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Comparative Study of Exhaustion and Fixation Behavior of Mono-Functional and Bi-Functional Reactive Dye on Cotton Knitted Fabric

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Abstract

Reactive dyes are the most common dyes utilized in the dyeing of cotton; these still cause significant environment concerns for the textile industry. Waste water treatment of pollutants from dyeing is difficult to conduct economically. One method to reduce residual color in wastewater is to increase exhaustion and fixation values of dyes. Increasing the exhaustion and fixation not only decrease the level of color in the effluent but the application will require lower levels of electrolytes, with an associate reduction of aquatic toxicity of effluent. In this study, the exhaustion of the two structural of reactive dyes was used one is mono-functional and another is bi-functional. It is supposed to find the effect of functional groups on exhaustion and fixation behavior of reactive dyes on cotton substrate in terms of physical and chemical analysis. It has been assessed using Isothermal dyeing experiments. Isothermal exhaustion experiments were conducted on the two dye types at same temperatures and electrolyte concentration. Bi-functional dyes (DCT, VS) had a greater exhaustion on cotton than the corresponding mono-functional dyes (VS). Laboratory dyeing experiments were conducted on the commercial mono-functional and bi-functional dyes. These experiments included an assessment of the effects of time. The fixation of yellow dye is higher than red dye. Exhaustion and fixation behavior of mono-functional reactive dye is lower than bi-functional reactive dye for yellow colorant. But only fixation behavior of yellow dye is lower than red dye.

Keywords: *Exhaustion, Fixation, Mono-functional, Bi-functional, K/S value etc.*

Introduction

Cellulose is the most abundant naturally occurring polymer. Cellulose has proven useful as a raw material for many industrial products. The textiles industry uses many types of cellulosic materials: Cotton, Flax, Hemp, Jute and regenerated cellulosic fibres such as Rayon, Tencel & Lyocell [01]. In recent years, reactive dyes have been most commonly used the reactive dyes are the best for cotton for its wide range of application and better fastness properties [2]. There for 50% of cellulosic fibers are dyed with reactive dyes. Share of reactive dyes among all textile dyes is 29%. Due to their strong interaction with many surfaces of synthetic and natural fabrics, reactive dyes are used for dyeing wool, cotton, nylon, silk, and modified acrylics [3-4]. Reactive dyes typically form covalent ether linkages between the dye and the substrate when subjected to the proper conditions. These covalent bonds produce dyeing with very high wet fastness properties. Since the development of reactive dyes, there have been several useful review papers pertaining to their development, application and usage [05]. In 1957, Hoechst brought their vinyl sulphone reactive dyes for cellulose to the market. These dyes formed covalent bonds with cellulose in a different manner than the mono and dichlorotriazine reactive dyes. Like the triazines, Remazol dyes react with cellulose and form a cellulose ether [06].

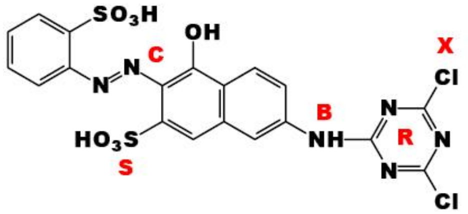

Figure-3: Generic structure of a fiber reactive dye.

The molecular structure of reactive dyes (Figure-3) consists of a chromogen (C) with solubilizing groups (S), a bridging group (B), a reactive group (R) and a leaving group (X). The reactive groups are capable of reacting with Nucleophilic groups (NH_2, -SH, and –OH) in textile fibers by addition or substitution reactions.

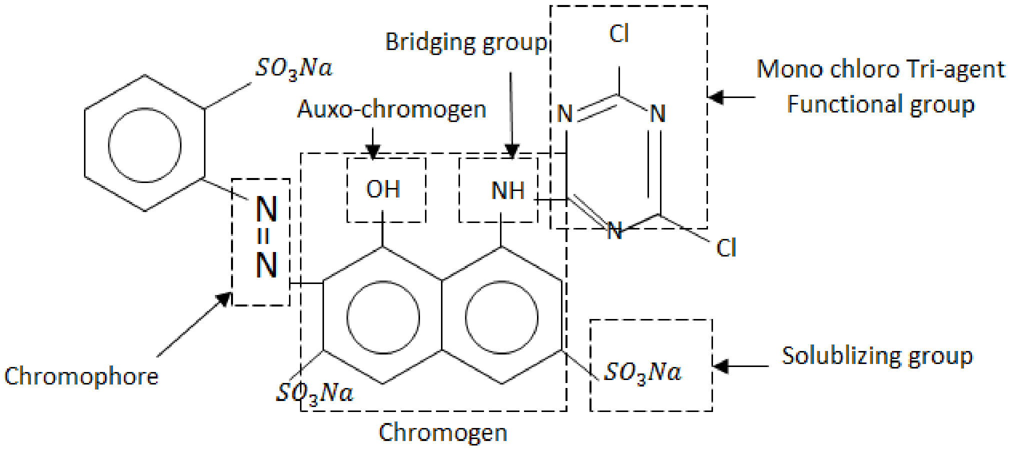

Figure-4: CI Reactive Red 1.

The chromogen a conjugated system containing one or more chromophores provides the color. The bridge separates the reactive group from the chromogen. The bridge prevents the color generated by the chromogen from changing once the chromogen is attached to the reactive group [07]. The general structure of reactive dye is as below [08]. Here, X is D-B-G and D = Dye part or color producing chromogen part, B = Bridging Part, G = Reactive group bearing part, X = Reactive group. For example; the reactive site of the dyes reacts with functional group on fiber under influence of heat and alkali [9]. Textile industry involves wide range of raw materials and processes to engineer the required shape and properties of the final product. Out of various activities in textile industry, chemical processing contributes about 70% of pollution [10]. Waste stream generated in this industry is essentially based on water-based effluent generated in the various activities of wet processing of textiles. The main cause of generation of this effluent is the use of huge volume of water either in the actual chemical processing or during re-processing in preparatory, dyeing, printing and finishing [11]. Gray fabrics, after its manufacturing, are subjected to several wet processes such as pretreatment process involving demineralization, scouring, bleaching and mercerization etc. The pretreated fabric is then dyed using textile dyes and finished by softener padding. The pretreatment and dying process results in large volume of effluent that has harmful effect on environment [12]. This is because dyes have a synthetic origin and a complex molecular structure which makes them more stable and difficult to be biodegraded [13]. Therefore exhaustion and fixation of various dye on fabric has a vital role to prevent the environment pollution. This research focused on the development of an optimal dye application process for a series of new homo bi-functional fiber reactive dyes. The results indicated that the Bi-functional reactive dyes had greater in affinity for cotton than the corresponding Mono-functional fiber reactive dyes. Further work in this area should focus on dyeing utilizing the Bi-functional reactive dyes on production scale dyeing equipment. With the large scale dyeing it would be possible to reevaluate the physical properties, after conducting on a more uniform washing procedure.

