20mins	35℃	8	64.44%

Adsorbent	**Adsorbent Dose**	**Concentration of the dye solution**	**Contact Time**	**Temperature**	**pH**	**Maximum Amount of dye Removed**
Activated carbon cloth	0.4g	100mg/L	26mins	25°C	4	54.10%
Blust furnace slag	1g	100mg/L	50mins	30°C	6.5	69.21%
Fly ash	0.3g	45mg/L	40mins	40°C	8	75.23%
Carbon aceous adsorbent	0.2g	43mg/L	33mins	50°C	4	70.08%
Poly aluminum chloride (PAC)	2g	100mg/L	45mins	37° C	6.5	50-60%
Hydrillaverticillata	0.55g	200mg/L	150mins	30°C	8	85%
Zee mays dust carbon	0.5g	10-50mg/L	60mins	30°C	9	62%
Bentonite	0.05g	5-10&20mg/L	60mins	37°C	8.2	72%
Ginger waste	0.2g	200mg/L	45mins	32°C	5.5	58%

Adsorbent	**Adsorbent Dose**	**Concentration of the dye solution**	**Contact Time**	**Temperature**	**pH**	**Maximum Amount of dye Removed**
Tamarixaphylla leaves	1g	300mg/L	40mins	30^{o}C	5	55%
Perlite	0.1g	100mg/L	40mins	32^{o}C	8	71%
Annonasqumosa seed	0.2g	50mg/L	50mins	35^{o}C	7	73.5%
Ground nut shell	0.1-1g	100-200mg/L	120mins	37^{o}C	5.5	56%
Tamarind seed	2.85g	100mg/L	175mins	37^{o}C	2-9	67%
Borassus bark	1g	200mg/L	45mins	30^{o}C	6	55%
Mont morillonite clay	o.o5g	100mg/L	55mins	32^{o}C	5.7	50%
Brown root fungi	0.1g	200mg/L	75mins	37^{o}C	8	70%
Maize cob powder	0.02g	100mg/L	150mins	37^{o} C	9	70%
Rose apple carbon	0.05g	300mg/L	45mins	37^{o}C	5.5	72%

Adsorbent	**Adsorbent Dose**	**Concentration of the dye solution**	**Contact Time**	**Temperature**	**pH**	**Maximum Amount of dye Removed**
Coconut shell carbon	0.1g	200mg/L	40mins	37^{o}C	5.62	65%
Rice huck	1g	40mg/L	45mins	32^{o}C	5.2	94.91%
Sugarcane baggase	1g	200mg/L	50mins	37^{o}C	6.5	60%
Nirgudi leaf powder	0.2g	300mg/L	60mins	37^{o}C	8	50%
Borassusaethiopum (African fan,palm)	0.001g	100mg/L	45mins	37^{o}C	6.45	73%
Pine bark	0.1g	300mg/L	55mins	37^{o}C	6	73%
Wood fiber of phoenix tree	1g	10-100mg/L	60mins	37^{o}C	8	55%
Durian peel	0.4g	220mg/L	50mins	37^{o}C	7	68%
Tamarind fruit shell	0.05g	200mg/L	45mins	37^{o}C	9	50%

Adsorbent	Adsorbent Dose	Concentration of the dye solution	Contact Time	Temperature	pH	Maximum Amount of dye Removed
Bamboo	1g	40mg/L	45mins	32^{o}C	5.2	50-60%
Ricinuscommunis	0.3g	40mg/L	60mins	37^{o} C	6	68%
Arundodonax root carbon	0.1g	100mg/L	45mins	32^{o}C	7	65%
Oil palm trunk fiber	1g	200mg/L	50mins	37^{o}C	9	65%
Rice straw derived char	0.02g	10-100mg/L	60mins	37^{o}C	4	58%
Silica gel	0.1g	100mg/L	40mins	32^{o}C	5	70%
Surfactant – modified alumina	1g	300mg/L	45mins	37^{o}C	6	55%
Mahua oil cake	1g	100mg/L	120 mins	30^{o} C	9	60%
Sorel’s cement	0.1g	10-100mg/L	60mins	37^{o}C	8	60%
Titanium (IV) oxide	0.01g	300mg/L	60mins	32^{o}C	9	63%

