Decolourization of Reactive Dyes in Aqueous Solution Using Selected Agro Waste

By

Emima Priscilla, V

(13PBX001)

A Thesis Submitted to the

Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore – 641 043.In Partial Fulfillment of the Requirements for the Degree of

Master of science

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Certified as Bonafide Research Work

27/3/15

Signature of the

Head of the Department

Signature of the

Guide

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1. INTRODUCTION

Saving water to save the planet and to make the future of mankind safe is the need of the day. With the growth of mankind, society and technology, our world is reaching to high horizons but the cost which we are paying or will pay in near future is too high. One of the important class of the pollutants is dye, and once they enter into the water it is no longer good and sometimes difficult to treat as the dyes have a synthetic origin and a complex molecular structure which makes them more stable and difficult to be biodegraded (Rai *et al*., 2005).

Industrialization in India has resulted in water pollution by discharging of effluent in natural water bodies. The textile industries use dyes and pigments to color the textile product and discharge a huge amount of waste water. The removal of color from these effluents is one of the growing concerns of environmental issues, since some of the dyes and their degradation products or intermediates may be carcinogenic and toxic (Metes *et al*., 2000).

Even small traces of the non- biodegradable and highly toxic dyes can be harmful to the mankind. Effluents from dye production and dyeing mills are highly objectionable if discharged into open water without any proper treatment. The presence of coloring material in water system also reduces penetration of light and photosynthetic activity. Dyes are also major component of the wastes, which are led into the soil and water bodies (Mittal *et al*., 2007).

Synthetic textile dye effluent has high fluctuation in p^H, large amount of suspended solids along with high COD (Chemical Oxygen Demand) (Bakshi *et al*., 1999). Several chemical, physical and biological methods are used for the removal of dyes from waste water. However the chemical and physical methods have several draw backs such as high cost and release of hazardous secondary waste (Saratale *et al*., 2009).

Adsorption has become one of the most effective treatment processes for the removal of heavy metal ions from aqueous environment (Ranjan *et al*., 2009). An activated carbon has been proven to be very effective in removing dyes

from waste water. The activated carbon is still considered expensive and currently the development of low- cost adsorbents include natural, agricultural, and industrial by- product wastes. The availability of wastes is high and no cost with their good performance in removing dyes from textile waste water or effluent (Aziz, 2007).

The basic feature of adsorption processes is surface accumulation of material. There are two types of adsorption. If the attraction between the solid surface and the adsorbed molecules is physical in nature, the adsorption is referred to as physical adsorption (physiosorption).On the other hand if the attraction is due to chemical bonding; the adsorption process is called chemisorptions. It is difficult to remove chemisorbed species from the solid surface (Levan *et al*., 1997).

Among the biosorbents used for the removal of heavy metals and other pollutants, agricultural residues are preferred because of high availability, very cheap, reusable, environmental friendly, and offer a low cost and straight forwarded treatment process for removing metal ions (Sud *et al*., 2008). From the agricultural residue, tree leaves have most researched in recent year. They are even cheaper and broadly accessible in great supply (Zolgharnein *et al*., 2010). Some biosorbents such as coconut copra meal (Ho and Ofomaja, 2006), rise husk, Saw dust (Sharma *et al*., 2009) and mango peel waste(Iqubal *et al*., 2009), have been used for adsorption.

Optimization of the biosorption process is critical and should be ascertained. Multivariable optimization has several advantages over the conventional one – at –the time method. The adsorption process might be influenced by some variables such as p^H value, adsorbent amount, sorbate concentration, shaking time and temperature (Volesky , 2007).

Recently, a number of conventional methods have been used for waste water treatment, such as precipitation, ion exchange, electro chemical reduction, flocculation, electro flotation, irradiation, ozonation and red ox treatment, but these methods involve large liquid surface area and long detention period. Adsorption

has an edge over the above methods due to being sludge free and having ease of operation, low initial cost, simple design and insensitivity to toxic substances (Monojkumar, 2010).

Hence the present study, **“Decolourization of reactive dyes in aqueous solution using selected agro waste”** aims with the following objectives,

- To screen and select the reactive dye decolorizing agrowaste
- To optimize various parameters such as p^H, temperature, time, concentration, adsorbent for dye decolourization
- To reuse the decolorized water for dyeing
- To evaluate the dyed fabric

2.0 REVIEW OF LITERATURE

The review of literature pertaining to the study **"Decolourization of reactive dyes in aqueous solution using selected agro waste"** is discussed under the following headings.

2.1 Textile industries and environmental pollution

2.2 Textile waste water treatment

2.3 Dyes

2.3.1 Classification of Dyes

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2.3.3 Toxicity effects of dyes

2.4 Dyestuff and color removal from textile effluent

2.4.1 Advantage of Dye Removal Method

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2.5.1 Effect of solution pH

2.5.2 Effect of initial Dye concentration

2.5.3 Effect of temperature

2.5.4 Effect of Amount of adsorbent

2.1 Textile industries and environmental pollution

Environmental pollution caused by the rapid industrialization is one of the major and most important problems of the modern world (Vivexe *et al.,* 1998). The huge grow in the textile industries has been resulted in an immense increase in the complexity and the volume of the dye containing waste water. Several textile dyes are reported to be carcinogenic and mutagenic in nature (Eichlerova *et al.,* 2006). Waste water discharged from different industries such as the textiles, leather, paper, food, hair coloring, etc. are usually polluted by dyes for example, malachite green is most commonly used for the dyeing of cotton, silk, paper, leather and also in manufacturing of paint and printing inks. Most of the dye, including malachite green, are toxic and must be removed before discharge into receiving streams (Hasan *et al.,* 2008).

The textile industries are the greatest generators of liquid effluent, due to the high quantity of water used in the dyeing process (Selen *et al.,* 2008). Fifteen percent of the total world production of dyes is lost during the dyeing process and is released in textile effluent (Zollenger, 1991). As clean fresh water is increasingly more difficult to obtain in parts of the world, recycling of Water is seen as a means to increase water supply. However, some waste water contains high concentration of metals, which will pose a risk to all forms of life along food chain. For example consumption of the rice irrigated with river water containing cadmium (Rocha *et al.,* 2009).

Wet processing operations during textile chemical processing i.e. desizing, scouring, bleaching, dyeing, printing and finishing, are the major causes of water pollution. A major contribution to color in textile waste water is usually the dyeing, the washing operation after dyeing during which as much as 50% of the dye might be released into the effluent. During dyeing, most of the dye is exhausted on the fiber, but the unfixed dye goes into waste water causing deep color. The waste water is extremely variable in composition due to large number of dyes and other chemicals used in processing (Kocamrisch, 1987).

The waste water discharged from dyeing process exhibited high biological oxygen demand (BOD), high chemical oxygen demand (COD) are highly colored, hot, alkaline and contain high amounts of dissolved solids (Rajeshwari *et al*.,

2001). The disposal of colored water such as dyes and pigments into receiving waters changes the environment, as they are carcinogenic and toxic to humans and aquatic life (Lee *et al.,* 1999).

2.2 Textile waste water treatment

Many treatment methods have been developed to remove dyes from waste water, which can be divided into physical, chemical and biological method such as photo degradation (Noguia *et al.,* 2005), Photo catalytic degradation (Haehem *et al.,* 2001), biodegradation (Parashetti *et al.,* 2006), and adsorption (Zhang *et al.,* 2008). Adsorption techniques have potential for removing oxygen and inorganic pollutans from waste water due to their high efficiency and ability to separate a wide range of compounds (Jain *et al*., 2007).

2.3 Dyes

Dyes are a kind of organic compound with a complex aromatic molecular structure that can bring bright and firm color to other materials. However, the complex aromatic molecular structures of dyes are more stable and more difficult to biodegrade (Calvete *et al*., 2010).

Dyes are basically chemical compounds that can connect themselves to surfaces or fabrics to impart color. The majority of dyes are complex organic molecules and are required to be resistant to many things such as the action of detergents (sokolowska, 1996). Synthetic dyes may pose a significant source of pollution due to their recalcitrance nature. This will give undesirable color to the water body which will reduce sunlight penetration and resist photochemical and biological attacks to aquatic life (Wong, 2004). In up to date data, more than 100,000 commercial dyes are known with an annual production of over 7x10 tones / year worldwide and approximately 100 tones / year of dyes is discharged into water streams (yagub *et al.,* 2012).

Dyes are one of the most hazardous chemical compound class found in industrial effluents which need to be treated since their presence in water bodies reduce light penetration (Royer *et al.,* 2010). They are also aesthetically objectionable for drinking and other purposes. Dyes can also cause allergy,

dermatitis, skin irritation and also provoke cancer and mutation in humans (Broabstin, 2009).

Synthetic dyes are stable to light, heat and many oxidizing agents, and more difficult to be biodegraded. Due to the increasing enforcement in legislations, effluent containing dyes require proper treatment prior to discharge, not only for their high COD and potential toxic breakdown products, but also for color, which may pose aesthetic problem. The biosorption of mono-compact synthetic dye system by various biosorbents, as most industrial effluents contain a mixture of several dyes and little attention has been given to biosorption of multi-component dye. To evaluate the interaction and competitions between biosorbates and biosorption, the nature of mechanism and the extent of competition have been inadequately understood (Vijayaraghavan and yun, 2008).

2.3.1 Classification of Dyes

There are several ways for classification of commercial dyes. It can be classified in terms of structure, color and application methods (clarbe and liker, 1980). Due to the complexities of the color nomenclature from the chemical structure system, the classification based on application is often favorable (Gupta, 2009). The classification based on chemical structure for the common class of the dyes is presented in Table 1. Dyes are usually classified based on their particle charge upon dislocation in aqueous application medium (Mishra, 1993). Such as cationic (all basic dyes), anionic (direct, acid, and reactive dyes), and non-ionic (disperse dyes).

Table 1

Classification of dyes

Dye classes	Fiber	Substrate
Acid	Polyamide	Wool, nylon, silk, inks, leather and paper
Basic	Acrylic	Inks paper, polyacrylonitrite
Direct	Cellulose	Nylon, rayon, paper, leather and cotton
Disperse	Polyester	Polyamide, acrylic, polyester, acetate and plastics
Reactive	Cellulose	Wool, cotton, silk and nylon
sculpture	Cellulose	Rayon and cotton
Vat	Cellulose	Wool and cotton

(Hunger, 2007)

2.3.2 Reactive Dyes

Reactive dyes are water soluble and 5-10% of the dyes go in the dye bath giving highly colored effluent causing serious troubles in the environment (Asher and Bhatli, 2012). these dyes are colored molecules used to dye cellulose fibers. They are characterized by nitrogen to nitrogen double bonds (N=N azo bonds). The color of azo dyes is due to this azo bond and associated chromospheres. The dyes are first absorbed onto the cellulose and they react with the fiber. The reaction occurs by the formation of a covalent bond between the dye molecule and the fiber which is much more resistant to unusual conditions of use, than the physico-chemical bond between other classes of dyes and cellulose. The reactive systems of these dyes react with ionized hydroxyl groups on the cellulose substance (Lambert *et al.,* 1997).

2.3.3 Toxicity effects of dyes

Basic dyes have high intensity of color and are greatly visible even in very little concern (Viraraghavan, 2002). The complex dyes are generally chromium based, which is carcinogenic (Gupta, 1990). Dyes may affect the photosynthetic activity in aquatic life due to decreased light penetration and may also be toxic to some aquatic life due to the presence of metals, aromatics, etc. (Lazar, 2005).

2.4 Dyestuff and color removal from textile effluent

Color removal is a pertinent problem for all categories of textile effluent due to the variety of chemicals issued in dyeing and printing of fiber, yarn or fabric. Color pollution can be most efficiently controlled by good source reduction practices, administrator and engineering controls, process and product design and work practices. The search for dynamic response and impaired productivity has served to focus the attention of the coloration industry on right first time removal from textile effluent (RFT) production techniques (Orgwa *et al*., 1988).

A high level of RFT minimizes waste and makes a significant contribution to reduce color loads in the effluents (Glover and Hill, 1993). Improving the exhaustion levels of the various dyes in the dye bath is another area which has received lot of attention from researchers as it will not only improve shade reproducibility and problem of repeat shade but also reduce to a matter of controlling and handling spills and clean up (Bradbur and Kent, 1994).

2.4.1 Advantage of Dye Removal Method

Physical treatment such as adsorption by activated carbon results in good removal of wide variety of dyes. Most membrane filtration removes all dye types. From exchange or regeneration no adsorbate will loss. Biological treatment of decolourization by white – rot fungi and other microbial cultures in 24-30 hours adsorption by live and dead microbial systems of dyes have a particular affinity for binding with microbial species. In photochemical (NaCl) sodium hypochlorite no sludge is produced and foul odors are greatly reduced. In chemical treatments ozone can be applied in its gaseous state and does not increase the volume of wastewater and sludge (Salleh *et al.,* 2011).

2.4.2 Disadvantage of Dye Removable Method

Physical treatments are very expensive and the adsorption by activated carbon is not effective for all dyes. Membrane filtration requires a lot of dissolved water. And electro kinetic coagulation results in high sludge production. Biological treatment for enzyme production has also been shown to be unreliable under aerobic conditions. Adsorption by living microbial biomass is not effective for all dyes. Photochemical formation of by–products will release of aromatic amines and electrochemical destruction are relatively high flow rates cause a direct

decrease in dye removal. Chemical treatment agent needs to be activated by some means sludge generation for short half- life (Salleh *et al.,* 2011).

2.4.3 Adsorption of dyes

The term adsorption refers to the accumulation of 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 (Dabrowsbi, 2001). Chemical adsorption or chemisorptions is illustrated the formation of strong chemical associations between molecules or ions of adsorbate to adsorbent surface, which is generally due to the exchange of electrons (Allen *et al*., 2005) and thus chemical sorption generally is irrepressible. Adsorption on most of the adsorbate including agriculture by-product is controlled by physical forces with some exception of chemisorptions. The main physical forces controlling adsorption are van der vaals forces, hydrogen bonds, polarity, dipole interactions (Ali *et al*., 2010). This process provides an attractive for the treatment of polluted water, especially if the sorbent is inexpensive and does not regain an additional pretreatment step before its application. Adsorption has been found to be superior to other techniques in terms of flexibility and simplicity of design, initial cost, insensitivity to toxic pollutants and ease of operation. Adsorption also does not produce harmful substances (Gini, 2006).

2.5 factors affecting adsorption of dye

There are many factors affecting dye adsorption such as solution pH, temperature and initial dye concentration. Thus the effects of these parameters are to be taken into dye removal treatment processes.

2.5.1 Effect of solution pH

One of the most important factors affecting the capacity of adsorption in waste water treatment is solution p^H. The efficiency of adsorption depends on the solution pH, since variation in pH leads to the variation in the degree of ionization of the adsorption molecules and the surface properties of adsorbent (Nondi *et al.,* 2009).

Chowdhery *et al.,* (2011) studied the effect of solution pH on the adsorption of basic green 4 dye by Ananas comosus leaf powder and they noticed that at a pH range from 2 to 10, the dye removal ratio was found to be maximum at pH 10 Dagwood and seen,(2012) studied the effect of solution pH on the adsorption of Cango red and reported maximum at pH 3.5.(Ibrahim *et al*.,2010) studied the adsorption of RB4 dyed by modified barley straw and they found that RB4 gives a complete removal of 100% at pH 3 and decrease value below 50% as the pH was increased. Table 3 represents different studies on the effect of solution pH on dye adsorption.