Materials and method

The fabric which was used for experiment that was Single jersey 100% cotton knitted with well scoured and bleached fabric and GSM 150. Two types of functional group of reactive dyes were used. They are BEZAKTIV YELLOW V-2R and BEZAKTIV RED V-3N as mono-functional dyes. The BEZAKTIV YELLOW S-3R and BEZAKTIV RED 150% S-3B are as bi-functional dyes. The name of the Company of dyestuff is BEZEMA which origin in Switzerland. Gluber Salt was used as electrolyte. Same concentration of electrolyte was used during the dyeing process without further treatment and that was 20 g/l. Sodium Carbonate was used as alkali. Same concentration of alkali was used during the dyeing process without further treatment and that was 10 g/l. After dyeing, for the measurement of fixation Felson NOF was used as washing agent without further treatment. The concentration of Felson NOF was 1g/l. IR sample Dyeing Machine, Hot Air Dryer, Electric Balance, Spectrophotometer are used for testing. Stock solution preparation: 1% stock solution was prepared. For this 1gm dyes was added to 100 cc of water. Salt and alkali was added as solid state by Isothermal Process. Exhaustion is define as the mass of dye taken up by the material divided by the total initial mass of dye in the bath, for a bath of constant volume [8]. Exhaustion can be measured by methods- Measurement of concentration of dye solution and Amount of dye present in fiber in respect of time.

Exhaustion process in presence of electrolyte

Dyes-1%, Salt- 20 g/L, Material: Liquor-1:20 and Temperature-60^{0}C are used. These experiments were conducted using an IR laboratory dyeing machine with a liquor ratio of 1:20 for the every dye. The initial dye baths were set up for 1.0% (owf) dyes. Initially 39 ml soft water was added to each IR tube. Then, 1 cc of concentrated dye solution was added to each tube via a 5 ml burette. Two gram of cotton sample was loaded into dye bath. Then salt were added to the dye bath. The tubes were then placed into the IR dyeing machine at a temperature of 30°C. The temperature was increased to 60°C at the maximum rate of rise and held for 5 min. Then the dye bath is run for first is 5 minute and successively for second, third ,fourth , fifth , six , seven ,eight , nine , ten is 15, 20 ,25 ,30 ,35 ,40 ,45 ,50 .The baths were then cooled to the desired dyeing temperature at 30°C,the maximum rate of cooling and held for 5 minutes. Then the dye bath is drain and the sample was squeezed by hand. Then the sample was dried by the hot air dryer. Finally the exhaustion was measured by spectrophotometer in terms of K/S value.

Exhaustion process in presence of alkali

Dyes-1%, Salt-20 g/l, Soda-10 g/l, Material: Liquor-1:20 and Temperature-60^{0}C are used. These experiments were conducted using an IR laboratory dyeing machine with a liquor ratio of 1:20 for the every dye. The initial dye baths were set up for 1.0% (owf) dyes. Initially78 ml soft water was added to each IR tube. Then, 2 cc of concentrated dye solution was added to each tube via a 5 ml burette. Four (two pieces of 2 gram each) gram of cotton sample were loaded into dye bath. Then salt and soda were added to the dye bath. The tubes were then placed into the IR dyeing machine at a temperature of 30°C. The temperature was increased to 60°C at the maximum rate of rise and held for 5 min. Then the dye bath is run for first is 5 minute and successively for second, third ,fourth , fifth , six , seven ,eight , nine , ten is 15, 20 ,25 ,30 ,35 ,40 ,45 ,50 .The baths were then cooled to the desired dyeing temperature at 30°C,the maximum rate of cooling and held for 5 minutes. Then the dye bath is drain and the sample was squeezed by hand. Then the sample was dried by the Hot air dryer. Finally the exhaustion was measured by spectrophotometer in terms of K/S value.

Fixation process

The amount of dye (g/l) presence in the fibre after washing unless color bleeds. These experiments were conducted using an IR laboratory dyeing machine with a liquor ratio of 1:20 for the every dye. The initial dye baths were set up for 1.0% (owf) dyes. Initially 78 ml soft water was added to each IR tube. Then, 2 cc of concentrated dye solution was added to each tube via a 5 ml burette. Four (two pieces of 2 gram each) gram of cotton sample were loaded into dye bath. Then salt and soda were added to the dye bath. The tubes were then placed into the IR dyeing machine at a temperature of 30°C. The temperature was increased to 60°C at the maximum rate of rise and held for 5 min. Then the dye bath is run for first is 5 minute and successively for second, third ,fourth, fifth , six , seven ,eight , nine , ten is 15, 20 ,25 ,30 ,35 ,40,45 ,50 .The baths were then cooled to the desired dyeing temperature at 30°C,the maximum rate of cooling and held for 5 minutes. Then the dye bath is drain and the sample was squeezed by hand. Then the sample was dried by the Hot air dryer. Then the second, fourth, sixth, eighth and tenth sample were taken for washing by Felson NOF. Finally the fixation was measured by spectrophotometer in terms of K/S value. At the end of the dyeing process the fabric samples were washed by Felson NOF at 90°C for 3 min. Then the sample is cold washed by hand and then dried the sample by Hot air dryer.

