CHAPTER-II

REVIEW OF LITERATURES

Extensive literatures have been reviewed pertaining to the present study on natural dyes and some of them were given below:

2.1 International scenario

Many works on natural dyes were done at international level from the last two three decades. Crews (1982) evaluated two ultraviolet filters of polyester film, one colourless and one with a strong yellow colour for their effectiveness in reducing fading of wool dyed with selected natural dyes and one synthetic dye. Results showed that clear filters offer no protection against fading for some natural dyes.

Crews (1987) constructed the fading rate curves of selected natural dyes from colour difference measurements by using a tristimulus colorimeter. Examination of the curves showed that most natural dyes fade rapidly initially followed by a slower rate of fading. Only the most lightfast natural dyes fade at a constant rate over time.

Frigerio (1992) compared characteristics of natural dyes with synthetic dyes to minimize environmental pollution. Logwoad, tropical legume dyes, yellow woad of Cuba, dyes extracted from insects, indigo, mollusks extraction and extraction from Sandalwood, saffron, curcuma, nuts, henna and lichens were described.

Koren (1994) used linear gradient elution methods for the HPLC analysis of plant and scale insects red for anthraquinonoid mordant dyes and molluscan blue and red purple indigoid vat dyes. The method enables the use of same elution program for the detection of different chemical classes of dyes. In addition, it significantly shortens the retention times of natural anthraquinonoid dyes over those previously published. For the first time a new dye, probably dibromoindirubin has been detected in *Murex trunculus*, a sea snail.

Tsatsaroni and Eleftheriadis (1994) dyed cotton and wool fabrics with the aqueous extract of saffron containing crocin as the main colorant species. The dyeing was carried out with and without metal salts as mordants. The wash and light fastness of the dyed fabrics were studied. The colour of the fabrics was investigated in terms of CIE L* C* H* values.

Gallotti (1995) studied the feasibility of using plant-based dyes for textile application with reference to the use of set-aside land for non-food crops. Then the processes used to extract dyestuffs from the plant materials were described: traditional methods; ultra-filtration and inverse osmosis; extraction with fluids in a supercritical state. Finally, the analysis of natural dyes was discussed with reference to analysing the dye and its precursor, checking the purity of the extract and identifying the dyestuffs on textile materials.

Tsatsaroni and Kyriakides (1995) studied the dyeing of cotton and wool fabrics with the natural dyes, chlorophyll and carmine after treatment with the enzymes - cellulase, α-amylase and trypsin. Wash and light fastnesses of the dyed samples were studied. Enzymatic pre-treatment resulted in an increase in pigment uptake in all cases compared with the corresponding untreated samples, and did not affect fastness properties. Pre-treatment with metallic salts and dyeing of pre-treated samples were also carried out and the fastness properties of the dyed materials were studied.

Shirata *et al*. (2000) isolated *Janthino bacterium lividum* from wet silk thread whose colour became bluish-purple. This bacterium produced large amounts of bluish-purple pigment on some media containing amino acids, such as Wakimoto medium. The pigment was extracted with methanol and was identified as a mixture of violacein and deoxy violacein. Dyeing could be performed by a simple procedure consisting of either dipping in the pigment extract or boiling with the bacterial cells. The colour fastness of the dyed material was about the same as that of materials dyed with vegetable dyes, but the colour faded easily when the material was exposed to sunlight.

Bohmer (2002) described indigo blue which has been used for 4000 years, the blue of all old textiles. The history and chemistry of natural indigo and blue dyestuffs were traced. Historical examples of indigo blue obtained through archaeology were described. Indian production was noted in the 19^{th} Century and discovery of the chemical composition of indigo. The structure and origins of indigo are discussed with two main methods of dyeing - direct dyeing and vat-dyeing. Other ingredients were listed and the process methods explained. Indigo plants, their cultivation and the process of extraction were detailed.

Choo and Lee (2002) extracted and analyzed natural dyes by using traditional Korean methods of dyeing cloths. Nine plants were used, either singly or in combination, to produce a wide range of colours. Some of the fabrics were then analysed for chemical identification of their dye components and mordants. This body of reference data will permit a more scientific understanding of traditional dyeing crafts, essential for authentic restoration and proper conservation.

Dweck (2002) studied some of the existing methods for colouring the hair and skin using natural material (such as henna) and proposes a parallel technology that exists in the dyeing of wool and fabrics to extend the colour range.

Tawfik (2002) discussed the suitability of turmeric in the fine powder form as natural dye in printing cotton, polyester and their blended fabrics using pigment-printing technique. Variable studied included concentration of the colour, nature of thickening agent, type of fixation and pH of the printing paste. The printed goods were evaluated by measuring the K/S and the overall fastness properties. Thermo fixation was more suitable than steaming. It can be concluded that turmeric can be used as natural dye successfully.

Orska-Gawrys *et al*. (2002) used reversed-phase HPLC with diode-array UV–Vis spectrophotometric detection for identification of natural dyes in extracts from wool and silk fibres from archaeological textiles. The examined objects originate from 4th to 12th Century Egypt and belong to the collection of Early Christian Art of the National Museum in Warsaw. Extraction from fibres was carried out with HCl solution containing ethanol or with warm pyridine.