Table 2

The effect of solution pH on the adsorption of dyes by different adsorbents

Adsorbents	Dye name	pH range	% removal range
Activated clay	methylene blue	2.9	60-95
Activated carbon	blue	2-11	Increase
Activated rice Husk	acid yellow 36	2-9	45- 80
Pine leaves	blue	2-11	20-80
Pine Cone	cango red	3-55 - 10.95	5.5 – 6.75
Pine Cone	blue	3.47 – 7.28	63.83 – 94.82

(Liu *et al*., 2012)

2.5.2 Effect of initial Dye concentration

The percentage adsorption for dye removal is highly dependent on the initial dye concentration. The effect of initial dye concentration depends on the immediate relation between the concentration of dye and the available sites on an adsorbent surface. The percentage of dye removal decrease 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 the capacity of the adsorbent and this may be due to the high driving force for mass transfer at a high initial dye concentration (Bulut *et al.,* 2006).

2.5.3 Effect of temperature

Effect of temperature is another significant physico – chemical process parameter because temperature will change the adsorption capacity of the adsorbent (Arguum *et al.,* 2008). If the amount of adsorption increases with increasing temperature then the adsorption is an exothermic process this may be due to increasing mobility of the dye molecules and an increase in the number of active sites for the adsorption. Decrease in adsorption with increasing temperature indicates that the adsorption is an endothermic process this may be due to increasing temperature decreasing adsorption force between the dye species and the active sites on the adsorbent surface as a result of decreasing the amount of adsorption (Salleh *et al.,* 2012). Table 3 shows the compilation of results of various studies on the effects of temperature on the dye adsorption by various adsorbents.

Table 3

The effect of temperature on the adsorption of dyes using various adsorbents

Adsorbents	Dye name	Temperature Range (k)
Pine leaves	Methylne blue	313-333
Activated clay	Methyl Orange	293-303
Saw dust	Acid yellow 23	298-303
Sugarcane bagasse	Rhoda mine B	303-323
Sugarcane bagasse	Basic blue 9	303-323
Treated rice husks	Methylne blue	293-313

(Vimonses *et al.,* 2008)

2.5.4 Effect of Amount of adsorbent

Adsorbent dosage is an important process parameter to determine the capacity of an adsorbent for a given amount of dye adsorbed at the operation conditions. The percentage of dye removal increase with increasing adsorbent dosage, the surface of adsorbent will increasing by increase the amount of the adsorbent (Srinivasan and Viraraghavan, 2006).

3.0 EXPERIMENTAL PROCEDURE

The experimental procedure adopted for the present study **"Decolourization of reactive dyes in aqueous solution using selected agro waste"** is discussed under the following headings

3.1 Collection of dyes

3.2 Collection of different agrowastes

3.3 Screening of different agrowastes for decolorizing reactive dyes

3.4 Optimization of various parameters for the decolorization of Reactive dye.

3.4.1 Optimization of agro- waste concentration

3.4.2 Optimization of contact time

3.4.3 Optimization of pH

3.4.4 Optimization of temperature

3.5 Decolorization of reactive dye solution using selected agro-waste under optimized conditions

3.6 Reuse of Decolourized solution for dyeing selected fabric

3.6.1 Selection of Fabric

3.6.2 Dyeing of selected fabric with reactive dye using fresh and decolorized water

3.6.3 Dyeing procedure

3. 7 Evaluation of dyed fabric

3.7.1 Subjective Evaluation- visual inspection

3.7.2 Objective Evaluation

3.7.2.1 Fabric weight

3.7.2.2 Fabric thickness

3.7.2.3 Fabric Strength and Elongation

3.7.2.4 Fabric Stiffness

3.7.2.5 Absorbency Tests

- Drop test
- Sinking test
- Capillary rise test

3.7.2.6 Color Fastness Tests

- Fastness to sunlight
- Fastness to Wet and dry crocking
- Fastness to washing
- Fastness to Wet and dry pressing

3.8 UV-Vis analysis

3.9 FTIR analysis

3.1 Collection of dyes

Selected Reactive dyes were supplied by ultra chemicals, Tirupur and stored at room temperature.

Table 4 Reactive dyes selected

S.No	Reactive Dye	C.I Number
1	T Blue G Reactive	021
2	Navy GDB Reactive	005
3	Yellow R Reactive	107

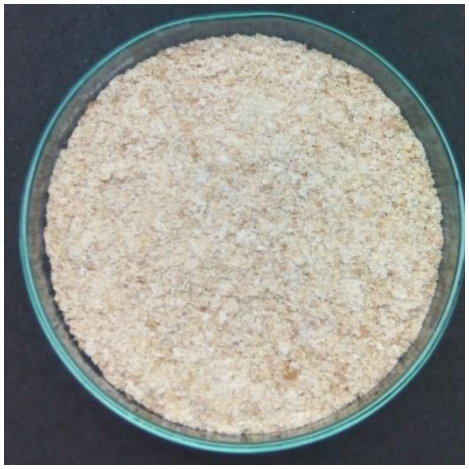
3.2 Collection of different agro wastes

Agrowastes such as groundnut shell, sugarcane bagasse, wood dust, orange peel, rice husk, corn stalk, wheat dust, water hyacinth stem, sisal fiber, onion peel and garlic peel were selected for the pilot study. The selected agrowastes were collected from the local market, dried in shade and powdered (plate 1).

PLATE 1

SELECTED AGROWASTES

Sugarcane beggase



Wheat dust

Onion peel

Water hyacinth stem

Garlic peel

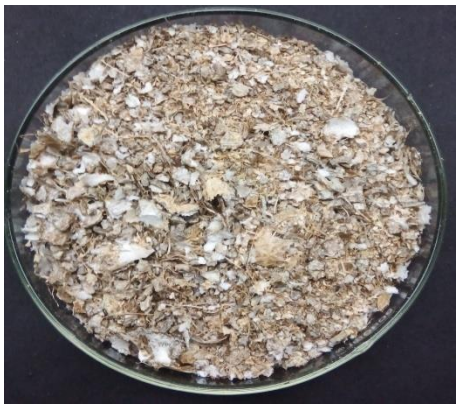
Wood dust

Rice husk

Sisal fiber

Corn stalk

Orange peel



Groundnut shell

3.3 Screening of different agrowastes for decolorizing reactive dyes

About 1 gram of each agro residue was added separately into a series of beakers containing reactive dye baths, made of T blue G reactive, navy blue GDB reactive, yellow R reactive dye prepared at a concentration of 0.01%. The per cent decolourization of each agrowaste was determined for 6 days. The color intensity was measured at 417nm (yellow R reactive), 584nm (T blue reactive), 528nm (navy blue GDB reactive) by measuring the absorbance at UV-visible spectrophotometer. The per cent decolourization was calculated by the following formula.

$$\% \text{ Decolourization} = \frac{\text{Initial absorbance- Final absorbance}}{\text{Initial absorbance}} \times 100$$

3.4 Optimization of Various parameters for the decolourization of Reactive dye.

3.4.1 Optimization of agro- waste concentration

To determine the optimum quantity of agrowaste to decolourize reactive dye solution 0.5g, 1.0g, 1.5g, 2.0g, and 2.5g of wheat dust and sugarcane bagasse were added separately to beakers containing 0.01% of navy blue GDB reactive, T. blue reactive, yellow R reactive dyes. Absorbance was measured at 417nm (yellow R reactive), 584nm (T. blue reactive), 528nm (navy blue GDB reactive) in UV- visible spectrophotometer. The concentration at which per cent decolourization was maximum was selected as optimum concentration and fixed for subsequent optimization studies.

3.4.2 Optimization of contact time

To determine the optimum contact time for decolourization of reactive dye, the beakers containing 0.01% of reactive dye with selected agro- waste, was incubated at different time intervals (6 hours,12 hours,18 hours,24 hours,30 hours,36 hours,42 hours and 48 hours). The per cent decolourization was determined.

3.4.3 Optimization of pH

Set of 250ml beakers were taken and 0.01% of reactive dye solution was added to each one. The pH was adjusted to 5,6,7,8,9,10 and 11 using 1N HCL and 1N NaOH. The selected agro-waste at optimum concentration was added to all the beakers, having different pH. The per cent decolourization was determined after 30 hours.

3.4.4 Optimization of tem1perature

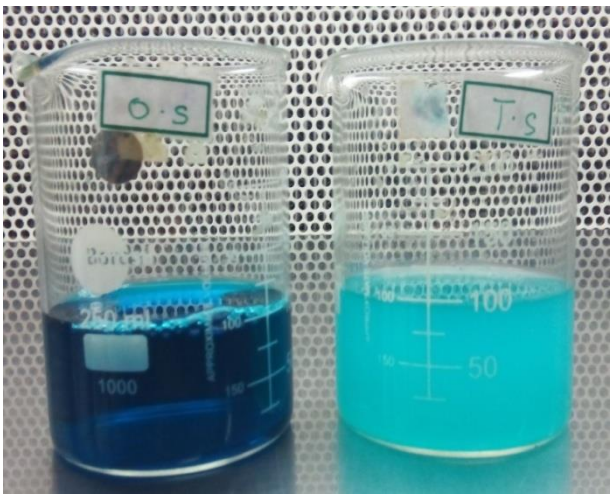
To determine the optimum temperature for decolourization of reactive dye, the beakers containing 0.01% reactive dye with selected agro waste was incubated for 30 hours at different temperatures such as 40^{o}C, 50^{o}C , 60^{o}C, 70^{o}Cand 80^{o}C. Per cent decolourization was determined.

3.5 Decolourization of reactive dye solution using selected agro-waste under optimized conditions

Yellow R reactive, navy blue GDB reactive, T. blue G reactive dye solution was decolorized using agrowastes at an optimum concentration of 2% and pH. Decolourization was carried out for 30 hours at 50^{o}C. The decolorized solution was reused for dyeing (plate 2).

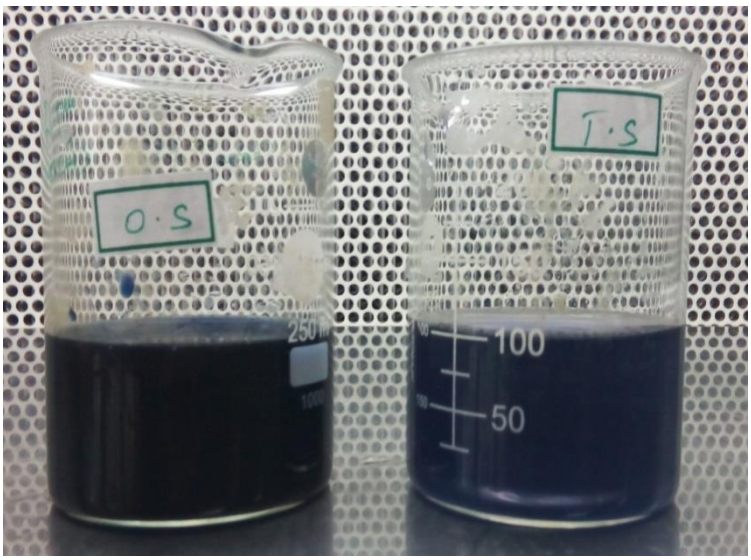
PLATE 2

DECOLOURIZATION OF REACTIVE DYE SOLUTION USING SELECTED AGROWASTE UNDER OPTIMIZED CONDITIONS



Control and decolourized reactive yellow R

Control and decolourized reactive T Blue G



Control and decolourized reactive navy blue GDB

3.6 Reuse of Decolourized solution for dyeing selected fabric

Dyeing waste water are known to present strong color and high COD values since more than 15% of textile dye are generally lost in waste water stream during dyeing operation. Reactive dyes have become one of the major classes of colorants for dyeing of cellulose fiber (Bing *et al*., 2013).wastewater reuse involves environmental benefits, because, it decrease discharge of pollutants and collected of high quality water from ground and surface aquifers. Moreover, wastewater recycling permits industry to diminish costs for depuration processes for fresh-water availability. Wastewater reclamation and reuse is a promising alternative, which can both conserve or supplement the available water resource and reduce or eliminate the environmental pollution.

3.6.1 Selection of Fabric

Cotton fiber differs markedly from other cellulose fibers in morphological traits. Due to many features, cotton even though was discovered later than other fibers gained a superior position and stimulated immense development in textile industry. Cotton fabric shows good durability and utility. It is a chemically stable material, and it stays undamaged even under the continuous exposure of weak acids and alkalis. High it has water-absorbing capacity. In humid atmosphere cotton fabric can absorb 27% of water without getting damp. Cotton fabric are easy to dye. Cotton fabric has very low elasticity characteristics, so they almost don’t stretch. They are easy washable and can be ironed even at high temperature (Satish and Khana, 2013). Hence cotton was selected for the present study.

3.6.2 Dyeing of selected fabric with reactive dye using fresh and decolorized water

Dyeing is the application of colorant to the substrate in order to enhance thye appearance by the attraction of hue. The selected cotton fabric was desized and then dyed with reactive dye using decolorized and fresh water. Dyeing using reactive dye involves the following steps;

- Exhaustion of the dye bath by the addition of the salts
- Fixation of the exhausted dye bath by the addition of fixing agent
- Washing off the unfixed dye

3.6.3 DYEING PROCEDURE

TABLE 5

DYEING PARAMETERS

Parameters	Amount
Fabric	1 meter
Shade	5%
Material : Liquor Ratio	1.30
Fixing agent	10%
Temperature	$70^{o}C$

The selected (desized) cotton fabric was dyed using fresh and decolorized water. The fabric was soaked in fresh water and decolorized water for 30 minutes and squeezed. The dye stuff was made into paste with warm water, which is then added to the measured amount of water and stirred well. The wet fabric was then immersed into the dye bath and kept for 10 minutes. The fabric was taken out and fixing agent was added to the dye bath and the content was mixed thoroughly. The fabric was again immersed in the dye bath for 30 minutes at $70^{o}C$, the fabric was washed thoroughly by changing the water thrice. Finally the sample was taken out and squeezed and dried in shade. Following the same procedure, dyeing was performed in decolourized water for selected cotton fabric.

3. 7 Evaluation of dyed fabric

3.7.1 Subjective Evaluation- Visual inspection

The fabric samples dyed with fresh and decolorized water were evaluated visually by panel members. The panel members comprising of 20 PG students specializing in the field of Textile and Clothing, evaluated the fabric for General appearance, brilliancy of shade and evenness of dyeing.

3.7.2 Objective Evaluation

Textile testing as a whole refers to the vigorous testing done on textile materials which may be inside the laboratory as well is in natural setting.

3.7.2.1 Fabric weight

Fabric weight as the relative weight of the fabric and expressed as the weight of a particular size of piece as grams/square yard.

Fabric weight of the original and dyed sample was determined using GSM cutter. It is a device to cut specimen of 100 square centimeters of a fabric very accurately. It has 4 blades that cut the fabric, when the hand wheel is rotated by applying light pressure. The samples where cut and weighed accurately sing digital balance having 0.01sensitivity. The value in grams multiplied by 100 gives grams/ square meter of the fabric.

The sample was weighed for five times and the mean value was calculated and recorded.