Measurement of K/S Value

To obtain K/S data, the fabric samples from equilibrium and laboratory dyeing procedures were dried and pressed with an iron set on medium high. The samples were then analyzed using a Data color Spectra flash SF600X instrument equipped with SLI-Form software. Then obtain K/S verses Wave Length graph from Data color machine. The maximum K/S value was recorded for each fabric sample.

Recipe

Mono-functional reactive dye: Sample weight-2 gm, BEZAKTIV YELLOW V-2R-1%, BEZAKTIV RED V-3N-1%, Salt-20 g/L, Material: Liquor-1:20 and Temperature-60^{0}C.
Bi-functional reactive dye: Sample weight-2 gm, BEZAKTIV YELLOW S- 3R-1%, BEZAKTIV RED 150% S- 3B-1%, Salt-20 g/L, Material: Liquor-1:20 and Temperature-60^{0}C.
Mono-functional reactive dye: Sample weight-4 gm (two pieces of 2 gram each), BEZAKTIV YELLOW V-2R-1%, BEZAKTIV RED V-3N-1%, Salt-20 g/L, Soda-10 g/L, Material: Liquor-1:20 and Temperature-60^{0}C.
Bi-functional reactive dye: Sample weight: 4 gm (two pieces of 2 gram each), BEZAKTIV YELLOW S- 3R-1%, BEZAKTIV RED 150% S- 3B-1%, Salt-20 g/L, Soda-10 g/L, Material: Liquor-1:20 and Temperature-60^{0}C.

Result and discussion

Color strength (Exhaustion) analysis in presence of electrolyte

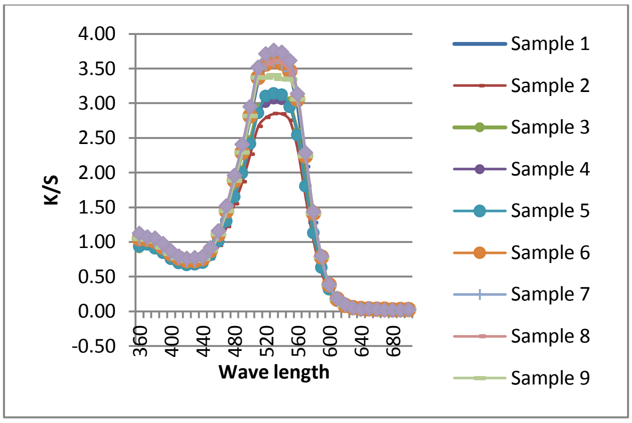

Figure-5: BEZAKTIV RED V-3N (Mono-functional).

The rate of exhaustion at first 5 minutes is 3.61.Then it is decreases up to 25 minutes. Then remain the same for about next 15 minutes. Again increases up to 50 minutes with some fluctuation and the corresponding K/S value is 3.76.Here the rate of exhaustion increases with the time. So it is difficult to make a decision. For this further investigation can be carried out. The rate of exhaustion against the time is plotted in the column chart.

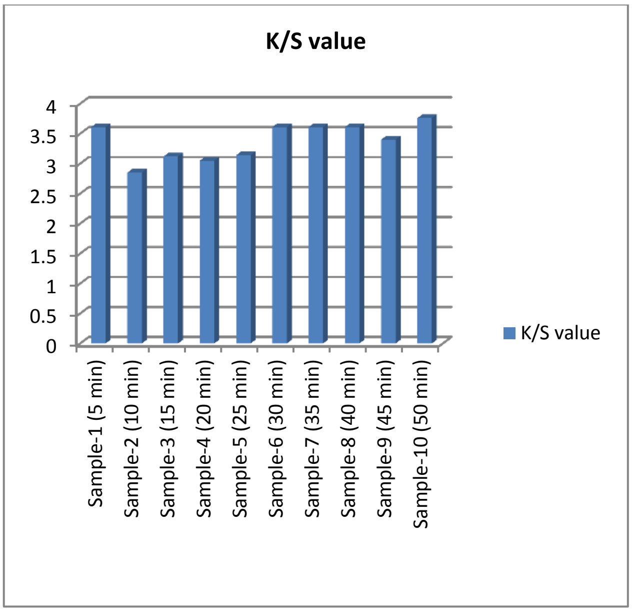

Figure-6: Column chart of BEZAKTIV RED V-3N (Mono-functional)

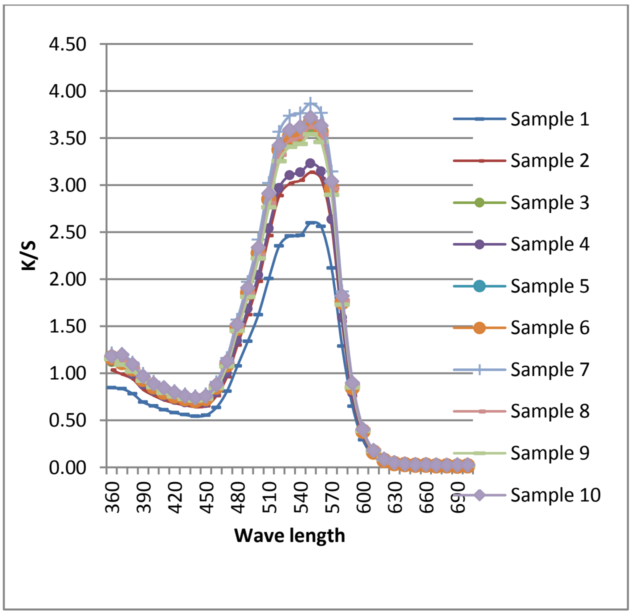

Figure-7: BEZAKTIV RED 150% S-3B (Bi-functional).

The rate of exhaustion at first 5 minutes is 2.60. Then increases up to 35 minutes with some fluctuation and the corresponding K/S value is 3.87. Then it is decrease up to 50 minutes. The rate of exhaustion against the time is plotted in the column chart.