Bochmann and Weiser (2003) studied results of dyeing linen and wool with five plant extracted dyes (weld, madder, Chinese indigo, dyer's chamomile, Canadian golden rod) and evaluated by using different mordants. Colour fastness and resistance to light, rubbing and washing fastness were also evaluated.

Angelini *et al*. (2003) evaluated six weld genotypes (*Reseda luteola* L.) for their agronomic characteristics in a 4-year field study carried out under rainfed condition in Central Italy in order to point out productive potential and the best harvest time to maximise yield of dye. The dry powder from leaves and reproductive structures was used in the dyeing of cotton, wool and silk yarns. Good and bright yellow colours were observed using a ratio 30:100 (w/w) of weld on the textile materials. Finally, all dyed specimens exhibited good resistance to light and wash fastness making the use of weld a viable alternative to synthetic yellow dyes.

Bains *et al*. (2003) optimized dyeing conditions for the use of mango bark in dyeing cotton, and evaluated colourfastness of the samples. The preparation of the dry mango bark (*Mangifera indica*) and cotton samples were specified, and the mordants listed. The optimum concentration of myrobolan was noted with the optimum extraction time of dye material and optimum medium. This was followed by the optimum concentration of dye material and dyeing time of dye material. The selection of mordant concentration was then discussed, with the method of mordanting used. The colourfastness evaluation of the dyed samples covered washing, rubbing, light and perspiration fastness.

Bechtold *et al*. (2003) performed the extraction of the dye components from the plant materials with boiling water without addition of chemicals or solvents. Based upon a rigorous selection of possible plant sources, selection of natural dyestuffs applicable in a one-bath dyeing step was established. A broad variation in shade and colour depth can be achieved by applying mixtures of natural dyestuffs in various combinations of iron- and alum-mordants. More than 60% of tested dyeing achieved acceptable fastness properties.

Cevallos-Casals and Cisneros-Zevallos (2003) evaluated anthocyanin-based aqueous Andean red sweet potato and purple corn extracts under different pH, temperature, and light conditions, and compared to commercial colorants. Red sweet potato and purple carrot colorants, rich in acylated anthocyanins, showed higher stability than purple corn and red grape colorants, rich in non-acylated anthocyanins. Parameters measured included degradation index, polymeric colour, colour retention and spectral data.

Yoshizumi and Crews (2003) investigated photo degradation characteristics of fading of wool cloth dyed with selected natural dyes stuff on the basis of solar radiant energy. UVA and UVB fluorescent lamps were also applied to examine wavelength dependencies on the fading characteristics. The natural dyestuffs were observed to have poor light fastness in comparison with AATCC Blue Wool L2. These results provide an important key to understanding the poor light fastness of some natural dyestuffs.

Zhou *et al*. (2003) listed typical examples of bio-dyestuffs including insect and tree secretions, and vegetable dyes. The plants providing red, yellow, blue, green and black colours were also listed and the method of extraction detailed. The problems faced by bio-dyeing were noted. Bio-materials can be used to replace harmful, energy or material-expensive chemical treatments for pre-treatment and finishing.

Ferreira *et al*. (2004) described the sources and structures of dyes used to colour Western historical textiles. Most blue and purple colours were derived from indigo-obtained either from woad or from the indigo plant-though some other sources (e.g. shellfish and lichens) were used. Reds were often anthraquinone derivatives obtained from plants or insects. Most other colours were produced by over-dyeing e.g. greens were obtained by over-dyeing a blue with a yellow dye. Direct analysis of dyes isolated from artefacts allows comparison with the historical record.

Gaffney (2004) discussed dyeing techniques based on using the plant dyes like madder, indigo, palamut, walnut, ezentere, sutlegen, weld, camomile, and pomegranate. Madder, a probable native to Anatolia, is obtained from the dried, ground up, and soaked roots of the cultivated dye. Palamut is obtained from the drying and ground up of the barks and acorns. The laudable Turkish efforts in reviving the usage of natural dye plants seem to suffer in monetary terms, owing to the time involved with the traditional dyeing process.

Turkmen *et al*. (2004) used plants traditionally to dye carpets and woven matting in the eastern Mediterranean region. The survey was carried out in Kedisli, Feke, Aladag, the surrounding village of Adana, and in Osmaniye (Turkey).

According to the survey results, 37 species of plants belonging to 29 families were used in natural dye production. The total dyes contents of collected mordants and dye obtained from some of these plants were used to treat the wool and cotton yarn and yarn's dyed properties were tested.

Cristea and Vilarem (2005) evaluated the light fastness of selected natural dyes (madder, weld and woad) and the effect of some commonly used antioxidants and UV absorbers on the light fastness of these dyes. A poor light fastness of the three natural dyes in comparison with synthetic ones was established beyond question. Nevertheless, the use of some additives can improve this default of natural dyes. In all the cases, the use of UV absorbers or antioxidants improved the light fastness of dyed fabrics. The most effectives were the vitamin C and the gallic acid.