3.7.2.2 Fabric thickness

Fabric thickness gauge was used to measure thickness of the sample. It has 2 parts the anvil and pressure foot. Pressure was given at the foot to make the gauge zero. The sample was placed between the cleaned pressure foot and anvil. The reading shown by the dial was noted. For each sample, thickness was determined at 5 different places away from 2 inch of the selvedge.

3.7.2.3 Fabric Strength and Elongation

Breaking strength is the measure of resistance of the fabric to a tensile load or stress in both warp and weft direction. Elongation measures the extent of

deformation along the axis of a material under a tensile stress, and expressed in units of length of the fabric when loaded.

The original and dyed fabric was tested for tensile strength using Eureka Cloth tensile strength tester. 12 inch × 2 inch specimen from each samples were cut both in warp and weft direction of the fabric, 2 inches apart from selvedge. The specimen was placed between the upper and lower clamp. The dial reading was set to zero by adjusting the pendulum over the quadrant scale. The elongation pointer was checked for its position in zero. Before starting the machine the pendulum lock was released and machine was stitched to run. At certain point the fabric starts to break, the machine was switched off and the dial reading in lb was taken.

Elongation reading was noted from the elongation scale. The specimen was removed and the machine positioned back to original and the five specimens of both directions from each sample were tested and readings were noted.

3.7.2.4 Fabric Stiffness

Shirley stiffness tester was used to test the stiffness of the fabric. Sample A was cut to the size of 15 cm × 2.5 cm using the template. The sample was placed on the platform with the template at the top of it, so that the leading edges coincide. Both were slowly pushed forward until the leading edges of the sample and the template project beyond the edge of the platform. The sliding of the sample was stopped when it cut both the index line engraved on the side of the platform. five readings were taken for each sample. Mean values of the bending length in warp and weft wise direction was calculated.

3.7.2.5 Absorbency Tests

Drop Test

Absorbency is defined as the potentiality of a material to take in and retain a liquid, usually water, in the pores and interstices. A drop test is a count of number of drops required to penetrate through the surface of the fabric (AATCC Technical Manual, 2008).

A burette filled with distilled water was clamped in a stand. The fabric Sample was mounted in an embroidery frame and was placed at the base of the stand. The distance between the sample and burette nozzle was kept constant. The nozzle of the burette was opened just to allow a drop of water and allowed to absorb into the material. The time taken for this was noted. Same procedure was repeated for five times and the mean value was calculated. Similarly the water drope absorbency time was recorded for all the samples and their mean values were calculated.

Capillary Rise Test

The capillary travel method measures the rapidity of absorption. 5 pieces of the fabric sample were cut measuring 15 cm length and 2.5 cm width. One end of the sample strip was pasted with a glass rod which was placed on heavy wooden blocks and, the strip was allowed to immerse in a tray of distilled water. The rise of the water level in the strip was noted by keeping time as constant (1minute). The same procedure was repeated for the other samples and the mean value was calculated and recorded (paul, 2005)

Sinking Test

Sinking test is a simple test that helps to measure the wet ability of a fabric reports AATCC Technical Manual (2008).

In this method the fabric sample was cut into a number of equal sized squares of 1” × 1” and added to a 1000 ml beaker which was filled with distilled water. The stop watch was started when the fabric struck the surface of water and stopped when the last corner sank below the water surface. The mean time for sinking was calculated and recorded.

3.7.2.6 Colour Fastness Tests

Dye- fiber interactions are varied and their strength or combined strength determines both the outcome and performance of the dyeing. Dyeing does not mean only to impact attractive on the fiber but to obtain fast color on it.

In this study, four color fastness tests were carried out. They are color fastness to sunlight, washing, wet and dry crocking, wet and dry pressing.

Fastness to Sunlight

To test the fastness to sunlight the specimens 16 cm x 5 cm were cut from each sample of dyed fabrics and divided into 8 equal parts measured as 20cm each, the specimens were covered with black chart. For the successive 7 days the specimens were exposed to direct sunlight. First portion was exposed and accordingly seven portions are exposed to sunlight. The first portion was exposed for 7 days and the 7^{th} portion was exposed for a day. The last was not exposed to sunlight and considered as control Comparisons were done using grey scale and the specimens were rated.

Fastness to Wet and Dry crocking

Crocking is the rubbing fastness of dyes. Crocking is the transfer of colorant from the surface of the colored fabric to an adjacent area of sample fabric or to another surface, principally by rubbing action. Fastness to crocking is important in both apparel as well as upholstery. Crocking test determine the extent to which color may be transferred from the surface of the dyed fabric to another by rubbing.

Sasmira Crock meter was used to determine the fastness of the dyed textile fastness to wet and dry crocking. It has metal bloks. The base block was stationary, while the upper block had an arrangement to move to and from the base by means of a rotating handle. There was a finger knob attached to the upper block to hold the cotton material with ring. The sample was fixed o the base block with longer side in the direction of rubbing then white desized original material (5*5cm) was fixed on the finger knob of upper movable block with a ring. The number of rubs given was standardized and fixed as ten rubs. Each sample was given ten strokes and the color change and staining on the white cloth were graded.

Fastness to washing

Major loss of color from the fabric is due to washing and results in straining over the adjacent fabric. Test sample of the dyed fabric measuring 5×10cm size were cut. Each of them was sandwiched between the undyed white cloth which was desized well. Specimen were completely soaked in the soap solution about 5g/l for 30 minutes at 40^{o}C, after that the sample was removed, rinsed in cold water thoroughly, squeezed well and dried. Evaluation of staining on the white adjacent fabric was found using a grey scale. The same procedure was carried out for other dyed samples.

Fastness to Wet and dry pressing

Color fastness of the sample to pressing was measured following the specification of Bureau of Indian standards (2000). Two specimens measuring 10cm × 10cm from each dyed sample were cut and one set of specimen covered at either side with 5cm × 5cm of desized white fabric. The prepared specimen was pressed for 5 seconds to assess its color fastness to dry pressing, while the other were covered with wet white cloth and pressed for 5 seconds to assess its color fastness to wet pressing. The same procedure was repeated for other fabrics. The color change in the dyed fabric was graded using grey scale.

3.8 UV-Vis analysis

Using UV-Vis spectrophotometer analysis was carried out for the control and decolourized sample.

3.9 FTIR analysis

FTIR Analysis was carried out for the control and decolourized sample.

4.0 RESULT AND DISCUSSION

The results of the present study **"Decolourization of reactive dyes in aqueous solution using selected agro waste"** are discussed under the following headings:

4.1 Screening of different agrowastes for decolorization of selected reactive dye

4.2 Optimization of various parameters for the decolorization of reactive dye

- 4.2.1 Optimization of agro-waste concentration
- 4.2.2 Optimization of contact time
- 4.2.3 Optimization of pH
- 4.2.4 Optimization of temperature

4.3 Decolorization of reactive dye using selected agro-waste under optimized conditions

4.4 Evaluation of dyed fabrics

- 4.4.1 Fabric weight
- 4.4.2 Fabric Thickness
- 4.4.3 Fabric Strength
- 4.4.4 Fabric Elongation
- 4.4.5 Fabric Stiffness
- 4.4.6 Absorbency tests
- 4.4.7 Colour fastness tests

4.5 UV-Vis spectral analysis

4.6 FTIR analysis

4.1 Screening of different agrowastes for decolorization of selected reactive dye

The decolorization efficiency of different agro-wastes such as Groundnut shell, Sugarcane bagassse, Wood dust, Orange peel, Rice Husk, Corn Stalk, Wheat Dust, Water Hyacinth stem, Sisal fiber, Onion peel and Garlic Peel were screened and the results are presented in Table 6 and Figure 1.

TABLE 6

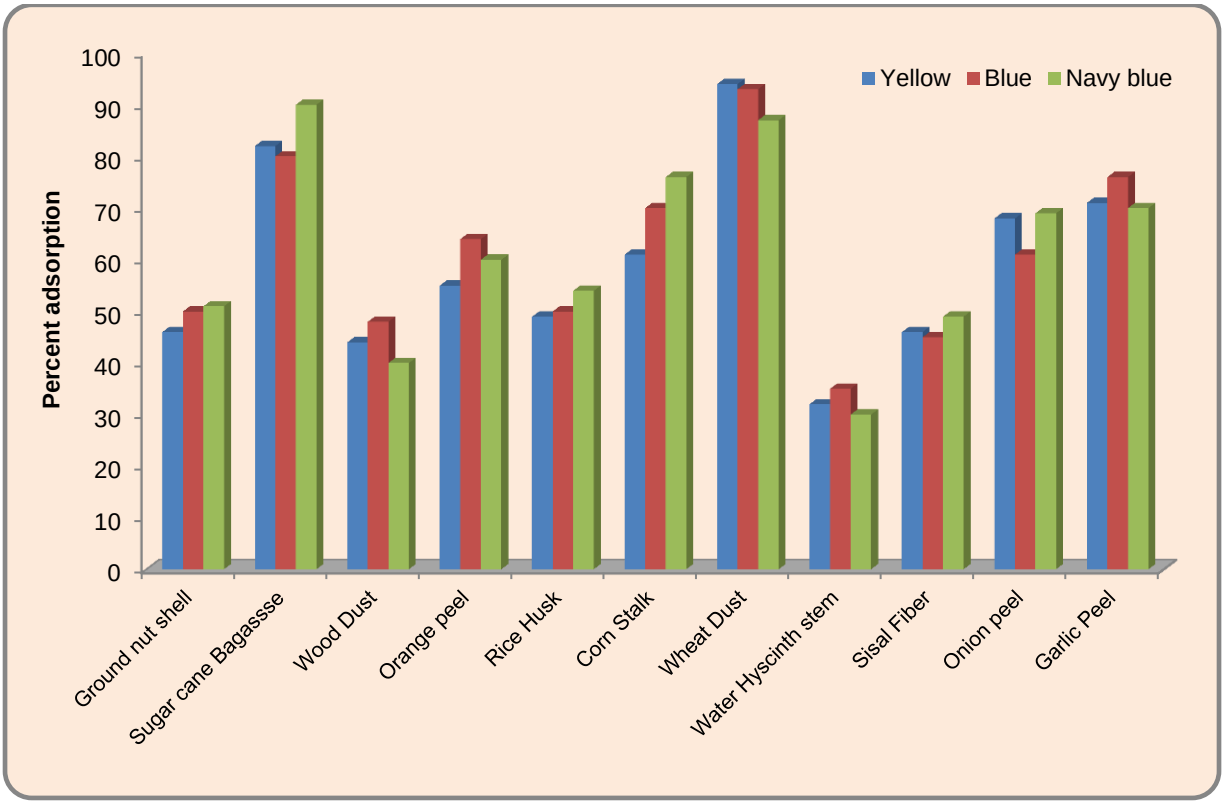
DECOLOURIZATION OF SELECTED REACTIVE DYES BY DIFFERENT AGRO-WASTES

Agro waste	Per cent decolourization		
	Yellow R reactive	T. Blue G reactive	Navy blue GDB reactive
Ground nut shell	46	50	51
Sugarcane bagassse	82	80	**90**
Wood dust	44	48	40
Orange peel	55	64	60
Rice husk	49	50	54
Corn stalk	61	70	76
Wheat dust	**94**	**93**	87
Water Hyacinth	32	35	30
Sisal fiber	46	45	49
Onion peel	68	61	69
Garlic Peel	71	76	70

*values are mean of triplicates

FIGURE 1

DECOLORIZATION OF SELECTED REACTIVE DYES BY DIFFERENT AGRO-WASTES



Among the selected agro-wastes, wheat dust showed maximum per cent decolorization for Yellow R reactive (94%), T. Blue G reactive (93%) and sugarcane bagasse for Navy blue GDB reactive (90%). Hence wheat dust was selected as the potent source for decolorization of reactive dyes. Yellow R reactive and T. Blue G reactive and sugarcane bagasse for Navy blue GDB reactive dye.

4.2 Optimization of various parameters for the decolorization of reactive dye

4.2.1 Optimization of agro-waste concentration

The effect of agro-waste concentration on decolorization of reactive dye was studied and the results are presented in Table 7 and Figure 2.

TABLE 7

OPTIMIZATION OF AGRO-WASTE CONCENTRATION

Agrowaste Concentration (%)	Per cent decolourization		
	Yellow R reactive	T. Blue G reactive	Navy blue GDB reactive
0.5	70	85	83.6
1.0	79.1	89.3	85
1.5	82.5	91	87.2
2.0	**94**	**93.2**	**89.7**
2.5	91	90	87

FIGURE 2

OPTIMIZATION OF AGRO-WASTE CONCENTRATION

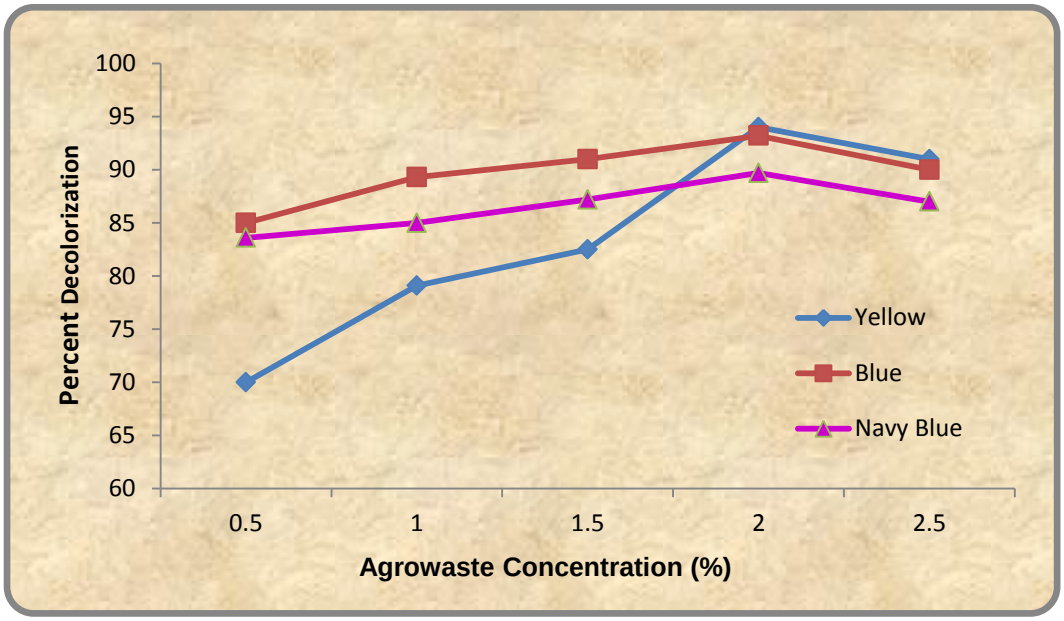


Table 7 and Figure 2 clearly indicates that per cent dye decolorization increased with increase in agrowaste concentration from 0.5% to 2.5%. wheat dust at a concentration of 2% results in maximum per centage of dye removal for yellow R (94%), and T.Blue G (93.2%). Similarly sugarcane bagasse at a concentration of 2.0% showed maximum decolourization for navy Blue GDB

(89.7%). Azhar et al., (2005) have been reported lowering in percentage removal of dye with increase in concentration which may be due to the lack of available active sites of an adsorbent as well as the formation of monolayer of dye on the surface of adsorbent and also any further formation of layer is highly hindered at higher concentration. Hence optimum concentration of 2.0% was used for subsequent experiments.