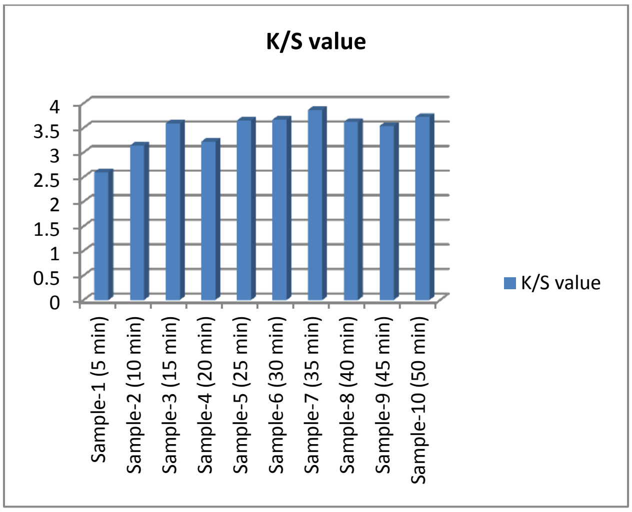

Figure-8: Column chart of BEZAKTIV RED 150% S-3B (Bi-functional).

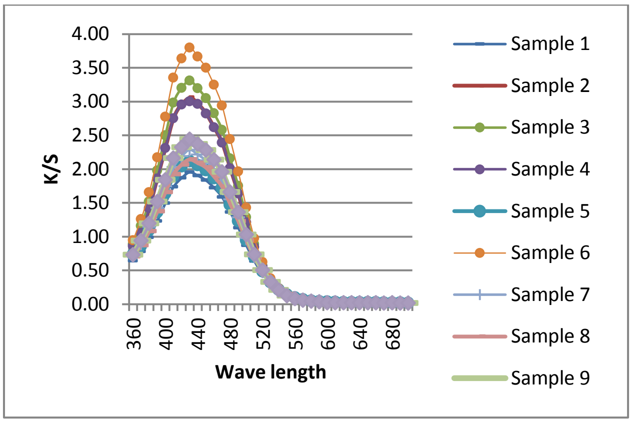

Figure-9: BEZAKTIV YELLOW V-2R (Mono-functional).

The rate of exhaustion at first 5 minutes is 1.95. Then increases up to 30 minutes with some fluctuation and the corresponding K/S value is 3.80. Then it is decrease up to 50 minutes. The rate of exhaustion against the time is plotted in the column chart.

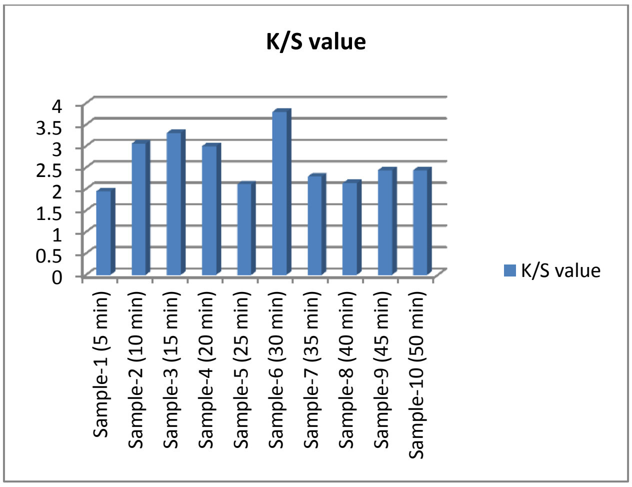

Figure-10: Column chart of BEZAKTIV YELLOW V-2R (Mono-functional)

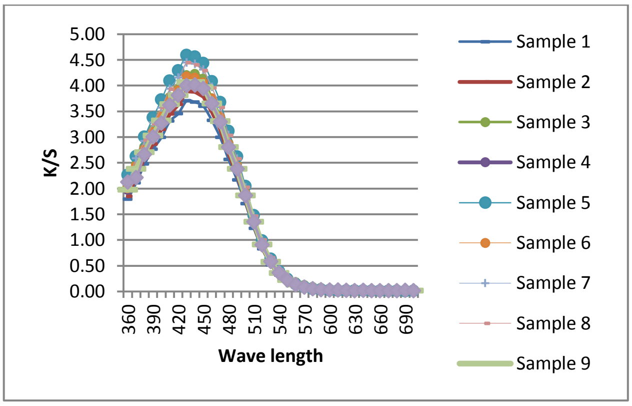

Figure-11: BEZAKTIV YELLOW S-3R (Bi-functional)

The rate of exhaustion at first 5 minutes is 3.70. Then increases up to 25 minutes with some fluctuation and the corresponding K/S value is 4.59. Then it is decrease up to 50 minutes with some fluctuation. The rate of exhaustion against the time is plotted in the column chart.

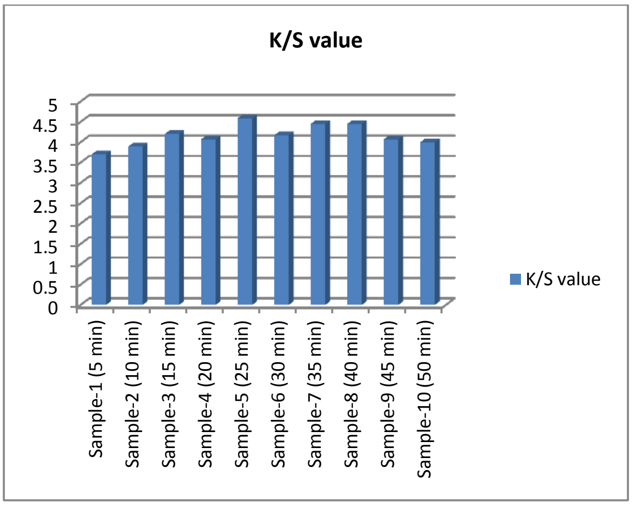

Figure-12: Column chart of BEZAKTIV YELLOW S-3R (Bi-functional)