De *et al*. (2005) established production media to yield prevailing red or orange pigment rich ethanolic extracts from *Monascus purpureus* C322. Since the production of the orange pigment-rich ethanolic extracts appeared to be more cost-effective than that of their red counterparts, the former might support the present demand for colorants of natural origin in the textile sector.

El-nagar *et al*. (2005) reported that synthetic dyes were more available than natural dyes, because of lower prices and wider ranges of bright shades with considerably improved colour fastness properties. Moreover, the light fading behaviours of both synthetic and natural dyes were studied in terms of the reflection spectra (400-800 nm), microstructure, and macrostructure of the sample's fibres.

Feng *et al*. (2005) dyed pure silk and cotton fabrics with natural dye *Lithospermum erythrorrhizon* by the traditional method and the camouflage properties of the dyed fabrics were evaluated. It was found by experiments that these fabrics have good camouflage protective functions in resistance to ultraviolet, visible, and near infrared rays.

Han and Yang (2005) used curcumin, a common natural dye for fabric and food colorations, as an antimicrobial finish due to its bactericidal properties on dyed textiles. A common dyeing process, either batch or continuous, could provide textiles with colour as well as antimicrobial properties. The relationship between the sorption of an interesting natural colorant onto wool and the antimicrobial ability of the dyed wool were investigated. Relations between the bacterial inhibition rate and curcumin concentration, and inhibition rate and K/S value were developed. Antimicrobial activity of wool fabric finished with curcumin can be predicted without antimicrobial testing based on the developed relationships

Kim *et al*. (2005) used pigment extracts from the root of *Lithospermum erythrorhizon* as natural red dyes, as well as basic drugs due to their numerous pharmacological activities. Accordingly, this study proposes a method of enzymatic pigment production based on the introduction of hydrolytic enzymes prior to the usual extraction to avoid repeated pigment extraction. *Bacillus* sp.

Bechtold *et al*. (2006) discussed the introduction of natural dyes into modern textile dye houses which requires the classification of products of standardised quality with regard to colour depth and shade of the dyeing. Canadian golden red was chosen as a representative example to test the methods that were available to assess the quality of different crops of plant material which had been collected over a period of five years final.

Bechtold *et al*. (2006) described that food and beverage industry releases considerable amounts of wastes which contain natural dyes. Wastes, e.g. pressed berries, pressed grapes, distillation residues from strong liquor production, and wastes and peels from vegetable processing, have been extracted with boiling water and test dyeing on wool yarn were performed. Colour strength, shade and fastness properties of the dyeing have been tested. The results prove the potential of such wastes as a source for natural dyestuff extraction.

Ke *et al*. (2006) dyed wool fabric with the extracts of *R. coptidis*. Colour evaluation was characterized with CIE, L*, a*, b*, c*, H O, K/S. Effects of mordant, extraction concentration, pH value of dye bath, and treatment temperature on colour values were studied. Results indicated that wool fabrics dyed with mordant, or at higher temperature, or in alkali solution possessed deeper shades and darker colours. And the wool fabric showed good antibacterial property after dyeing with *R. coptidis* extracts.

Kamel *et al*. (2006) discussed the dyeing of cationised cotton fabrics with lac natural dye by using both conventional and ultrasonic techniques. The effects of dye bath pH, salt concentration, ultrasonic power, dyeing time and temperature were studied and the resulting shades obtained by dyeing with ultrasonic and conventional techniques were compared. The values of dyeing rate constant, half-time of dyeing and standard affinity and ultrasonic efficiency have been calculated and discussed.

Mashaly (2006) studied the dyeing of nylon fabrics using lac as a natural dye in both conventional and ultrasonic techniques. The extractability of lac dye from natural origin using power ultrasonic was also evaluated in comparison with conventional heating. The results of dye extraction indicate that power ultrasonic was rather effective than conventional heating at low temperature and short time. The values of dyeing rate constant, half-time of dyeing and standard affinity and ultrasonic efficiency have been calculated and discussed.

Montazer *et al*. (2006) identified those liposomes as lipid vesicles that were composed of amphiphile molecules and can carry hydrophobic and hydrophilic materials. Liposomes were used as carrier for transfer of dye molecules into wool fibres. The preparation and production of multilamellar liposomes (MLV) from Soya lecithin were carried out and the behaviour of liposomes at different temperature was studied. The results showed that presence of liposomes in the dye-bath helps to increase the dye absorption on the wool fabric before 80°C.

Paul *et al*. (2006) attempt to find out the effect of different mordants viz., alum, chrome, ferrous sulphate and copper sulphate on colourfastness properties of cotton dyed with Kilmora dye. One natural mordant Myrobalan and four synthetic mordants viz., potassium aluminium sulphate, potassium dichlorate, copper sulphate and ferrous sulphate were selected. Dyeing was carried out by using all three mordanting methods pre-mordanting, simultaneous mordanting and post mordanting.