4.2.2 Optimization of contact time

The effect of contact time on the decolorization of reactive dyes was studied and the results are shown in Table 8 and Figure 3.

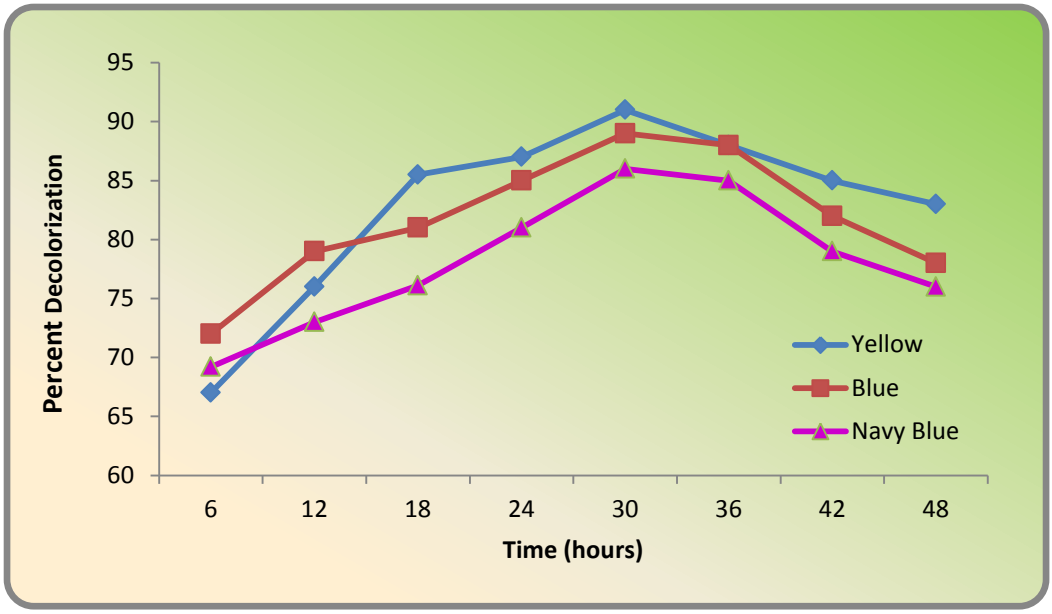
TABLE 8

OPTIMIZATION OF CONTACT TIME

Time (hours)	Per cent decolorization		
	Yellow R reactive	T. Blue G reactive	Navy blue GDB reactive
6	67	72	69.2
12	76	79	73
18	85.5	81	76.1
24	87	85	81
30	**91**	**89**	**86**
36	88	88	85
42	85	82	79
48	83	78	76

FIGURE 3

OPTIMIZATION OF CONTACT TIME



Maximum rate of decolorization was noticed after 30 hours of incubation for all the selected dyes Yellow R reactive (91%), T. Blue G reactive (89%) and Navy blue GDB reactive (86%). Further increase in contact time has negligible effects on percent decolorization. Hence contact time of 30 hours was fixed for subsequent studies.

4.2.3 Optimization of pH

To determine the optimum pH for the effective decolorization of reactive dye, the adsorption capacities of the adsorbents were studied at different pH range from 5-11 and the results are shown in Table 9 and Figure 4.

TABLE 9

OPTIMIZATION OF pH

pH	Per cent decolorization		
	Yellow R reactive	T. Blue G reactive	Navy blue GDB reactive
5	89.7	82.8	80.7
6	**94**	89.5	82
7	90.4	**95**	84
8	82	93.2	88.5
9	76	89	**93**
10	69	82	89.6
11	61	79	79

FIGURE 4

OPTIMIZATION OF pH

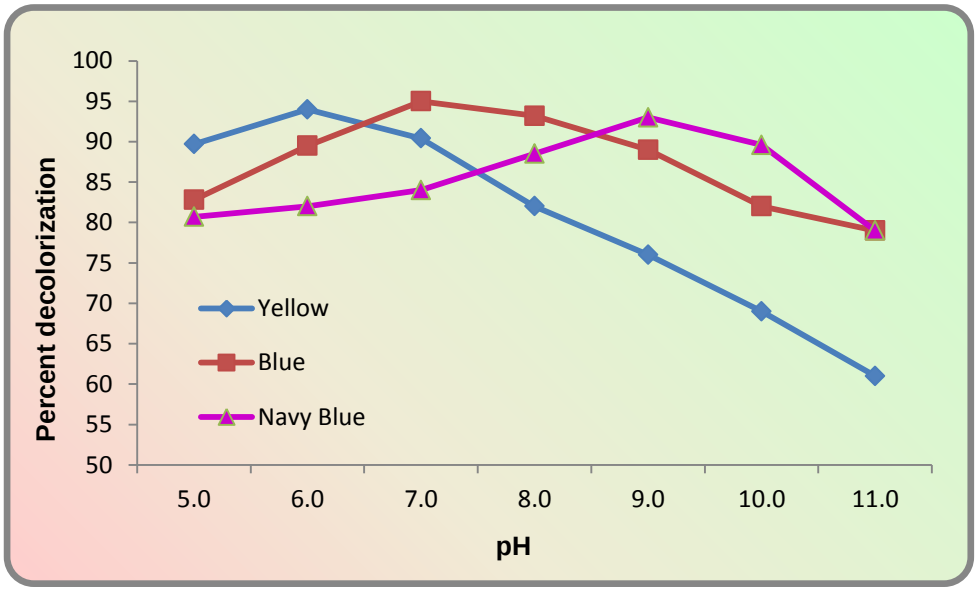


Table 9 and Figure 4 clearly indicates that the optimum pH for decolorization of reactive dyes was found to be at pH 6 for reactive yellow R (94%), pH 7 for T. Blue G (95%), and pH 9 for Navy blue GDB (93%). Valix *et al*., (2006) have reported an decrease in adsorption with increase in pH may be due to surface hydroxylation, surface complexation and ion exchange. The extent of adsorption is strongly dependent on the pH of the medium.

4.2.4 Optimization of temperature

Effect of temperature on decolourization of reactive dyes was examined at various temperatures such as 40°C, 50°C, 60°C, 70°C and 80°C with pH and agro- waste concentration at their optimum levels and the results are represented in Table 10 and Figure 5.

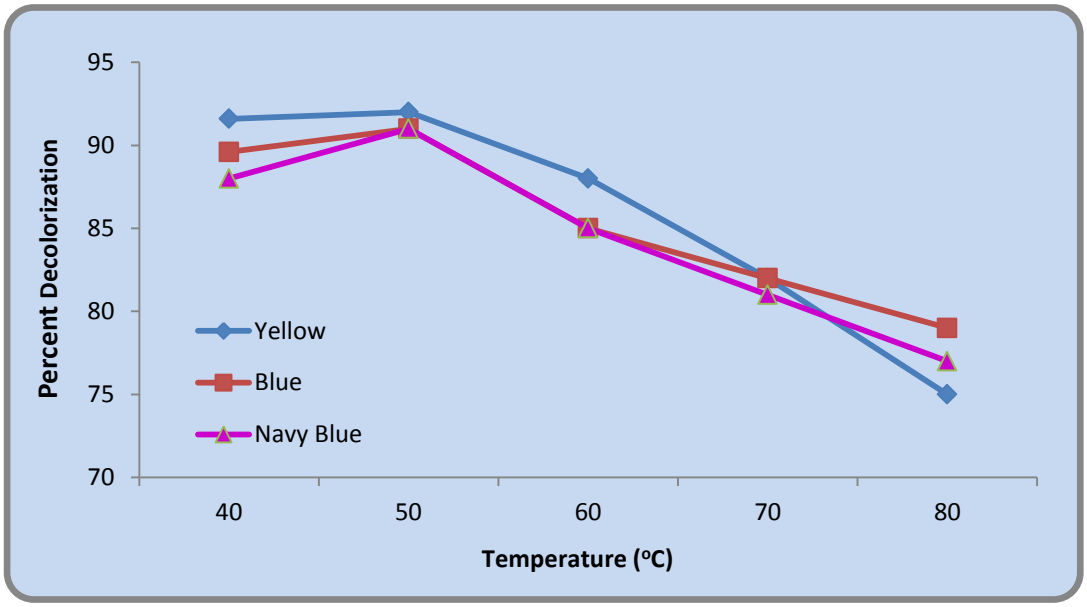
TABLE 10

OPTIMIZATION OF TEMPERATURE

Temperature (° C)	Per cent decolorizaton		
	Yellow R reactive	T. Blue G reactive	Navy blue GDB reactive
40	91.6	89.6	88
50	**92**	**91**	**91**
60	88	85	85
70	82	82	81
80	75	79	77

FIGURE 5

OPTIMIZATION OF TEMPERATURE



From Table 10 and Figure 9, it is clearly understood that the per cent dye decolorization was maximum at 50^{o}c. for all the selected reactive dyes. The decrease in adsorption with rise in temperature indicates that the process is exothermic.The decrease due to weakening of adsorptive forces between the active sites of adsorbat and adsorbent and also between the adjacent molecules of the adsorbed phase. The obtained result coincides with that of Nageshwar *et al*., (2004) who have reported that decolourization decreases with increase in temperature.

.4.3 Decolourization of reactive dye using selected agro- waste under optimized conditions

Table 11 shows the optimized conditions for the decolourization of selected reactive dyes

TABLE 11

DECLOURIZATION OF REACTIVE DYES USING SELECTED AGRO- WASTE UNDER OPTIMIZED CONDITIONS

Parameters	Optimized condition		
	Yellow R reactive	T. Blue G reactive	Navy blue GDB reactive
Adsorbent concentration (%)	2.0	2.0	2.0
Contact time (hours)	30	30	30
pH	6	7	9
Temperature(^{0}C)	50	50	50

The selected Yellow R reactive dye at a concentration of (0.01%) was decolorized using 2% of wheat dust at pH 6, for an incubation period of 30 hours at 50^{0}C. The reactive dye T Blue G dye at a concentration of 0.01% was decolorized using 2% of wheat dust at pH 7, for an incubation period of 30 hours at 50^{0}C. Reactive dye Navy Blue GDB at a concentration of 0.01% was decolorized using 2% of sugarcane bagasse at pH 9, for an incubation period of 30 hours at 50^{0}C.

4.4 Evaluation of dyed fabric

4.4.1 Fabric weight

The fabric weight and analysis of variance of the orginal sample, fabric dyed with reactive dye yellow R using fresh water (YDF), T.Blue G reactive (BDF), Navy blue GDB reactive (NDF). Similarly fabric dyed with reactive dye yellow R using decolourised water (YDT), T.Blue G reactive (BDT), Navy blue GDB reactive (NDT) are given in Table 12 and Figure 6.

Table 12

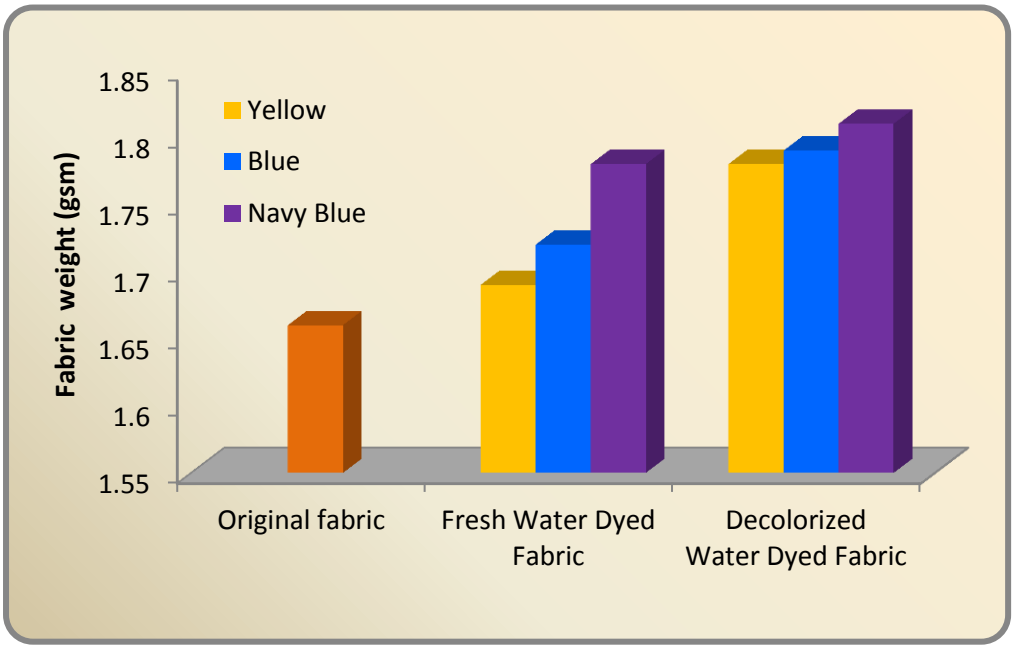
Fabric weight

Samples	Mean (GSM)	Loss/gain	% loss/gain	F-value
Original Fabric	1.66	-	-	**37.52***
YDF	1.69	0.03	1.8	
BDF	1.72	0.06	3.6	
NDF	1.78	0.12	7.2	
YDT	1.78	0.12	7.2	
BDT	1.79	0.13	7.8	
NDT	1.81	0.15	9.0	

* - Significant at 5% level

FIGURE 6

FABRIC WEIGHT



From Table 12 and Figure 6, it is clear that the weight of the dyed samples increased when compared to their original. The percent increase in weight for fresh water dyed fabric was 1.8% in YDF, 3.6% in BDF and 7.2% in NDF samples. Were as decolourized water dyed fabric showed 7.2% in YDT, 7.8% in BDT and 9.0% in NDT samples.

Statistical analysis proved that there was no significant difference among the dyed samples. Maximum increase in weight was observed in NDT sample which may be due to increase in dye absorption. The results support that the decolorized water can be effectively used for dyeing cotton fabric.

4.4.2 Fabric Thickness

Fabric Thickness and analysis values of the samples Original, fresh water dyed fabrics, decolourised water dyed fabrics are presented in Table 13 and Figure 7.