Color strength (Exhaustion) analysis in presence of alkali

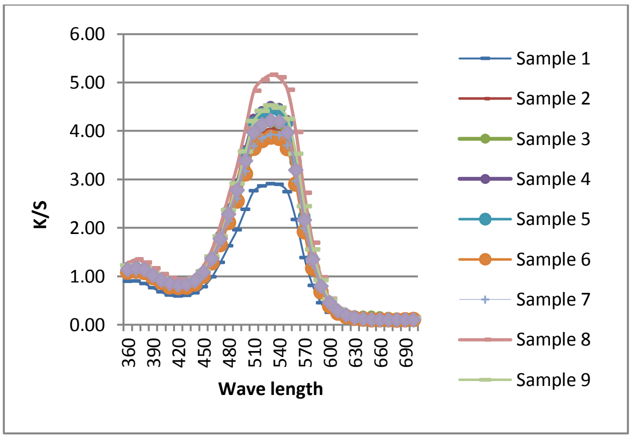

Figure-13: BEZAKTIV RED V-3N (Mono-functional)

The rate of exhaustion at first 5 minutes is 2.90. Then increases up to 40 minutes with some fluctuation and the corresponding K/S value is 5.15. Then it is decrease up to 50 minutes with some fluctuation. The rate of exhaustion against the time is plotted in the column chart.

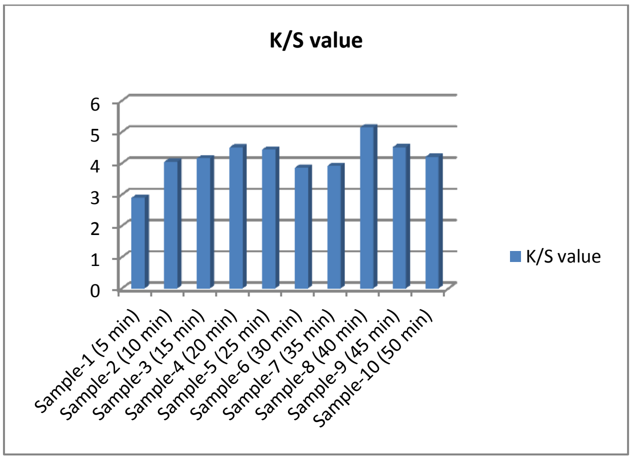

Figure-14: Column chart of BEZAKTIV RED V-3N (Mono-functional)

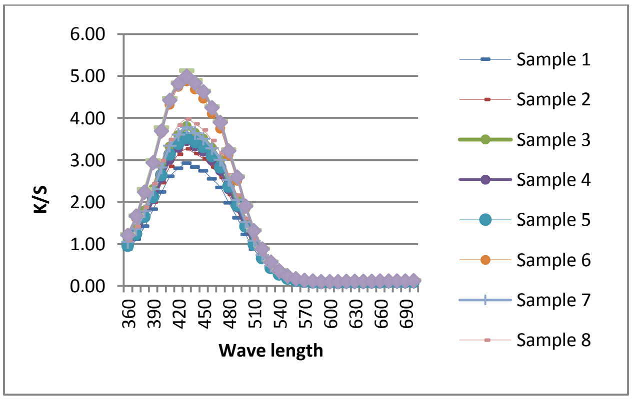

Figure-15: BEZAKTIV YELLOW V-2R (Mono-function)

The rate of exhaustion at first 5 minutes is 2.92. Then increases up to 45 minutes with some fluctuation and the corresponding K/S value is 5.12. Then it is decrease up to 50 minutes. The rate of exhaustion against the time is plotted in the column chart.

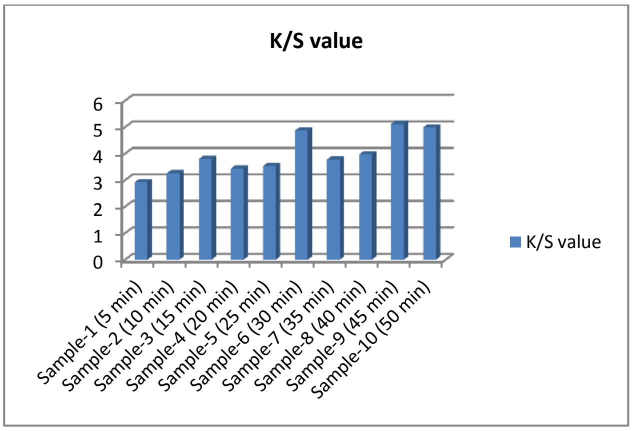

Figure-16: Column chart of BEZAKTIV YELLOW V-2R (Mono-function)

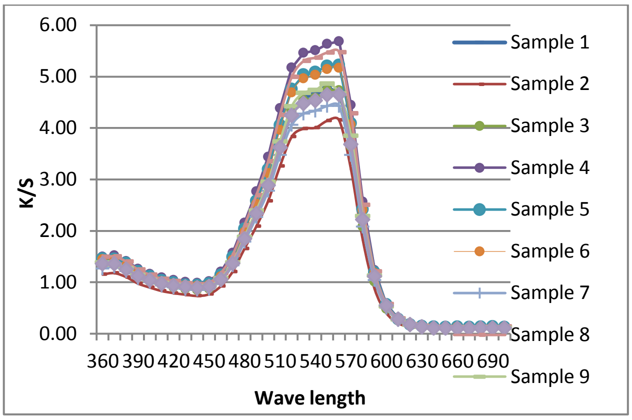

Figure-17: BEZAKTIV RED 150% S-3B (Bi-functional)

The rate of exhaustion at first 5 minutes is 4.79.Then decreases for the second 5 minutes. Then increases up to 20 minutes and the corresponding K/S value is 5.63. Then it is decrease up to 50 minutes with some fluctuation. The rate of exhaustion against the time is plotted in the column chart.