Zhou and Shao (2006) analyzed the mordant dyeing of cotton with *Gardenia*, including pre-mordant, one-bath and post-mordant. The dyeing properties such as dye K/S value and colour fastness were investigated. According to the structure and property of mordants including alum, copper sulphate, iron sulphate and rare earth, the interaction mechanisms among *Gardenia*, mordant and cotton fibres were analyzed and the processing factors affecting the mordant dyeing were discussed.

Bechtold *et al*. (2007) used the aqueous extract of ash-tree bark (*Fraxinus excelsior* L.) as a model to study the shade reproducibility of dyeing on wool. A metal-mordanting process using $FeSO_4 \cdot 7H_2O$ mordant was chosen as a system with particular potential for industrial application. The exhaust dyeing process with immediate use of the extracts as a dye bath and direct addition of $FeSO_4 \cdot 7H_2O$ stock solution as a meta-mordant process showed good shade reproducibility and satisfying levelness of the dyed material. The quality of bark and the extraction step were found to be of significant importance for the colour depth.

Clementi *et al.* (2007) discusses the light fastness of wool textile samples, using two complementary experimental techniques: absorption and emission UV-vis spectroscopy and chromatography (HPLC-PDA) dyed with madder and its principal components alizarin and purpurin. The results from the two techniques integrate well each other and provide complementary and useful indications about the sensitivity of the dyed textiles to ageing, showing that purpurin was the principal component responsible for the spectral and chromatic properties of madder as well as for its degradation.

Colombini *et al*. (2007) described an analytical procedure based on GC-MS to identify in textiles the most common flavonoid yellow dyes used in Europe since ancient times, extracted from weld, young fustic, dyer's broom, sawwort and the berries of some species of *Rhamnus*. Two photooxidative degradation pathways for colour fading, one involving the mordant metallic ion and the other the light as a catalyst, were suggested.

Feng *et al*. (2007) investigated the ultraviolet protective properties of the fabrics dyed by *Rheum* and *Lithospermum erythrorhizon* were investigated. Experimental results revealed that the fabrics dyed with natural dyes had good ultraviolet protective properties. They could absorb about 80% of the ultraviolet rays. Natural dyes such as Rheum and *L. erythrorhizon* had comparable UV-absorption performance to the common UV-absorber, benzophenone.

Guinot, *et al.* (2007) investigated aqueous extracts of plant by-products (carrot, onion, black carrot, sage, spinach and thyme) for dyeing capacity on fibres and for both colorant and antioxidant potential using colorimetric and chromatographic tools, and FTC assay, respectively. Light fastness of onion, sage and thyme samples, evaluated following a normalised test, was very promising considering industrial restrictions.

Koyuncu (2007) studied the dyeing of wool yarn using *Rheum ribes* roots as natural dye in conventional method. The effects of dyeing show higher colour strength values obtained by the latter. Dyeing with *Rheum ribes* roots has been shown to give good dyeing results. The results of washing fastness properties of the dyed wool yarn were fair to good. CIELAB values have also been evaluated and discussed.

Lee (2007) extracted natural colorant from *Coffea arabica* L., using water as extradant at 90°C for 90 min. Studies have been made on the dyeing, colour fastness, and deodorization properties of cotton, silk, and wool fabrics dyed with *Coffea arabica* L. extract solutions, The best mordants were found to be $FeSO_4$, $CuSO_4$, and $SnSO_4$ for improving the colour strength (K/S) of cotton, silk, and wool fabrics.

Lu *et al*. (2007) performed experiment of wool fabrics dyeing with sorghum red as natural dye by mordant dyeing method. The experimental results were as follows: the consistency of the dye was the key factor on dyeing depth in pre-mordant process, the dyeing depth enhanced with consistency of the dye solution increasing; the pH value was the second factor that affected the depth, the depth improved with the increase of pH value. The depth improved with the rise in temperature indicating sorghum red dye as suitable to dye wool fabric.

Nagia and Mohamedy (2007) described two anthraquinone compounds which were produced by liquid cultures of *Fusarium oxysporum* (isolate no. 4), isolated from the roots of citrus trees affected with root rot disease used for dyeing of wool fabrics. The values of dyeing rate constant, half-time of dyeing and standard affinity have been calculated and discussed. The effect of dye bath pH, salt concentration, dyeing time and temperature were studied.

Savvidou and Economides (2007) investigated sources of natural dyes in a paper-dyeing operation. The production of natural dyes was achieved by aquatic extraction of plant materials in order to obtain an environmentally friendly method of producing the dyes. The extracted dyes were applied on de-inked mechanical pulp. A broad variation in shade and colour depth was achieved by applying mixtures of plant extracts in various combinations.

Septhum *et al*. (2007) studied the formation of complexes between alum with morin and quercetin in aqueous solution with and without pH control by UV-visible spectroscopy. The stoichiometries of the complexes were evaluated using the molar ratio method.

Hou *et al*. (2008) purified catechu dye with a micro-filtration membrane and the stability of catechu dye to different levels of temperatures and pH were investigated. The effects of the dyeing conditions on colour characteristic values and colour fastnesses of the dyed wool fabrics were also investigated. The results show that the liquor of catechu dye was stable at pH values of 3-7 and its colour changes to a deeper brown-red when its pH value was above 8. The preferable dyeing conditions for wool fabric with refined powder catechu dye were as follows: dyeing temperature of 100^{o}C, pH value of 6.5 for the dye bath and catechu dye of 1- 4 % (o.w.f).