Table 13

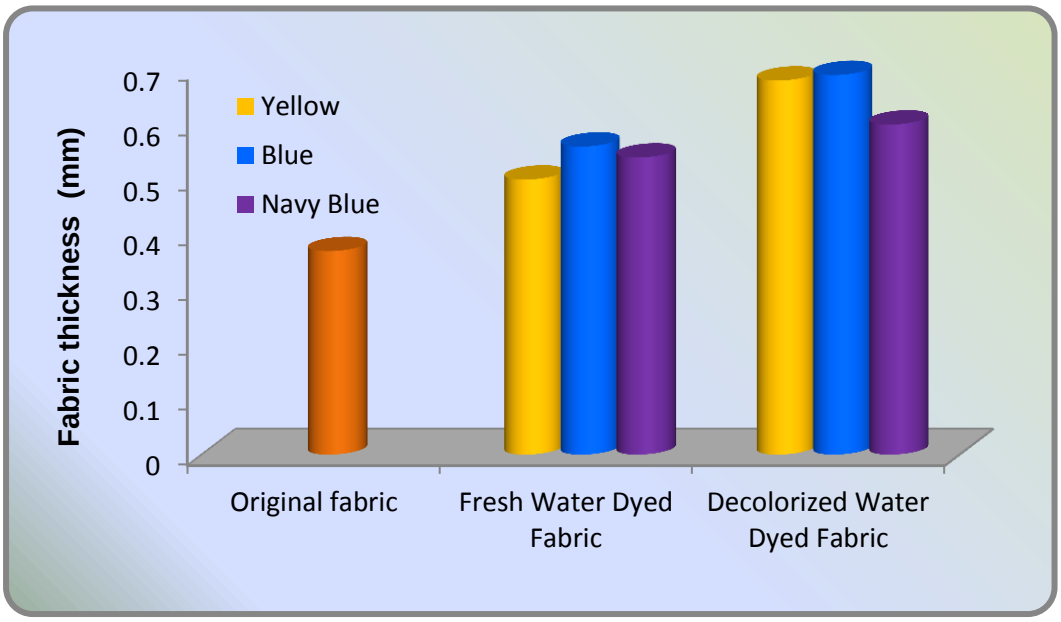
Fabric Thickness

Samples	Mean (mm)	Loss/gain	% loss/gain	F-value
Original Fabric	0.37	-	-	
YDF	0.50	0.13	35.1	
BDF	0.56	0.19	51.3	**33.99***
NDF	0.54	0.17	45.9	
YDT	0.68	0.31	83.7	
BDT	0.69	0.32	86.4	
NDT	0.60	0.23	62.1	

* - Significant at 5% level

FIGURE 7

FABRIC THICKNESS



From Table 13 and Figure 7, it is clear that the thickness of the dyed samples increased when compared to their original. The increase in thickness for fresh water dyed fabric was 35.1% in YDF 51.3% in BDF and 45.9% in NDF. Were as in decolorized water dyed fabric showed 83.7% in YDT, 86.4% in BDT and 62.1% in NDT samples over original.

Statistical analysis proves that there is a significant difference as 5% level among the samples.

4.4.3 Fabric Strength

Fabric strength and analysis of variance of the samples Original, fresh water dyed fabrics, decolourised water dyed fabrics are presented in Table 14 and Figure 8.

Table 14

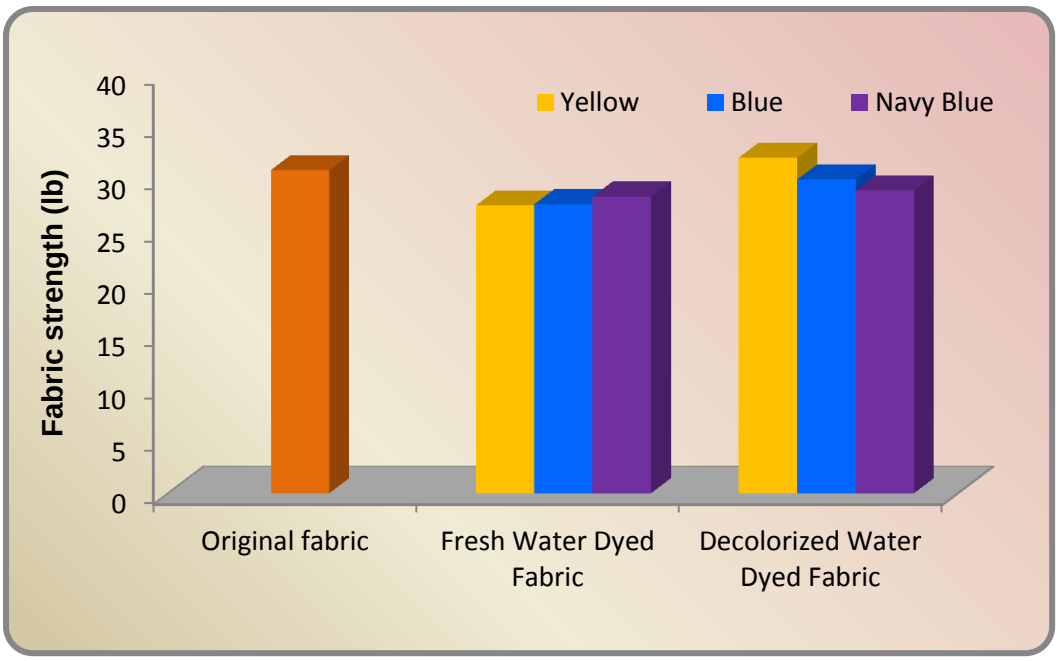
Fabric strength

Samples	Mean(cm)	Loss/gain	% loss/gain	F-value
Original Fabric	30.80	-	-	13.532*
YDF	27.42	-3.38	-10.9	
BDF	27.54	-3.26	-10.5	
NDF	28.28	-2.52	-8.1	
YDT	31.99	1.9	3.8	
BDT	29.90	-0.9	-2.9	
NDT	28.87	-1.93	-6.3	

* - Significant at 5% level

FIGURE 8

FABRIC STRENGTH



From Table 14 and Figure 8, it is clear that fabric strength decreased in all the dyed samples except YDT when compared over the original.

Statistical analysis proves that there was a significant difference at 5% level when compared between the dyed samples. Hence the result supports that the fabric strength of decolorized water dyed samples is on par with fresh water dyed sample.

4.4.4 Fabric Elongation

Fabric elongation and analysis of variance of the original, fresh water dyed and decolorized water dyed fabrics are presented in Table 15 and Figure 9

Table 15

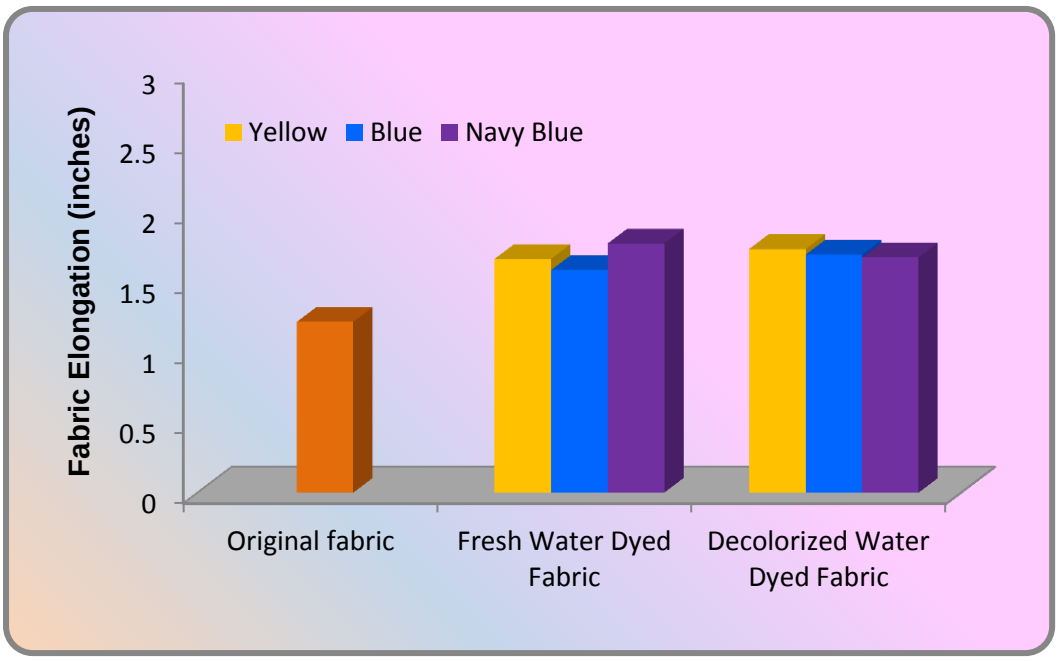
Elongation of the fabric

Samples	Mean(inches)	Loss/gain	% of loss/gain	F-value
Original Fabric	1.22	-	-	
YDF	1.67	0.45	36.8	
BDF	1.59	0.37	30.3	
NDF	1.78	0.56	45.9	
YDT	1.74	0.52	42.6	**9.56***
BDT	1.70	0.48	39.3	
NDT	1.68	0.46	37.7	

* - Significant at 5% level

FIGURE 9

FABRIC ELONGATION



From Table 15 and Figure 9, it is clear that there was an increase in elongation of the dyed samples when compared over original and maximum increase was found in NDF (45.9%).

Statistical analysis proves that there is a significant difference of 5% when compared between the samples.

4.4.5 Fabric Stiffness

Fabric stiffness and analysis of variance of original, fresh water dyed fabrics, decolorized water dyed fabrics are presented in Table 16 and Figure 10.

Table 16

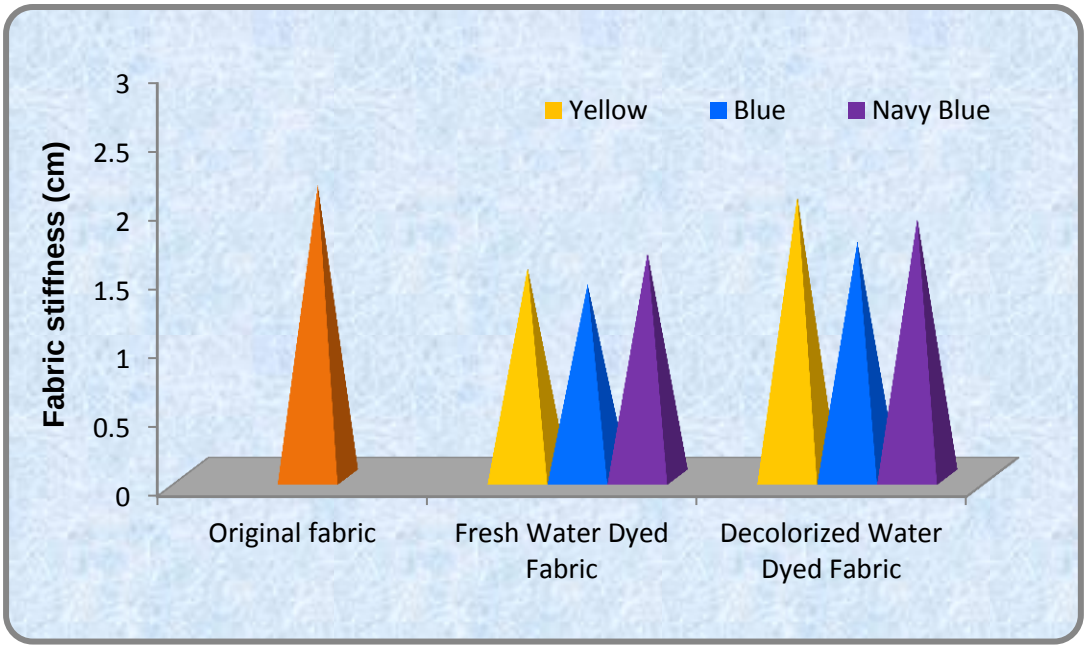
Fabric Stiffness

Samples	Mean(cm)	Loss/gain	% of loss/gain	F-value
Original Fabric	2.12	-	-	**11.412***
YDF	1.52	-0.6	-28.3	
BDF	1.40	-0.72	-33.9	
NDF	1.63	-0.49	-23.1	
YDT	2.04	-0.08	-3.7	
BDT	1.71	-0.41	-19.3	
NDT	1.88	-0.24	-11.3	

* - Significant at 5% level

FIGURE 10

FABRIC STIFFNESS



From Table 16 and Figure 10, it is clear that the fabric stiffness of all the dyed samples decreased when compared over the original. Maximum decreased was formed in sample BDF followed by YDF.

Statistical analysis proved that there was a significant difference at 5% level when compared among the samples.

4.4.6 Absorbency test

The results related to absorbency test of the samples are presented in Table 17 and Figure 11.

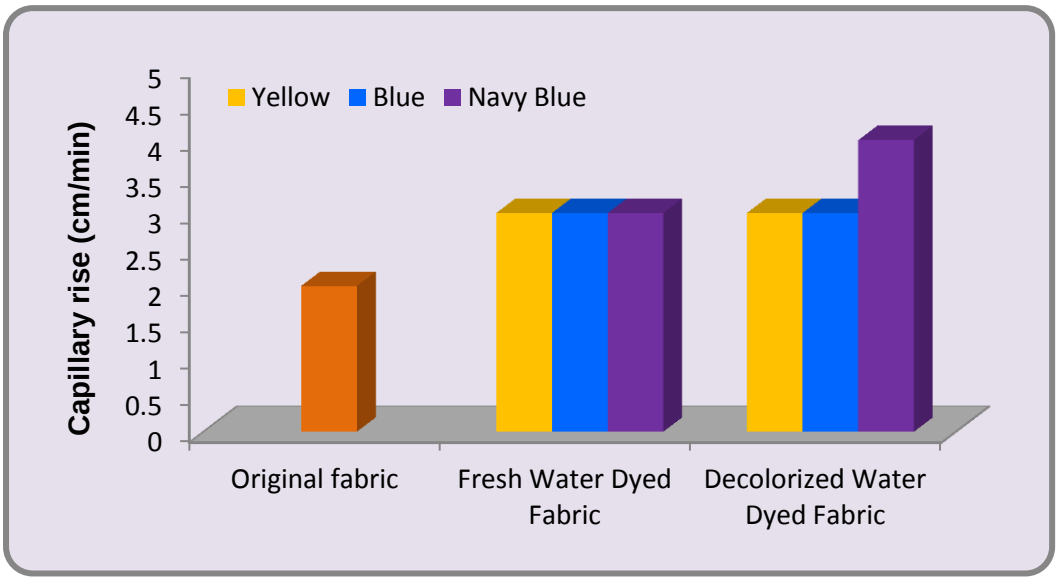
TABLE 17

ABSORBENCY TEST

Absorbency test	Samples						
	Original	Fresh water dyed sample			Decolourized water dyed sample		
		YDF	BDF	NDF	YDT	BDT	NDT
Capillary rise(cm/min)	2	3	3	3	3	3	4
Drop test (sec)	6	4	5	4	5	5	4
Sinking test (sec)	21	9	8	9	10	7	8

Figure 11

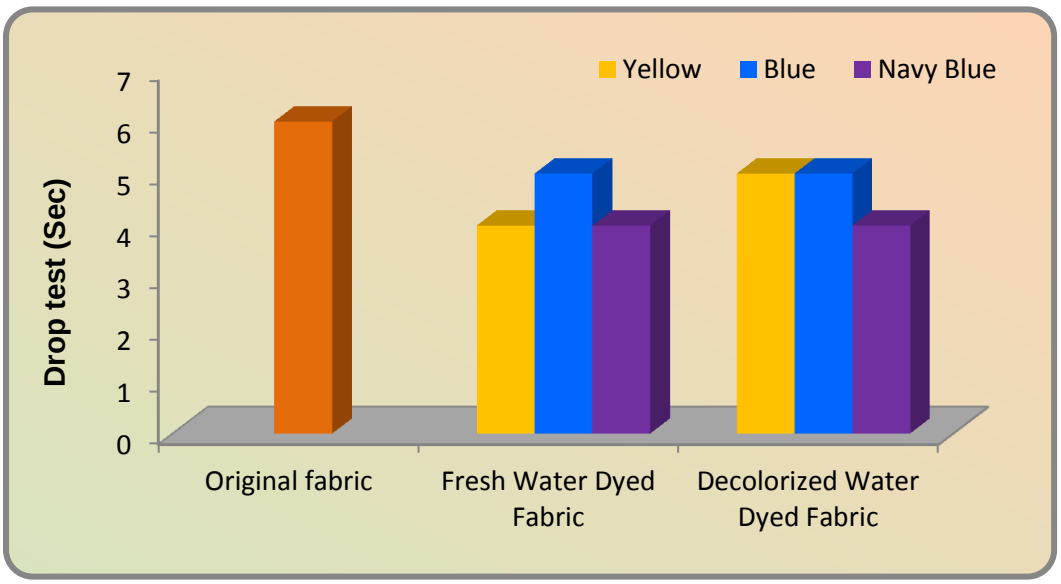
capillary rise



From Table 17 and Figure 11, it is evident that the capillary rise of all the dyed fabrics increased when compared to the original. Maximum increases in capillary rise were found in NDT (4cm). The results proved that the absorbency of decolourized water dyed sample is on par with the fresh water dyed sample.