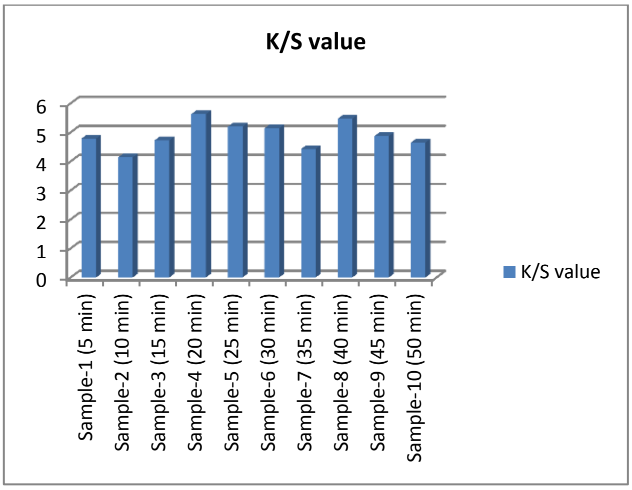

Figure-18: Column chart of BEZAKTIV RED 150% S-3B (Bi-functional)

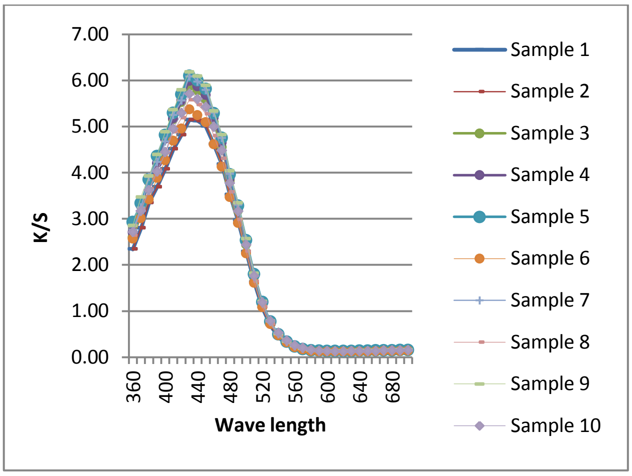

Figure-19: BEZAKTIV YELLOW S-3R (Bi-functional)

The rate of exhaustion at first 5 minutes is 5.14. Then increases up to 45 minutes with some fluctuation and the corresponding K/S value is 6.17. Then it is decrease up to 50 minutes. The rate of exhaustion against the time is plotted in the column chart.

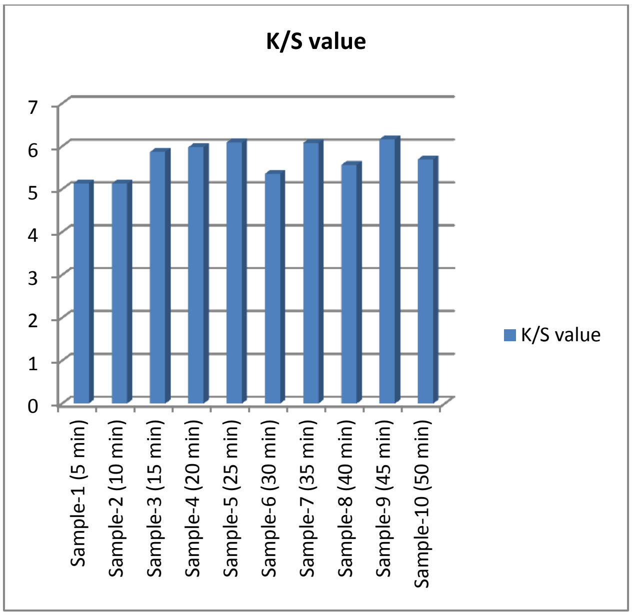

Figure-20: Column chart of BEZAKTIV YELLOW S-3R (Bi-functional)

Color strength (fixation) analysis

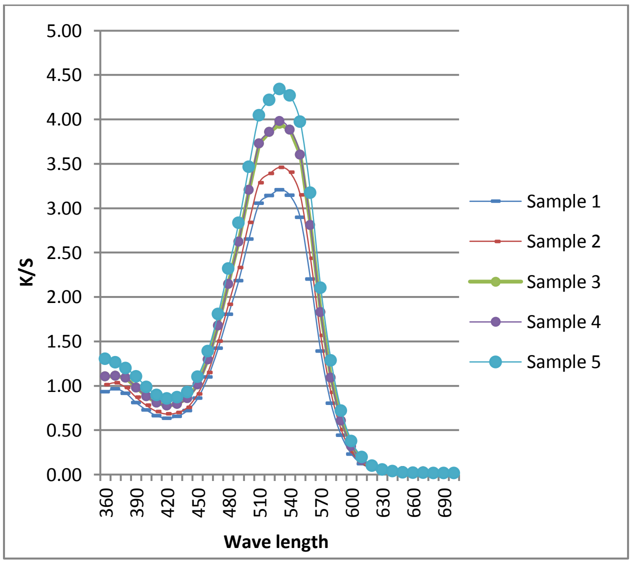

Figure-21: BEZAKTIV RED V-3N (Mono-functional).

The rate of fixation at first 10 minutes is 3.21. Then it is increase up to 50 minutes and the corresponding K/S value is 4.34. Here the rate of fixation increases with the time. So it is difficult to make a decision. For this further investigation can be carried out. The rate of fixation against the time is plotted in the column chart.

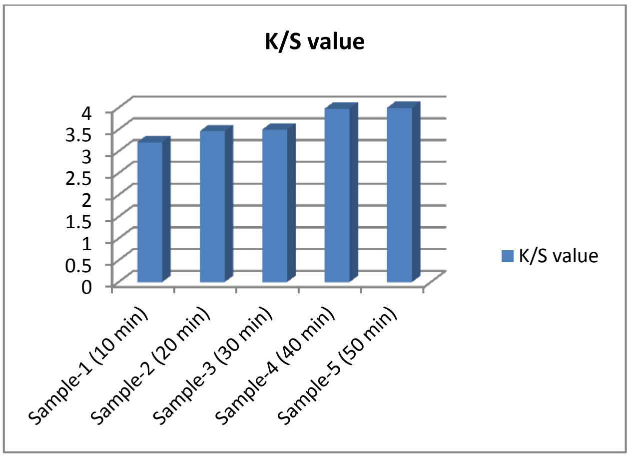

Figure-22: Column chart of BEZAKTIV RED V-3N (Mono-functional)