Adeel *et al*. (2009) studied the natural dye extracted from pomegranate rind and found that it might be used as a possible substitute of synthetic dyes having banned aryl-amine moieties. A systematic study was also done on extraction, characterization and improving the properties of the dye was a must to minimize the cost investment, yield maximization and dye purity.

Kamel *et al*. (2009) studied on the dyeing properties of cotton fabrics with *Croccus sativus* (Saffron flowers) using ultrasonic method. The colour strength of cotton fabrics dyed with natural colouring matter from saffron by the ultrasonic method was better than the traditional method. Using different mordants as well as different methods of mordanting dyed cotton fabrics gives a wide range of beautiful colourful hues.

Osman *et al.* (2009) evaluates the levelness (L) parameters by using different variables, including: a) three different natural fabrics; namely, wool, silk and cotton dyed with yellow natural dye from onion skins under the effect of different mordants, and b) three different natural dyes; namely, onion skins, turmeric and madder applied on wool fabric samples under the effect of different mordants.

Estrella *et al*. (2010) aims to identified the natural dyes employed in the manufacture of eight fragments of the collection of Coptic textiles from the Spanish National Archaeological Museum, using HPLC-DAD. Two extraction methods, the classical methanol/hydrochloric acid extraction and a mild extraction using 5% formic acid in methanol, were evaluated using several reference fibres dyed with a selection of red, yellow, blue, purple and black dyestuffs.

Lech and Jarosz (2011) used High-performance liquid chromatography coupled with spectrophotometric and electrospray mass spectrometric detection

(HPLC–UV–Vis–ESI MS) for characterization of natural dyes present in historical art works. The gradient program was developed for identification of 29 colorants of various polarities. Moreover, for extraction of colorants from historical textiles a two-step sequential procedure was proposed, excluding evaporation used in earlier procedures. The developed method was successfully applied to identification of indigotin, carminic, kermesic, flavokermesic, dcII, dcIV, dcVII, and ellagic acids as well as luteolin, apigenin, and genistein in red, violet, and green fibres taken from three selected historical chasubles which belong to the collection of the Wavell Cathedral treasury (Cracow, Poland).

Musyoki *et al*. (2012) studied on the sources of natural dyes and tannins among the Somali community living in Garissa County, Kenya. The findings showed that the main sources of livelihood included livestock production, sale of dye and tannin products. Natural dyes were a major input on woodcarvings, mainly utensils used for milking and storage of milk and water. Both men and women in the community used *Lawsonia inermis* L. for hair dyeing and skin decoration. The main plant sources for dyes and tannins were enumerated as *Commiphora holtiziana*, *Acacia bussei*, *Lawsonia inermis* and *Commiphora campestris* Engl, among others. The mordant used were Magadi soda and ashes from trees *Salsol adendroids* Pall. Var Africana Brenan (Durte).

Seher and Yurdun (2012) estimated the DNA damage of indigotin, 6-bromo indigotin, indirubin and 6-bromo indirubin by in vitro alkaline single-cell gel electrophoresis (SCGE-Comet) in the peripheral lymphocytes. The cytotoxic effects of indigo and indigoid dyes were assessed by trypan blue exclusion. The result indicates that indigo and indigoid dyes would be genotoxic at higher concentrations.

Selvam *et al. (*2012) studied the anti-microbial activity of turmeric natural dye against different bacterial strains like *Salmonella paratyphi*, *Psuedomonasaeruginosa*, *Vibrio harveyi*, *E. coli*, *Staphylococcus lutea* etc. In this study it was observed that the banana fibre coated with turmeric extract possess a good antibacterial activity against pathogenic microbes. At a dose level of 100µl the turmeric extract was able to inhibit the growth of all the bacteria tested.

Umar *et al*. (2013) investigates the extraction of colour from locust beans fruits pods to dye cotton and silk fabrics using the mordanting treatment with these mordants of $CuSO_4$, Ferrous (II) & (III0 Sulphate and Alum. Aqueous and solvent extraction method was adopted for this experiment. The colour obtained was different shades ranging from soft, light brown and brown, depending on the mordant used.

2.2 Works on Natural Dyes at National level

Kharbade and Agrawal (1988) studied the natural dyes in historic textiles from the mid-nineteenth century using thin layer chromatography (TLC) and micro-chemical tests. Yellow, brown and red dyes were analyzed by TLC and blue by micro-chemical tests. Seventy samples which were taken from museum textiles were compared with reference materials prepared in the Laboratory as well as with chemically pure major dye components of natural dyes. It was also seen from the results that mixtures of two dyes have been used to obtain desired shades.

Teli *et al*. (1994) successfully applied the natural dye extracted from turmeric on the cotton material. They described that if fabric was treated with tannic acid and/or metal salts and then dyed, the dyeing show improvement in depth and performance properties such as fastness to light, washing, rubbing (dry and wet) etc. They used $CuSO_4$ and $FeSO_4$ and got variation in tones, improvement in light fastness and properties otherwise inferior. The influence of concentrations of tannic acid and metal salts on cotton dyeing was also studied.