Drop test

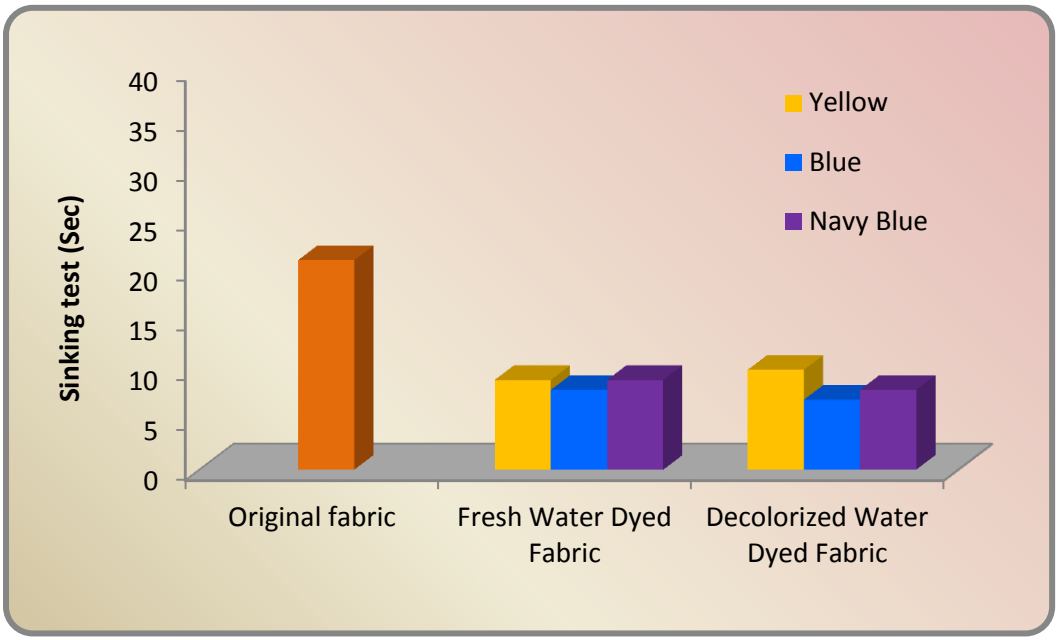
Figure 12



From Table 17 and Figure 12, it is clear that the time taken for the absorption of a drop of water decreased in all the dyed samples when compared to the original. The result indicates that absorption of all the fabrics increased on dyeing.

Sinking test

Figure 13



From Table 17 and 13, it is clear that the time taken to sink decreased in all the dyed samples. The results proved that absorbency of the fabric increased on dyeing. Maximum decreased was observed in sample BDT. To conclude the absorbency property of decolourized water dyed sample in on par with fresh water dyed sample.

4.4.7 Colour fastness test

The results of colour fastness tests to sunlight, pressing and crocking results of dyed fabric are presented in Table 18.

Table 18

Colour fastness test

Color Fastness Tests	Samples					
	Fresh water dyed sample			Decolourized water dyed sample		
	YDF	BDF	NDF	YDT	BDT	NDT
Sunlight	4	4	4	5	4	4
Pressing Dry staining	5	4	4	4	5	4
Wet staining	4	4	4	4	4	4
Crocking Dry staining	4	4	4	5	4	4
Wet straining	4	4	4	5	4	4

5- Excellent 4- Good 3- Fair 2- Poor 1- Very poor

From Table 18, it is evident that all the dyed samples have good fastness to sunlight. With regard to pressing and crocking all the samples have good fastness. Hence it could be concluded that the color fastness property of decolourized water dyed sample is on par with fresh water dyed samples.

4.5.1 UV-Vis spectral analysis

UV- Vis spectral analysis has been used to confirm the degradation processes of dye that was due to decolorization (Aksu, 2003). UV- Vis spectral analysis was reported earlier study the decolorization process of various textile dyes (Moosvi *et al*., 2005). Spectrophotometric analysis of the dye showed maximum absorbance at 420nm in (yellow R reactive), 452nm in (T. blue reactive) and 596nm in (navy blue GDB reactive), while decolourized sample showed maximum absorbance in the UV range (appendix 2).The dye removal is attributed to the degradation when the major visible light absorbence peak would be completely disappear or a new peak will appear (Bhatt *et al*., 2005). Results indicate that the peeks in the visible regain have been shifted to UV region which rules the degradation of the dye by the agro waste.

4.5.2 FTIR analysis

The possible mechanism of yellow R reactive. blue reactive, navy blue GDB with degraded metastasize by inactive aerobic granules in single and binary solution was elucidated using the FTIR analysis in the range of 400-4000 cm^{-1}. The FTIR spectra , which could be identified based on the reports the strong band at 3734.19 cm^{-1} yellow R reactive, 3533.59 cm^{-1} T. blue reactive and 3772.76 cm^{-1} navy blue GDB reactive might reflect the overlapping of N-H and O-H stretching vibrations of hydroxyl and amine groups on the surface of inactive aerobic granules, and the band at 3741.90 cm^{-1} yellow R reactive, 3533.59 cm^{-1} T. blue reactive and 3780.48 cm^{-1} navy blue GDB reactive represent an asymmetric vibration of CH_2 (Appendix 3). A distinct band at 1689.64 cm^{-1} yellow R reactive, 1681.93 cm^{-1} T. blue reactive and 1597.06 cm^{-1} demonstrated the stretching vibration of C-O and C-N (amide I) peptidic bond of protein. Thus the shift has been occurred in this stretching 3533.59 cm^{-1}, 3772.76 cm^{-1}, 3734.19 cm^{-1}. The band intensity decreased sharply after biosorption ,

5.0 SUMMARY AND CONCLUSION

The textile industry, mother of Indian industrialization and second large employment generator after agriculture accounts for about 20% industrial production. It not only generates jobs in its own area, but also opens up scope for the other ancillary sectors. India earns about 27% of the total foreign exchange through textile exports. Textile industry has a unique position as a self reliant industry from the production of raw material to the delivery of finished products with substantial value addition at each stage of processing.

Rapid industrial development of the textile sector has resulted in economic advancement, but at the cost of environmental degradation. It is well known that textile processing units consumes large volumes of water for processes such as sizing, desizing, scouring, bleaching, mercerizing, dyeing, printing, finishing, and washing. Waste water generated at various stage of textile processing differs in its composition, strength as well as volume. Presence of color is unpleasant. Moreover, many synthetic dyes are harmful to human being, so the removal of color from textile effluent is environmentally important. Several color removal methods have been used for the decolorization of dye. Many of these methods are cost prohibited and suffered with one or other limitations.

In recent years, there has been considerable interest in the use of biological by-products and residues for adsorption. Among these materials, agricultural by-products and biomass are relatively cheap and exhibit very high adsorption capacities. The advantages of adsorption method are its simplicity of operation, low cost and eco-friendliness. Adsorption removes the complete molecule, leaving no fragments in wastewater. This is particularly relevant for metal containing dyes, where the coordination metal would remain in the effluent after non-adsorptive treatments, potentially in a more hazardous uncomplexed form.

The mechanism of dye adsorption on the agro-waste in color removal process is similar to dyeing textile material which involve the following step such

as diffusion of dye molecules from the solution to the surface of adsorbents, adsorption of dye molecules on the surface of the materials through molecular interaction and diffution of dye molecules from the surface into the interior of the adsorbent materials.

Bearing in mind the toxicological impacts of dye on environmental and the advantages of adsorption technique, the present study on “Decolourization of reactive dyes in aqueous solution using selected agro waste” has been designed with the following objectives.

- To screen and select the reactive dye decolorizing agrowaste
- To optimize various parameters such as p^H, temperature, time, concentration of absorbent for dye decolorization.
- To reuse the decolorized water for dyeing
- To evaluate the dyed fabric

Experimental procedure

Different agrowastes such as as groundnut shell, sugarcane bagasse, wood dust, orange peel, rice husk, corn stalk, wheat dust, hyacinth stem, sisal fiber, onion peel, garlic peel were screened for their decolourization capacities for selected reactive dyes (T. Blue G reactive ,Yellow R reactive and Navy blue GDB reactive). Based on percent decolourization, wheat dust and sugar cane bagasse was selected. Various experimental conditions like adsorbent concentration, contact time, pH, and temperature were optimized for effective decolourization of reactive dyes using wheat dust and sugarcane bagasse. The per cent decolourization was determined using UV- visible spectrophotometer.

In order to assess the reusability of decolourized water, it was utilized for dyeing selected fabric. Objective evaluation of the fabric such as fabric strength, fabric stiffness, fabric weight, fabric thickness, fabric elongation, absorbency test, colour fastness tests carried out for the dyed samples.

Findings

- Among the different agrowastes screened, wheat dust, sugarcane bagasse efficiently decolorized was observed to be more efficient for the decolorization of reactive dyes T. Blue G reactive, Yellow R reactive and Navy blue GDB reactive.
- An adsorbent concentration of 2% was found to be optimum for the decolorization of the selected reactive dyes.
- The optimum pH for decolorization of reactive dyes T. Blue G reactive, Yellow R reactive, Navy blue GDB was found to be 9 respectively.
- Maximum percent decolorization was noticed at 50^{o}C for all the selected dyes.
- A contact time of 30 hours, resulted in maximum decolourization of the selected dyes.
- Decolorization was carried out under optimized conditions. After decolorization, decolorized water was reused for dyeing the selected cotton fabric.
- Fabric weight of the sample dyed using fresh and decolourized water increased when compared over original. It may be due to the results of more dye uptake by the samples.
- Increased thickness was observed in decolourized water dyed sample than when compared with fresh water dyed samples.
- The strength of all the dyed samples decreased when compared with original
- The increased in elongation of the dyed samples was found to be (36.8%) in YDF, 30.3% in BDF and 45.9% in NDF. 42.6% in YDT, 39.3% in BDT and 37.7% in NDT.
- The fabric stiffness was found to be decreased in all the dyed samples with maximum decrease in BDF.
- Absorbance nature of the decolourized water dyed sample was found to be on par with fresh water dyed sample.
- Samples subjected to colour fastness test exhibited excellent colour fastness properties. Fastness to sunlight, pressing and crocking was rated as good for both the samples.

Conclusion

The present study proved that wheat dust and sugarcane bagasse could be effectively utilized for decolourization of reactive dyes and the decolourized water could be reused. wheat dust and sugarcane bagasse are cheaper easily available material, thus it is a better replacement of activated carbon used in adsorption. Both the material used in the present study are waste products , hence their use as an adsorbents on one hand would solve its disposal problem and on the other hand would provide an effective adsorbent for the removal of reactive dyes.

Scope for further study.

- Decolourization of reactive dyes in effluent could be carried out using agro waste.
- Decolourization of reactive dyes in effluent could be carried out using bacterial and fungal species.

BIBLIOGRAPHY

JOURNALS

- Ali H, (2010), Biodegradation of synthetic dye – a review, Water air soil pollut , Vol.213, No.1, Pp.251-73.
- Argun ME, (2008), Activated of pine cone using fenton oxidation for Cd (II) and pb (II) removal bioresour technol, Vol.99 No.18, Pp.8691-8.
- Asgher M, Bhatti HN, (2012) Evaluation of thermo dynamic and effects of chemical treatments on sorption potential of (citrus) waste biomass for removal of anionic dyes from aqueous solutions, Ecol Eng, Vol.38, No.1, Pp.79-85.
- Azar, S.S., Liew, A.G., Suhardy, D., Hatim, M.D.I., (2005), *Am*. J. Appl. Sci., Vol.2, No.11, Pp. 1499.
- Aziz, N., A.A., Ahamad, B.H., Hameed, (2007), adsorption of direct dye on palm ash: kinetic and equilibrium modelling. J. Hazard, Mater, Vol.141, Pp. 70-76.
- Baek, M.H., Ijagbemi, C.O., se-jin, O., kim, D.S., (2010), Removal of malachite green from aqueous solution using degreased coffee bean, J. Hazard, Mater, Vol.176, Pp. 820-828.
- Bakshi, D.K., Gupta, K.G., Sharma, p.,(1999),Enhanced biodegradation of synthetic textile dye effluent by *phenerochaete chrysoporium* under improved culture, World journal of microbiology and biotechnology Vol.15, Pp.507-509.
- Bekci, Z., seki, Y., cavas, L., (2009), Removal of Malachite green by using an invasive marine alga *caulerpa racemosa var*, Cylindracea, J., Hazard, Mater, Vol.161, Pp. 1454-1460.
- Bradbury, M J., kent, J.J., (1994) Soc dyers colour, Vol.110, P.173.
- Bulut Y, Aydin, H.A., (2006), Kinetics and thermodynamics study of methylene blue adsorption on wheat shells, Desalination, Vol.194, No.1, and Pp.259-67.
- Chen, H.Z., Liu, LY. (2007), unpolluted fractionation of wheat straw by steam explosion and ethanol extraction, Bioresour, Technol, Vol.98, Pp. 666-676.
- Chowdhury, S., chakaramorthy, S., Saha, P., (2011), Biosorption of basic green four from aqueous solution by Ananas Comosus (pineapple) leaf powder, Collaids surf B biointerfaces, Vol. 84, No.2, Pp.520-7.
- Clarke, E., Anliker, R., (1980), Organic dyes and pigments, Hand Environ chem., Vol.3, Pp.181-215.
- Cooper, P., (1995), TG sourthn, in colour in dye house effluent, society of dyes and colourists, Vol.73, Pp.20-25.