Adsorbent	Adsorbent Dose	Concentration of the dye solution	Contact Time	Temperature	pH	Maximum Amount of dye Removed
Acremoniumkiliense	0.1g	10-100mg/L	60mins	37^{o}C	4.5	55%
Chitosan beads	0.05g	20-240mg/L	55mins	30-50^{o}C	6	18.8-69.4%
Clayey soil	0.02g	300mg/L	45mins	37^{o}C	8	70%
Ac-Mno$_2$-Nc	0.2g	100mg/L	55mins	37^{o}C	9	65%
Tamarind kernel powder (TKP)	0.3g	200mg/L	60mins	32^{o}C	6.5	56%
Corn cob	1g	10-100mg/L	45mins	37^{o}C	4	62%
Bio materials	0.2g	200mg/L	50mins	32^{o}C	5.5	55%
Bio polymers and bio mass	1g	100mg/L	60mins	37^{o}C	8	70%
Pea shalls	0.3g	300mg/L	45mins	37^{o}C	6	65%
Daucuscarota	1g	100mg/L	45mins	32^{o}C	5.5	60%

Adsorbent	Adsorbent Dose	Concentration of the dye solution	Contact Time	Temperature	pH	Maximum Amount of dye Removed
Pumice	0.2g	200mg/L	50mins	37^{o}C	6	54%
Magnetic activated carbon	0.1g	40mg/L	60mins	37^{o}C	8	70%
Metal organic frame works(MOFs)	0.3g	100mg/L	45mins	37^{o}C	6.5	59%
Hen feathers	1g	40mg/L	50mins	37^{o} C	6	55%
Lemon peel	0.1g	100mg/L	45mins	32^{o} C	5.5	64%
Pomelo peel	0.2g	200mg/L	55mins	37^{o}C	8	75%
Date palm peel	1g	40mg/L	60mins	37^{o}C	4.5	70%
Tea leaves	0.8-6g	220mg/L	45mins	45^{o} C	7	77%
Potato plant (PSP)&(PLP)	0.5-3.0g	10-50mg/L	55mins	30-50^{o}C	7	67-58% & 75-68.2%

Adsorbent	**Adsorbent Dose**	**Concentration of the dye solution**	**Contact Time**	**Temperature**	**pH**	**Maximum Amount of dye Removed**
Andrographispaniculata leaf	1g	100mg/L	90mins	32ºC	5	67%
Areca husk	1g	100mg/L	50mins	37º C	6	55%
Palm flower	0.2g	100mg/L	45mins	45ºC	6-8	93.75%
Coconut fiber	0.1g	50mg/L	45mins	30ºC	-	90%
Clay	5g	50-600mg/L	60mins	40ºC	2	82%
Breadnut peel	-	100mg/L	240mins	32ºC	8.02	45%
Sulphuric acid-treated saw dust	1.0g	100mg/L	30-45mins	28ºC	6.0	55%
Sea shell powder	2.0g	10-100mg//L	120mins	28ºC	8.0	35%
Conch shell powder	3.0g	200mg/L	120mins	30ºC	8.0	47%
Native rice straw	5.0g	200mg/L	10h	32ºC	6.0	39%

Adsorbents with higher adsorption potential of malachite green dye.

Adsorbent	Adsorbent dosage	Concentration of dye solution	Contact time	Temperature	pH	Maximum amount of dye removed	Particle size
Tea leaves	0.8-6g	220mg/L	45mins	45^{o} C	7	94%	150μm
Chitson nanoparticles	0.5g	100mg/L	45mins	25^{o} C	4.6	78%	34.6nm
Clay	5g	50-600mg/L	60mins	40^{o}C	2	82%	300μm
Coal Fly ash	0.1g	10mg/L	40mins	40℃	5	90.5%	100μm
Rice husk	0.1g	9.3mg/L	45mins	30^{o}C	7	93.4%	>300<425μm
Hydrillaverticillata	0.26g	200mg/L	200mins	43.5^{o}C	8	85%	205μm
Banana peel	2g	1-40mg/L	60mins	25℃	7	82.6%	200-300μm
Neam leaf powder	0.3g	$2.5+10^{5}$mg/L	20mins	30℃	-	90-95%	5-20μm
Coconut fiber	0.1g	50mg/L	45mins	30^{o}C	-	90%	150μm
Palm flower(Borassusaethiopum)	0.2g	100mg/L	45mins	45^{o}C	6-8	93.75%	100-600μm

Conclusion

CONCLUSION

The research papers collected revealed about various low-cost adsorbents obtained from agricultural, industrial and other waste materials used for the removal of malachite green dye from aqueous solution by adsorption.

The following conclusions are derived after thoroughly going through the research articles collected

- Percentage removal of malachite green dye increased with decrease in concentration of dye solution due to the availability of more number of active sites on the surface of the adsorbent for less number of dye species due to low concentration of the dye solution.
- As the dosage of the adsorbents increases the percentage removal of the dye also increases due to the greater surface area available for the adsorption of more number of dye species.
- Smaller the particle size, greater is the surface area available for adsorption, therefore percentage removal of malachite green dye increases with decrease in the particle size of the adsorbent.

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