Rao *et al*. (1995) worked to replace chrome mordanting in anticipation of a total ban on chromium in industrial effluents and a viable alternative method of mordanting. Natural dyeing has scope for exploitation as there was a growing interest in the renewal of the art of extraction and application of natural colorants on textiles in view of worldwide awareness on the potential of possible toxicity and carcinogenic effects associated with some of the present day synthetic dyes and their intermediates.

Deo and Desai (1999) dyed cotton and jute fabrics with an aqueous extract of tea, containing tannins as the main colorant species. The dyeing was carried out with and without metal salts as mordants, using three different dyeing methods: pre-mordanting, meta-mordanting and post-mordanting. The resulting wash and light fastnesses of the dyed fabrics were good to excellent. Deep shades (K/S = 3.9) were obtained for jute in acidic media, while cotton fabrics could be dyed in medium depths (K/S = 2.0) under identical conditions of dyeing.

Ansari and Thakur (2000) extracted the natural dye from pomegranate and optimised the conditions of extraction. Optimization of conditions for extraction of

C.I. Natural Yellow 7 dye from pomegranate rind has been carried out by studying the effect of pH of extraction media, time and temperature of soaking/extraction and mass to liquor ratio on quality and yield of the dye. Dyeing experiments and analysis of red listed chemicals have also been carried out to see the efficiency and eco-friendliness of the dye and to explore the possibility of its commercial use as a substitute for synthetic dyes based on forbidden aryl amines.

Bhattacharya and Shah (2000) dyed wool fabric with *Areca catechu* by two different process sequences using various metal sulphates as mordant. The dyeing behaviour has been assessed by measuring K/S values and different fastness properties. The effect of different metal ions has been studied with respect to their influence on colour and fastness properties.

Bansal and Sood (2001) developed a dye from *Eupatorium* leaves, a common weed in Himachal Pradesh. The preparations of dye material and yarn samples were specified. Four mordants were used. Revealing the best dye extraction medium as alkaline, optimum cotton yarn dyeing time in *Eupatorium* material as 45 min and optimum harda concentration as 30% and the four best colours obtained were greenish raw umber, light greenish raw umber, light umber sienna and olive green. Colour fastness tests were reported with light umber sienna giving the best outcome.

Gulrajani (2001) evaluated the cotton dyeing by using various natural dyes alone and in combination to yield six basic shades: blue, yellow, red, black, green and fawn. These dyed fibres were then blended in various proportions along with undyed cotton fibres and spun on a rotor-spinning machine to produce 204 coloured yarns.

The fastness properties of the six basic shades were determined. The L*a*b* and L*C*h values of the yarns having 50% dyed fibre and 50% undyed cotton fibre was also determined.

Gulrajani *et al*. (2001) presented status of natural dyes with reference to the stake holders of natural dyes. He estimated the dye requirements, availability of natural dyes, technology for production and some important natural dyes and mordants were critically discussed. Application techniques and fastness properties of natural dyes were also briefly discussed. It was suggested that natural dyes were not substitutes for synthetic dyes. Some of the limitation of natural dyes such as use of banned metal salts as mordants, poor fastness properties and use of agricultural land for growing natural plants could overcome through research and development.

Gulrajani *et al*. (2001) demonstrated possibilities of nylon dyeing by using vegetable dyes like Annatto, Ratanjot and Berberine. Furthermore evaluation of sample fastness and colour value was undertaken. Dye origins were explained and the fabric sample specified. Dyeing solutions were specified and testing methods and equipment described. The K/S values were discussed and the percentage exhaustion dye absorbance reported. Good to moderate light and wash fastness resulted.

Gupta *et al*. (2001) described that Purpurin (1,2,4-trihydroxyanthraquinone) was the major colorant present in the roots of Indian madder (*Rubia cordifolia*). To gain an understanding of the dye-fibre interactions involved, kinetic and thermodynamic studies have been conducted with purpurin on nylon fibre. The dye was found to be sensitive to pH and high temperature. The rate of dye uptake, diffusion coefficient, standard affinity, heat of dyeing and entropy have been calculated and discussed.

Devi *et al*. (2002) determined *Eclipta prostrata*, a common weed found in most of the fields in Andhra Pradesh was a good source of natural dye for silk for production of green shades. Alkaline medium was suitable for extraction of dye from the plant and pleasant yellowish green shades were obtained on silk. The extraction and dyeing procedures were standardized based on the optical density before and after dyeing silk and visual appearance judged by a panel of 30 scientists.

Suneeta and Mahale (2002) described that a dye material extracted from *Parthenum* leaves has range of bright, soft even and lustrous colours on silk yarn. This dye can be effectively used at commercial level without any allergic effect.