- Crini, G., (2006), non conventional low-cost adsorbents for dye removal: a review, bioresour Technol, Vol. 97, No.9, Pp.1061-85.
- Dawood, S., Sen, TK., (2012) 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 Res, Vol.46, No.6, Pp.1933-46.
- Degs, Y., AI, Khrarishes, MAM., Alien, S J., Ahmad, M N., (2000),water Res, Vol.34, P. 927.
- Deniz, F., saygideger, S.D., (2010), Equilibrium, kinetic and thermodynamic studies of acid orange 52 dye biosorption by *Paulownia tomentosa* steud. Leaf powder as a low-cost natural biosorbent, Bioresou, Technol, Vol.101, P. 5137-5143.
- Easton, J.R., cooper,P., (1995), Colour in dye house effluent, society of dyes and colourists, Vol. 9, P.551.
- Eichlerova, I., Homolka, L., Benada, O., Hubalek, T., Nerud, F., (2006), Decolourization of orange G and remozol brilliant blue R by the white rot fungus *Dichomitus squalens*, toxicological evaluation and morphological study,Chemosphere, Vol. 69, Pp. 795-802.
- Fu, Y., Viraraghavan, T., (2002), Removal of congo red from an aqueous solution by fungus (*Aspergillus niger*), Adv Environ Res, Vol.7, No.1, Pp.239-47.
- Ghoreishi, S., Haghighi, R., (2003), Chemical catalytic reaction and biological oxidation for treatment of non-biodegradable textile effluent, Chem Eng J, Vol.95, No.1, Pp.163-9.
- Glower, B., Hill, L., (1993), Text chem, Colour. Vol.25, P.15.
- Gupta, V., (2009), Application of low cost adsorbents for dye removal –a review, J Environ manage , Vol.90, No.8, Pp. 2313- 42.
- Gupta. G., Prasad, G., Singh, V., (1990), Removal of chrome dye from aqueous solution by mixed adsorbents: fly ash and coal, Water Res, Vol.24, No.1, Pp. 45-50.
- Ho, Y.S., Ofomaja, A.E., (2006), Biosorption thermodynamics of cadmium on coconut copra meal as biosorbent, Biochemical engineering journal Vol.30, Pp. 117-123.
- Ibrahim S, (2010), Adsorption of anionic dyes in aqueous solution using chemically modified barley straw, Water Sci Technol .J, Int Assoc water pollut Res, Vol.62, No.5, P.1177.

- Iqbal, M., Saeed, A., Iqbal Zafar, S., (2009), FTIR spectrophotometry. Kinetics and adsorption isotherms modelling, ion- exchange, and EDX analysis for understanding the mechanism of Cd^{2+} and pb^{2+} removal by mango peel waste, Journel of hazardous materials, Vol.164, Pp.161-171.
- Janos, p., coskun,S., pilarova, V., Renjnek, J., (2009), Removal of basic (methylene blue) and acid (egacid orange) dyes from waters by sorption on chemically treated wood shavings, Bioresour, Technol, Vol.100, Pp. 1450- 1453.
- Lazar, T., (2005), color chemistry, synthesis properties and application of organic dye ad pigments, Color Res Appl, Vol.30, No.4, Pp.313-4.
- Lee, C.K., low, K.S., Gan, P., (1999), Removal of some organic dyes by acid treatment spent bleaching earth, Environ technol, Vol.20, Pp. 99-104.
- Lewis, D.J., (1997), Soc dyes colour, Vol.113, Pp.193.
- Lima, E.C., Royer, B., Vaghetti, J.C.P., Simon,N.M., da cunha, B.M., Pavan, F.A., Benvenutti, E.V., Veses, R.C., Airoldi, C., (2008), Application of Brazilian-pine fruit coat as a biosorbent to removal of reactive red 194 textile dye from aqueous solution, kinetics and equilibrium study. J, Hazard. Mater, Vol.155, Pp. 536-550.
- Liu, W., (2012), Kinetics and thermodynamics characteristics of cationic yellow X-GL adsorbtion on attapulgite/ rice hull based activated carbon nano composites Environ prog Sust Energ, Vol. 32, No.3, Pp.655-62.
- Mckay, G., (1982), Colourage, Vol. 29, P.11.
- Metes,S., Papic, N., Koprivanac, (2000),Environ. Technol, Vol. 21, P.97.
- Mishra, G., Tripathy, M.A., (1993), critical review of the treatments for decolourization of textile effluent, Colourage , Vol.40, Pp.35-35.
- Mittal. A., Malviya, A., Kaur, D., Mittal.J., Kurup.L.,(2007), studies on the adsorption kinetics and isotherms for the removal and recovery and recovery of methyl orange from waste water using waste materials. J. Kasard, Mater, Vol.148, Pp. 229-240.
- Nagaeshwar Rao, S., Lathasree, B., Shivasankar, V., Sadasivam, K., Rengaraj. J., (2004), *Environ. Sci*. Eng., Vol.46, No.2, Pp. 172.
- Nandi, B., Goswami, A., purkait, M., (2009), Removal of cationic dyes from aqueous solution by kaolin: kinetic and equilibrium studies, Appl clay Sci , Vol.42, No.(3-4), Pp.583-90.
- Newton, EJ.J., (1993), Soc dyers colour, Vol.109, Pp.138.
- Ogawa, T., Shibata, M., Yatome, C., Odala, E., (1998), Ball Environ contain toxicol, Vol.40, P.545.
- Papic, S., Koprivanac, N., Metes, A.,(2005), *Environ Technol*., Vol.21, Pp. 97.

- Pavan, F.A., Gushikem, Y., Mazzocato, A.S., Dias, S.L.P., Lima, E.C., (2007), Statistical design of experiments as a tool for optimizing the batch conditions to methylene blue biosorption on yellow passion fruit and mandarian peels, Dyes pigm, Vol.72, Pp. 256-266.
- Purkait, M., DasGupta, S., (2005) Adsorbtion of eosin dye on activated carbon and its surfactant based desorption, J Environ manage, Vol.76, No.2, Pp.135-42.
- Rai, H.S., Bhattacharyya, M.S., Singh, J., Bansal, T.K., Vats, P., Banerjee, U.C., (2005), Removal of dye from the effluent of textile and dyestuff manufacturing industry: a review of emerging techniques with reference to biological treatment, Crit, Rev. Env. Sci, Technol, Vol. 35, Pp.219-238.
- Rajeshwari, s., sivakumar, s., senthilkumar, p., subburam, v., (2001), Carbon from cassava peel, an agicultural waste, as an adsorbent in the removal of dyes and metal ions from the aqueous solution. bio resources techno, Vol. 80, No.3, Pp. 233-35.
- Ranjan, D., Talat, M., Hassan, S.H., (2009), Biosorption of arsenic from aqueous solution using agricultural residue 'rise polish'. Journal of hazardous materials, Vol.166, Pp.1050-1059.
- Salleh, MAM. (2011), Ationic and anionic dye adsorption by agricultural solid wastes: comprehensive review desalination, Vol.280, No. 1, Pp. 1-13.
- Sandra, J.C., Lonnie, R.B., Donna, F.K., Daniel, R.D., Louies, T., Frederick A.B., (1999), toxicity and metabolism of malachite green and leuco malachite green during short- term feeding to fisher 344 rates and B6C3F1 mice, Chem.-biol, Inract , Vol.122, Pp. 153-170.
- Saratale, R.G., Saratale G.D., Chang, J, S., Gowindwar, S.P., (2009), Decolourization and biodegradation of textile dye navy blue HER by trichosporon beigelii NCIM-3326.J.Hazard. Mater, Vol.166, Pp.1421-1428.
- Selen, M.A.G.U, de souza, peruzzo, L.C., de souza, Antonio, A.U., (2008), Numerical study of the adsorption of dyes from textile effluent. Appl. Maths. Model, Vol.32, Pp.1711-1718.
- Sen, TK., Afroze, S., Ang, H., (2011), Equilibrium, kinetics and mechanism of removal of methylene blue from aqueous solution by adsorption onto pine cone biomass of *pinus radiate*. Water air soil pollut , Vol.218, Pp. 499-515.
- Sharma, N., Kaur, S., (2009), Kinetic and equilibrium study on the removal of cd^{2+} ions from water using polyacrylamide grafted rice (*oryza sativa*) husk and (*tectona grandis*) saw dust journal of hazarders materials, Vol.163, Pp. 1338- 1344.

- Sokolowska, Gajda, (1996), Synthetic dyes based on environmental considerations. Dye pigment, Vol.30, No.1, Pp.1-20.
- Srinivasan, A., Veraraghavan, T., (2010), Decolourization of dye waste water by biosorbents: a review.J Environ manage, Vol.91, No 10, Pp.1915-29.
- Sud, D., Kaur, M.P., (2008), Agricultural waste material as potential adsorbent for sequestering heavy metal ions from aqueous solution –a review. Bio resource technology, Vol.99, Pp. 6017-6027.
- Thampi, J., Paul, R., (1997), Colourage, Vol.44, P.47.
- Valix, M., W.H., Cheng, G., McKay, (2006), *Langmuir*, Vol. 22, P.4574.
- Vandevivere, p.c., Bianchi, R., Verstraere, W., (1998), Treatment and reuse of waste water from the textile wet-processing industry: review of emerging technologies. J. Chem Technol, Biotechnol, Vol.72, Pp.289-302.
- Vimonses, V., (2009), kinetic study and equilibrium isotherm analysis of congo red adsorption by clay materials. Chem Eng J, Vol.148, No.2, Pp. 354-64.
- Volesky, B., (2007), Biosorption water research, 41, 4017-4029.
- Wang Y, S., Boyjoo, A., Choueib, Z.H., Zhu, (2005), water *res.,* Vol.39, P.129.
- Wong Y, (2004), Adsorption of acid dyes on chitosan-equlibrium isotherm analyses. Process Biochem, Vol.39, No.6, Pp. 695-704.
- Yagub, M.T., Sen, TK., Ang, H, (2012), Equilibrium, kinetics, and thermodynamics of methylene blue adsorption by pine tree leaves. Water air soil pollut , Vol.223, No.8, Pp. 5267-82.
- Yang, Y., and Shiqi, I., (1997), Text Res J, Vol.64, P. 433
- Zhang, J., Zhou, Q., ou, L., (2012), kinatic, isotherm, and thermodynamic studies of the adsorption of methyl orange from aqueous solution by chitoan/ alumina composite J chem, Eng Data, Vol.67, No.412-9.
- Zolgharnein, J., sharmoradi, A., (2010) a, Adsorption of Cr(VI) onto *Elaeagus* tree leaves; statistical optimization, equilibrium modelling and kinetic studies journal of chemical engineering Data Vol.55, Pp.3428-3437.
- Zollenger.H., (1991), Colour chemistry: synthesis, properties and application of organic dyes and pigment, second reviced ed. VHC, Weinheim.Vol.150, Pp. 774-782.

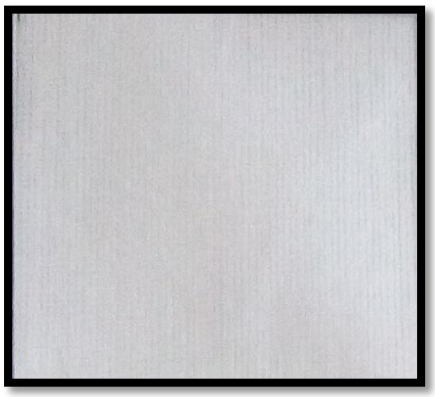
WEB REFERENCE

- Renovation and Reuse of Reactive Dyeing Effluent by a Novel Heterogeneous Fenton System Based on Metal Modified PTFE Fibrous Catalyst/H_2O_2 Bing Li,[1] Yongchun Dong,[1,2] Zhizhong Ding,[2] Yiming Xu,[1] and Chi Zou[1] . http://dx.doi.org/10.1080/0959333208616798

- International Journal of Photoenergy Volume 2013 (2013), Article ID 169493, 10 pages. http://dx.doi.org/10.1155/2013/169493

APPENDIX 1

ORIGINAL AND DYED FABRIC SAMPLES



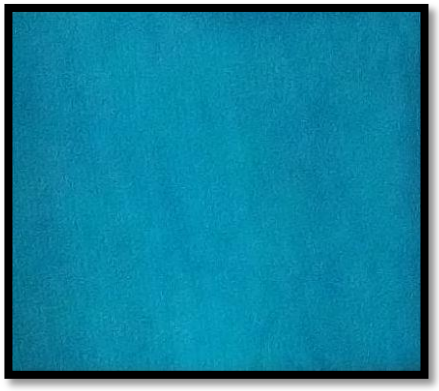
a,Original sample

b, Fabric dyed with reactive dye yellow R using fresh water

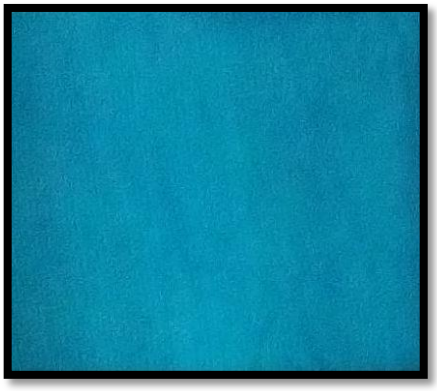
c, Fabric dyed with reactive dye yellow R using decolourized water

APPENDIX 1

ORIGINAL AND DYED FABRIC SAMPLES



d, Fabric dyed with reactive dye T Blue G using fresh water



e, Fabric dyed with reactive dye T Blue G using decolourized water

f, Fabric dyed with reactive dye navy blue GDB using fresh water

g, Fabric dyed with reactive dye navy blue GDB using

APPENDIX 2

UV SPECTRAL ANALYSIS

Overlay Spectrum Graph Report

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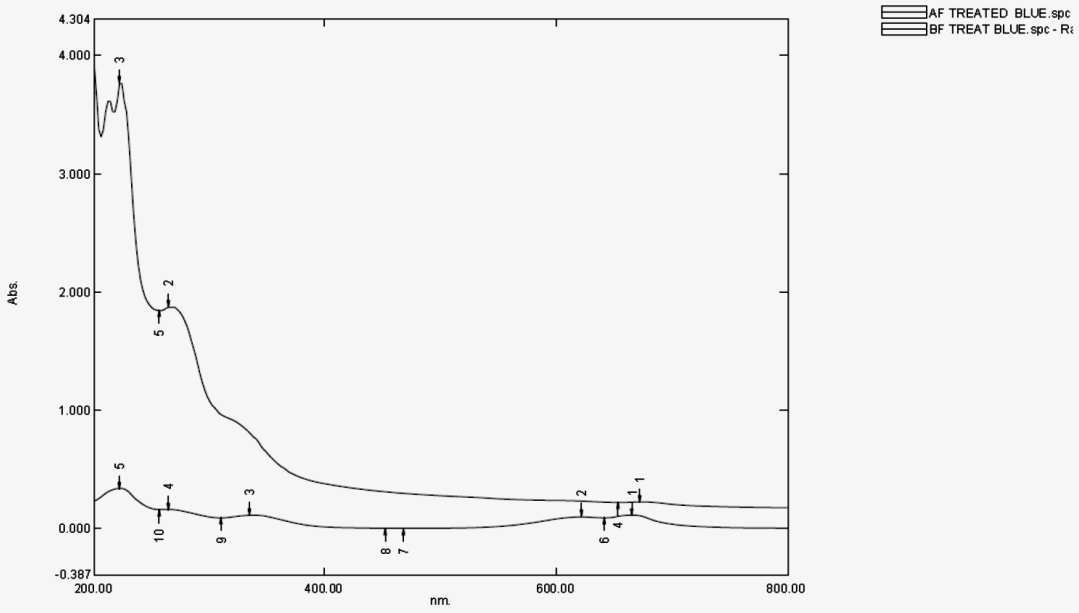