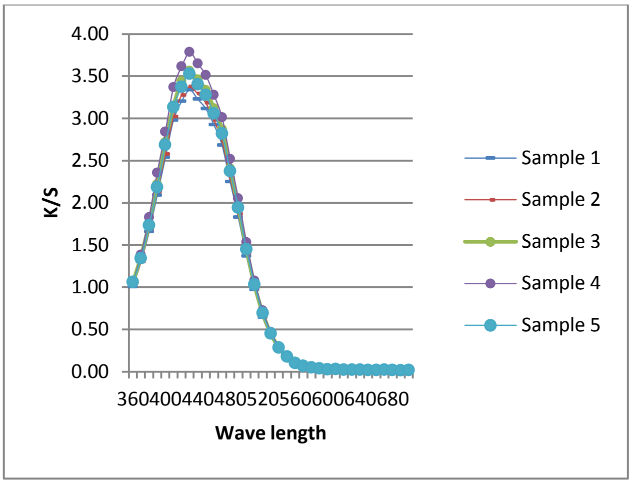

Figure-23: BEZAKTIV YELLOW V-2R (Mono-functional)

The rate of fixation at first 10 minutes is 3.00. Then it is increase up to 40 minutes and the corresponding K/S value is 3.78. Again decrease up to 50 minutes. The rate of fixation against the time is plotted in the column chart.

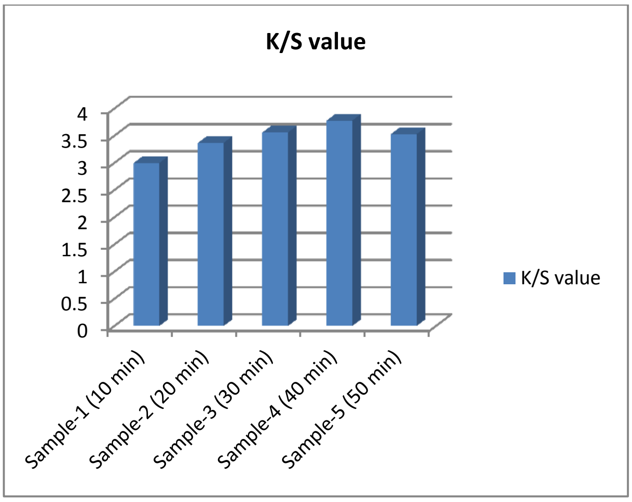

Figure-24: Column chart of BEZAKTIV YELLOW V-2R (Mono-functional)

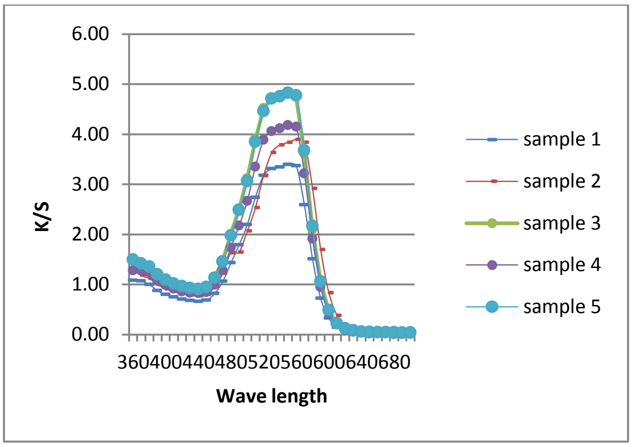

Figure-25: BEZAKTIV RED 150% S-3B (Bi-functional)

The rate of fixation at first 10 minutes is 3.40. Then it is increase up to 20 minutes and the corresponding K/S value is 3.84. Again decrease up to 50 minutes with some fluctuation. The rate of fixation against the time is plotted in the column chart.

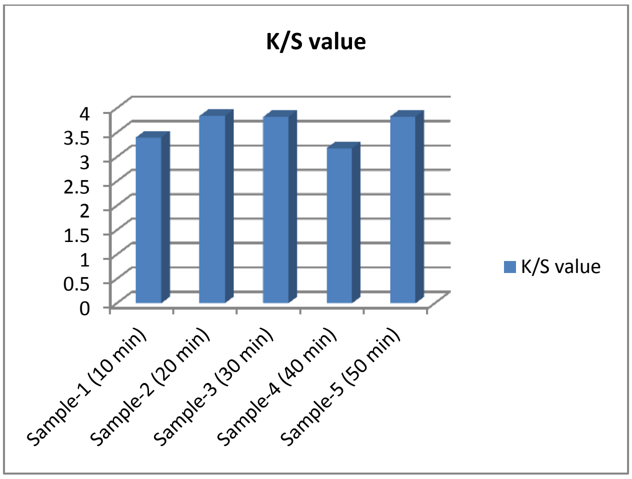

Figure-26: Column chart of BEZAKTIV RED 150% S-3B (Bi-functional)

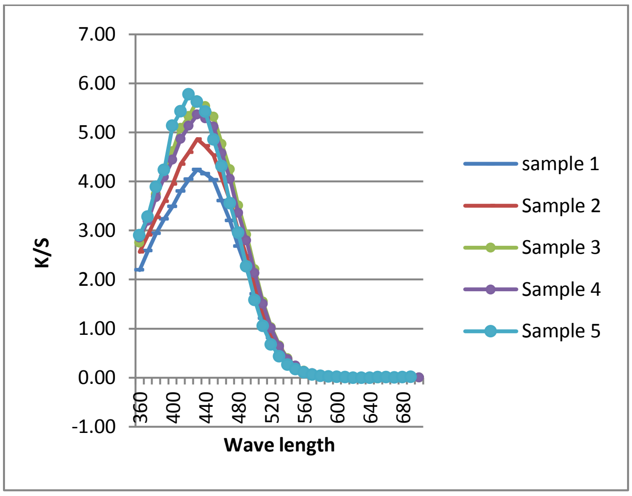

Figure-27: BEZAKTIV YELLOW S-3R (Bi-functional)

The rate of fixation at first 10 minutes is 4.24. Then it is increase up to 50 minutes with some fluctuation and the corresponding K/S value is 5.50. Here the rate of exhaustion increases with the time. So it is difficult to make a decision. For this further investigation can be carried out. The rate of fixation against the time is plotted in the column chart.