Teli *et al*. (2002) used water borne extracts of madder and tea to dye cotton fabric using conventional single dip dyeing methods with different mordanting methods. The results were compared with a new method that uses ferrous sulphate and tannic acid as mordants in a multiple dip process. Results show that the multiple dip method is capable of producing deeper shades, uses less dye and indicates a potential for industrial use. Ferrous sulphate mordant produced the deepest shades.

Mathur and Gupta (2003) dyed Bharat merino sheep wool yarn with turmeric (*Curcuma longa*) and was subjected to mordanting separating with natural mordant and chromium under identical condition. Out of the different concentration of the mordants used 3.5% natural mordant and 1.55 % chromium on the weight of yarn show similar colour fastness, reflectance, colour, shape and K/S values. The chemistry of wool dyeing and the physiochemical properties of dyed wool yarns were also discussed.

Mathur *et al*. (2003) described the extraction of natural colourant from neem (*Azadirachta indica*) for dyeing of wool yarn. Neem bark colourant showed two absorption maxima at 275 and 374 nm. Dyeing of wool yarn under the optimum conditions (pH, 4.5; colourant conc., 0.05 g/g of wool; treatment time, 60 min; and treatment temp., 97.5°C) showed very good light and wash fastness properties without deteriorating the quality of wool.

Paul *et al*. (2003) described dyeing procedure with walnut bark, a good source of brown colour and relatively eco-friendly with easy in application for rural population especially. Dyeing variables in using walnut dye to dye wool were tested, and the colourfastness of selected dye on woollen yarns was also investigated. Experiments were conducted to determine the optimisation of dyeing variables - medium of dye extraction, and optimisation of dye extraction time, dye concentration and dyeing time. Walnut bark was found to be a good source of brown colour, with a variety of fast shades using different mordants.

Paul *et al*. (2003) used the roots of *Berberis vulgaris,* to prepare a dye in order to optimise various variables for its use as dye. Four synthetic mordants were used for the study: alum, chrome, copper sulphate and ferrous sulphate. The medium of dye extraction, extraction time, and dye concentration were investigated. Overall, *Berberis* was found to be a good source for producing a number of fast shades ranging from yellow to black on woollen yarns by using different mordants.

Samanta *et al*. (2003) performed work on cotton fabric dyed with four different natural dyes (turmeric, myrobolan, madder, red sandalwood) using pre, post and simultaneous-mordanting techniques for dyeing. Aluminium sulphate was used as a mordant. Some samples were also dyed with a combination of turmeric with madder or red-sandalwood and a combination of myrobolan with madder or red sandalwood in different proportions. Selected mordanted and dyed samples were after treated with a cationic dye fixing agent. Turmeric also showed poor wash fastness, which was improved to some extent by after treatment with a cationic dye fixing agent and on combination of turmeric with other dyes of better fastness. Combined dye application of turmeric with the other dyes by the simultaneous-mordanting method resulted in a better shade development as the observed colour strength values were always higher than the calculated or the expected values.

Bhuyan *et al*. (2004) described natural dyes as important alternatives to synthetic dyes. A study was initiated in the year 2000 at the RRL (CSIR), Jorhat to extract dyes from parts of five different plant species indigenous to north-eastern India. The colour components responsible for dyeing were isolated and their chemical constituents were established based on chemical and spectroscopic investigations. The principal colour components from the species *Morinda angustifolia* Roxb., *Rubia cordifolia* L. and *Tectona grandis* L. were found to contain mainly anthraquinone moieties in their molecules. Those from the species *Mimusops elengi* L. and

Terminalia arjuna (Roxb.) Wight & Arn. contained flavonoid moieties in their molecules. The dyes obtained from the native plants may be alternative sources to synthetic dyes for the dyeing of natural silk and cotton.

Garima *et al*. (2004) executed work on wool dyeing by using *Reinwardtia* flowers and poplar leaves in the ratio of 50:50 each as natural dye. Different variables viz. wave length, dye material combination, dye extraction time, dye material concentration, dyeing time, pH and mordants were standardized.

Gupta *et al*. (2004) purified two components of Indian madder, purpurin (1,2,4-trihydroxyanthraquinone) and munjistin (1,3-dihydroxy-2-carboxyanthraquinone) and dyed nylon fabric with these two component. The light and wash fastness of dyed and mordanted samples has been studied. Purpurin showed much better resistance to photofading than munjistin. It was found that the type of mordant and the method of mordanting significantly affected the rate and extent of photofading. The use of copper or ferrous sulphate gave high resistance to fading, whereas stannouschloride or alum did not. On the other hand, light fastness was improved when post mordanting was conducted with copper or ferrous iron, but pre-mordanting was superior in the case of stanneous chloride or alum.

Gupta *et al*. (2004) described many of the plants from which natural dyes were obtained and also have medicinal properties. In the current study, the antimicrobial properties of eleven natural dyes against three types of Gram-negative bacteria were studied experimentally. Seven of the dyes showed activity against one or more of the bacteria. The minimum inhibitory concentration for three selected dyes was determined. The results demonstrate that certain dyes were able to reduce microbial growth almost completely in the case of *Escherichia coli* and *Proteus vulgaris*. Selected dyes would therefore be valuable for the dyeing of sheets and gowns for hospital use, and on articles which were less suitable for laundering such as mattresses and upholstery.