Page 1 / 1

Overlay Spectrum Graph Report

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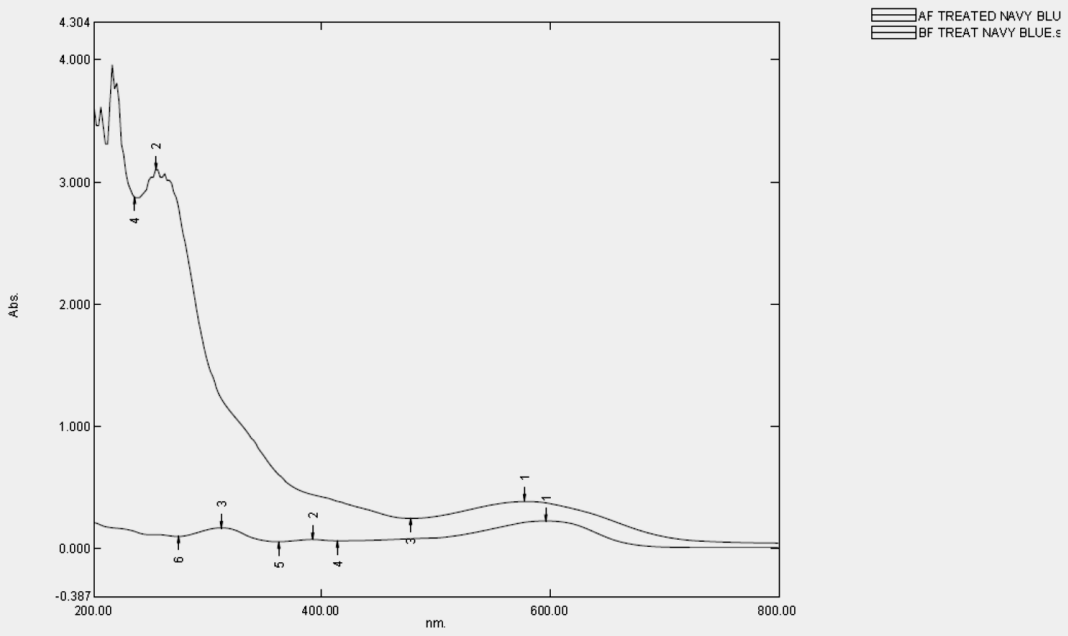
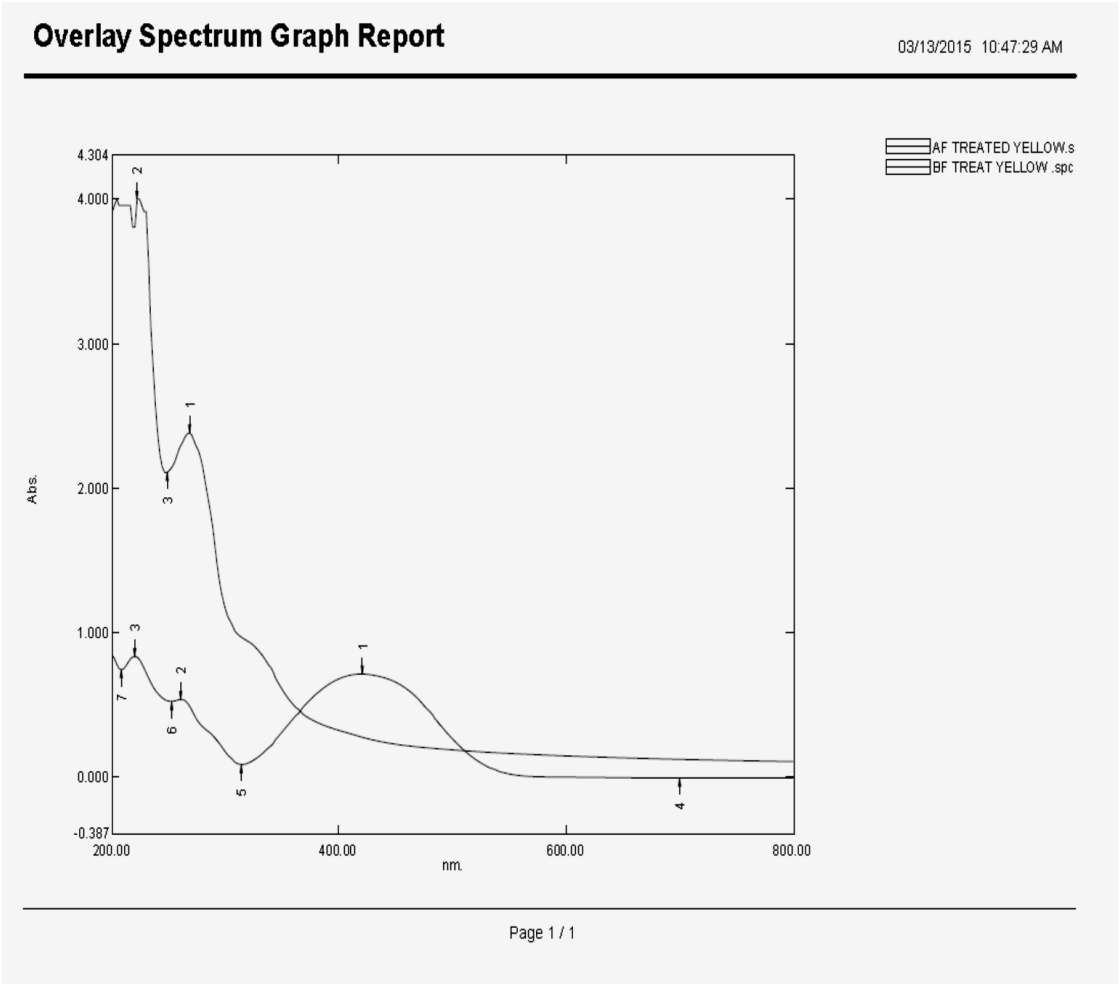
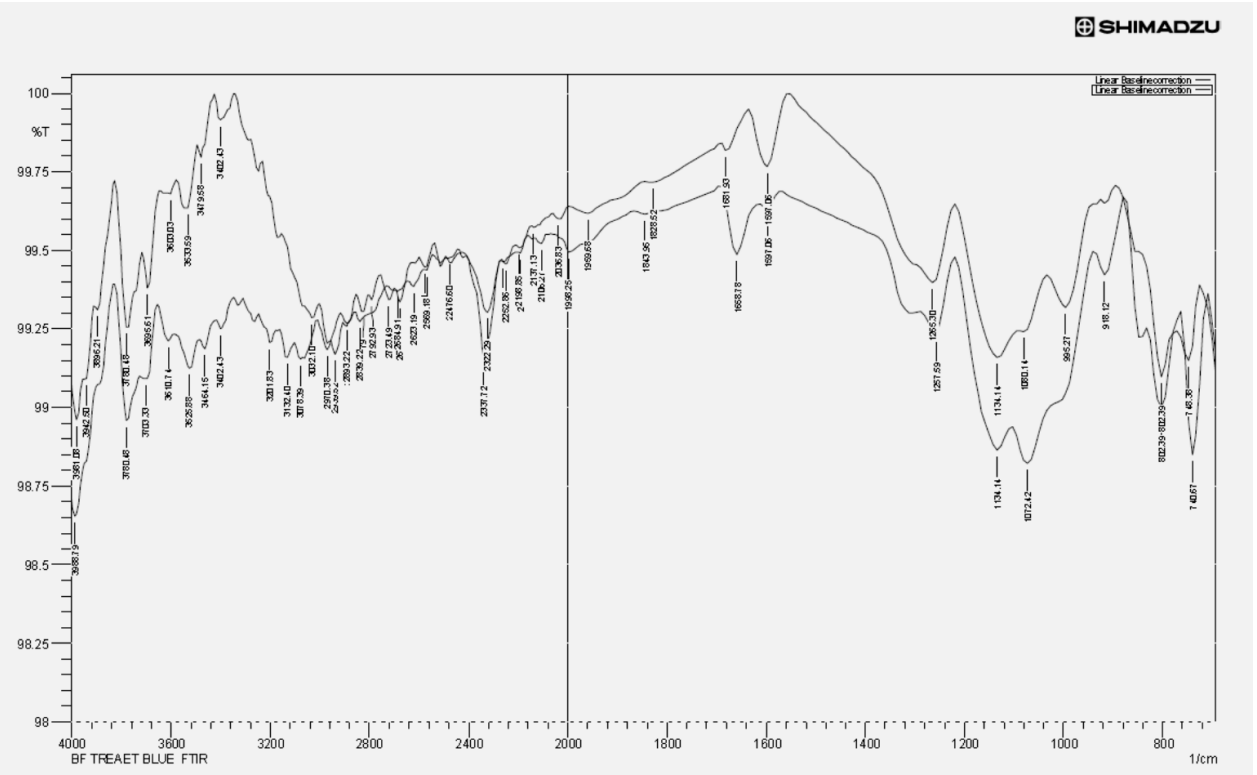


Page 1 / 1



APPENDIX 3

FTIR ANALYSIS



Comment;
AF TREAET BLUE FTIR
BF TREAET BLUE FTIR

No. of Scans;
Resolution;
Apodization;

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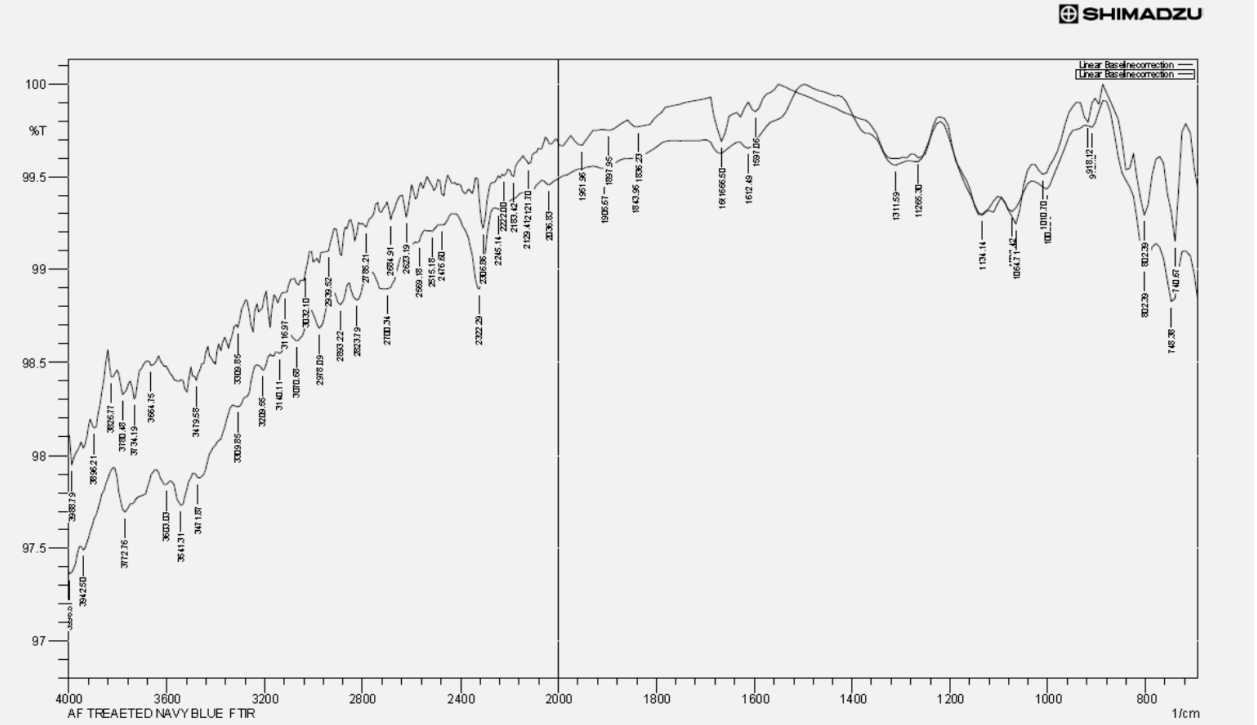

Comment;
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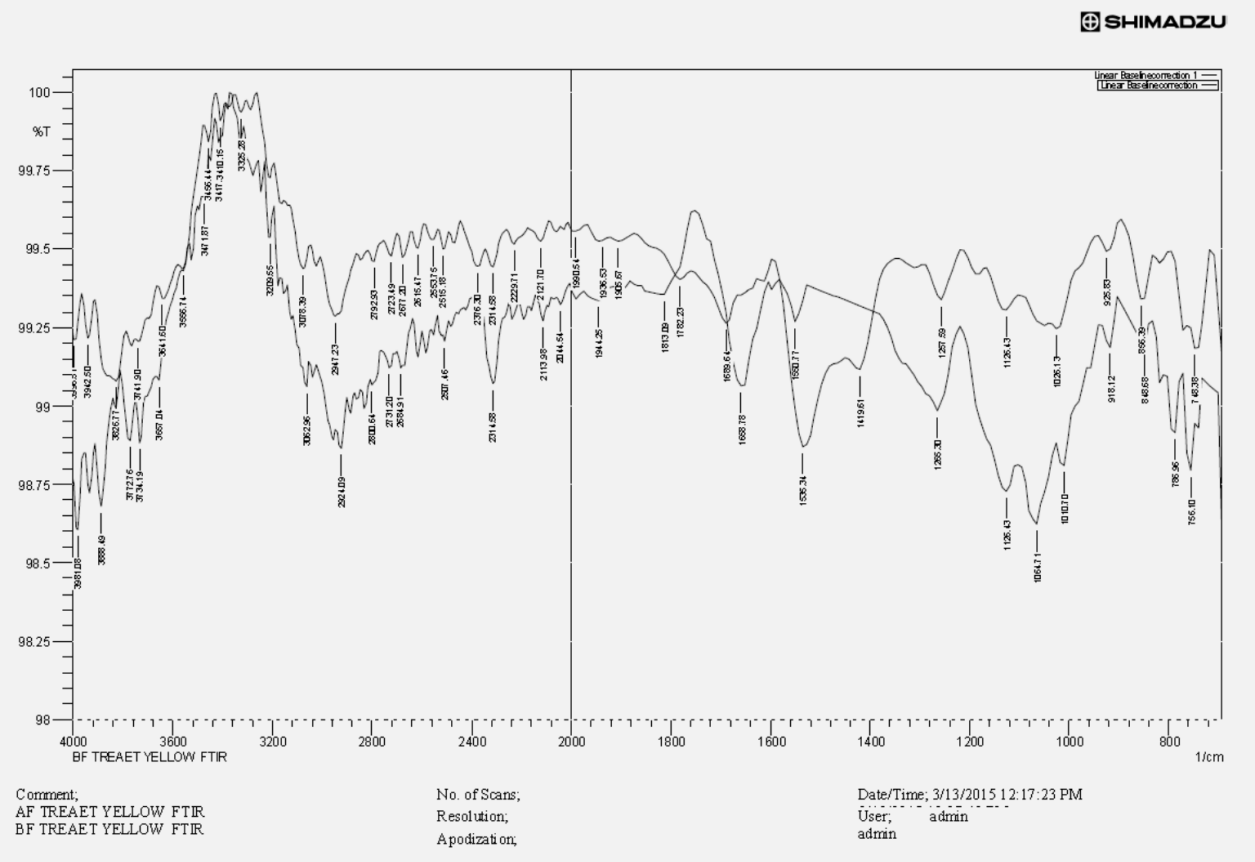
AF TREAETED NAVY BLUE FTIR

No. of Scans;
Resolution;
Apodization;

Date/Time; 3/13/2015 12:35:52 PM
User; admin
admin


SHIMADZU
Linear Baseline correction 1
Linear Baseline correction
%T
100
99.75
99.5
99.25
99
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98
4000
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
1/cm
BF TREAET YELLOW FTIR
Comment;
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BF TREAET YELLOW FTIR
No. of Scans;
Resolution;
Apodization;
Date/Time; 3/13/2015 12:17:23 PM
User; admin
admin