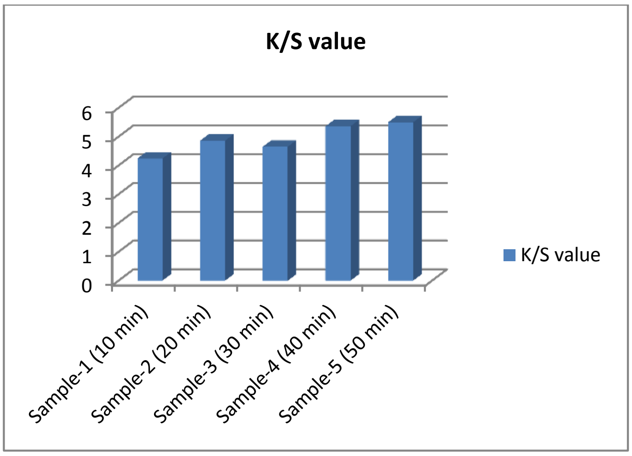

Figure-28: Column chart of BEZAKTIV YELLOW S-3R (Bi-functional)

Conclusion

In this study the rate of exhaustion and fixation was essential. But to measure the exhaustion and fixation, need latest spectrophotometer. Isothermal procedure was used to measure the K/S value by the spectrophotometer to compare the exhaustion and fixation behavior not to measure the other parameters. The accurate exhaustion and fixation point is not found out but tried to found the best possible result. Finding out the proper exhaustion and fixation point requires much research in this context. It is possible to compare the exhaustion and fixation behavior of these reactive groups which is much supported by the chemistry of these reactive groups. Here also describe the results and reasons of such result. From this result it is possible to mention the particular use of each of the reactive groups in the fields of textile dyeing or coloration which is a success of this study. It can also be cited the advantages of the dyeing behavior of these dyes. Therefore it is expected that the study is successful to achieve its objectives considering and overcoming its limitations. There is a significant increase in exhaustion and fixation on cellulosic fiber dyeing by using bi- functional reactive dyes. In case of mono-functional dye exhaustion, the red dye exhaustion is the highest (K/S=3.76) after the run time 50 minute and the yellow dye exhaustion is the highest (K/S=3.80) when the run time was 30 minute. So the exhaustion of yellow dye is higher than red dye. For the bi-functional dye exhaustion, the red dye exhaustion is the highest (K/S=3.87) after the 35 minute and the yellow dye exhaustion is the highest (K/S=4.59) after the 25 minute. The exhaustion of yellow dye is higher than red dye. In case of mono-functional dye exhaustion in presence of alkali, the red dye exhaustion is the highest (K/S=5.15) after the 40 minute and the yellow dye exhaustion is the highest (K/S=5.12) after the 45 minute. The exhaustion of yellow dye is lower than red dye. For the bi-functional dye exhaustion in presence of alkali, the red dye exhaustion is the highest (K/S=5.63) after the 20 minute and the yellow dye exhaustion is the highest (K/S=6.17) after 45 minute. The exhaustion of yellow dye is higher than red dye. In case of mono-functional dye fixation, the red dye fixation is the highest (K/S=4.00) after the 50 minute and the yellow dye fixation is highest (K/S=3.78) after 40 minute. The fixation of yellow dye is lower than red dye. For the bi-functional dye fixation, the red dye fixation is the highest (K/S=3.84) after the 20 minute and the yellow dye fixation is the highest (K/S=5.50) after the 50 minute. The fixation of yellow dye is higher than red dye. So exhaustion and fixation behavior of mono-functional reactive dye is lower than bi-functional reactive dye for yellow colorant. But only fixation behavior of yellow dye is lower than red dye.

Reference

[1]. Preston, C. The Dyeing of Cellulosic Fibres, Dyer's Company Publication Trust, United kindom, 1986.
[2]. M Ramasamy and P V Kandasaamy, Indian Journal of Fibre& Textile Research, Vol.30, September 2005, pp 315-323.
[3]. Mottaleb, M., and Littlejohn, D. (2001). Application of an HPLCeFTIR modified thermospray interface for analysis of dye samples. Ana Sci. 17:429-434.
[4]. Al-Degs, Y.S., El-Barghouthi, M.I., Khraisheh, M.A., Ahmad, M.N., and Allen, S.J.(2004).Effect of surface area, micropores, secondary micropores and mesopores volumes of activated carbons on reactive dyes adsorption from solution. Separation Science and Technology 39:97-111.
[5]. Ratte,I .Reactive Dyes for Cellulose 1953-1983,Reviews on Progress in Coloration,14,P.50-57,1984.
[6]. Von der Eltz, H. Vinyl SulphoneDyes:from Conception to success, Melliand Textriberichte,6,P.687-704,1971.
[7]. 7. Rivlin, J.The Dyeing of Textile Fibres Theory and Practice, Joseph Rivlin, Pennsylvania, 1992.
[8]. Lewis, D.M, in wool Dyeing, Lewis D. M, Ed.(Bradford: SDC, 1992).
[9]. Saeed Q, Bhatti, I.A., Zuber, M., Nosheen, S., Zia, M.A., Abbas M International Journal of Basic & Applied Sciences IJBAS-IJENS Vol: 12 No: 06, December 2012, pp 191-197.
[10]. S.N. Jayanth, R. Karthik, S. Logesh, R.K. Srinivas, & K. Vijayanand, Environmental issues and its impacts associated with the textile processing units in Tiruppur, Tamilnadu. 2nd International Conferences on Environmental Science and Development, IPCBEE, 2011, 4, 120-124.
[11]. B.G. Ridoutt,& S.A. Pfister revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Global Environmental Change, 2010, 20, 113–120.
[12]. V.M. Correia, T.Stephenson, S.J. Judd, Characterization of textile wastewater – a review. Environ Technol. 1994,15, 917–929.
[13]. P.A. Desai, & V.S. Kore, Performance Evaluation of Effluent Treatment Plant for Textile Industry in Kolhapur of Maharashtra. Universal Journal of Environmental Research and Technology, 2011, 1, 560-565.