Phukan and Phukan (2004) standardized the condition of dyeing mulberry silk yarn with the bark of Arjun tree, *Terminalia arjuna*. Mordants such as alum, chrome, copper sulphate, and ferrous sulphate were used for the study for the fixation of the dye molecule with the fibre. To remove the sericin, degumming was done before dyeing, with washing soda, alkaline and acidic methods were employed for dye extraction. Yarns were mordanted in the first stage and dyed in the second stage in the pre-mordanting method. In simultaneous mordanting, mordants and dyes were applied simultaneously in the same bath. In the post-mordanting method, however, the yarns were first dyed and then mordanted. The alum mordant and pre-mordanting method showed the best results in both alkaline and acidic medium for the Arjun tree dye. Yarns dyed with Arjun dyes showed colour fastness to washing, rubbing, light, and perspiration.

Rose *et al*. (2004) studied efficient dyeing of cotton yarns with a plant dye, Ornamental Mustard (*Brassica juncea*) with certain optimum variables. Experiments were therefore conducted to standardize the medium of dye extraction, wave length, extraction time, dye material concentration, dyeing temperature, dyeing time, and dyeing pH. Dye extraction in an alkaline medium with optimum wave length of 360 nm, extraction time 30 min, dye material concentration 7 %, dyeing temperature 100°C, dyeing time 45 min, and dyeing pH 10, gave excellent results for dyeing cotton yarns.

Sarkar (2004) reported the ultraviolet properties of textiles dyed with synthetic dyes and natural dye. However, no study has investigated the ultraviolet properties of natural fabrics dyed with natural colorants. This study reports the Ultraviolet Protection Factor (UPF) of cotton fabrics dyed with colorants of plant and insect origins. A positive correlation was observed between the weight of the fabric and their UPF values. Similarly, thicker fabrics offered more protection from ultraviolet rays. Thread count appears to negatively correlate with UPF. Dyeing with natural colorants dramatically increased the protective abilities of all three fabric constructions.

Shukla *et al*. (2004) dyed wool fabric with an aqueous extract from the bark of *Acacia pinnata* containing tannin as the major colorant. Dyeing with the combination of extracts of *Acacia pinnata* and banana stem has also been carried out and improvement in depth of colour without altering the tone observed. The colour of the fabrics has been evaluated on computer colour matching system in terms of K/S and L* a* b* colour coordinates. The dyeing shows moderate to good fastness to washing, light and rubbing.

Teli *et al*. (2004) discussed the results of the study of application of natural dyes such as Turmeric, Madder, Catechu, Indian Rhubarb and Henna on Cellulose Triacetate. Three different methods of application namely Pre-mordanting and Meta-mordanting and Post-mordanting were used with Copper sulphate, Ferrous Sulphate and Tannic acid and enhancement in depth of dyeing were studied. It is obvious that the final shade and tone depends upon dye-fibre mordant system. All the man-made fibres exhibited maximum depth of dyeing using post-mordanting technique. The performance properties varied depending upon the type of the dye, fibre and the mordant used.

Grover *et al*. (2005) discussed eco-friendly dyes which have gained much importance in dyeing of textiles, especially silk fabrics. The possibilities to extract dyes from plants and to optimize various dyeing variables of these dyes for dyeing of silk have been studied. The natural dyes which were selected for the study included Jatropha, Lantana, Hamelia, Euphorbia, Kilmora, and Walnut. Silk was initially degummed prior to dyeing, to make the fabric free from sericin, which obstructs the penetration of dyestuffs into the fibre. The results obtained from different experiments lead to the optimization of a standard recipe for dyeing of silk with each dye source.

Mahajan *et al*. (2005) studied the silk yarn dyeing with peach leaves by using six combinations of mordants namely Alum/ Chrome, Alum/ Copper Sulphate; Alum/ Ferrous Sulphate; Chrome/ Copper Sulphate; Chrome/ Ferrous Sulphate and Copper Sulphate/ Ferrous Sulphate in the ratio of 1:3, 1:1 and 3:1. On evaluation it was concluded that silk dyed with peach leaves showed excellent washing fastness except for few samples, very good light fastness and fair to good rubbing and perspiration fastness.

Mahanta and Tiwari (2005) studied on the natural dye-yielding plants and indigenous knowledge on dye preparation in Arunachal Pradesh, Northeast India.

Thirty seven species belonging to 26 families have been recorded. The indigenous knowledge system particularly associated with the extraction and processing of natural dyes from plants among the *Monpa*, *Apatani*, *Khampti*, *Tangsa* and *Wancho* tribes of Arunachal Pradesh has been documented.

Sarkar *et al*. (2005) worked on three varieties of fresh Marigold flowers viz., lemon yellow, golden yellow and maroon-yellow as raw materials for natural dyeing of cotton, wool and silk textiles. Amount of flower for particular volume of water and extraction time were optimized on the basis of intensity of colour of the extract as indicated by optical density. Colour data of different shades as produced were measured in term of L*, a*, b* values and the same have been reported in this paper. The colour fastness property to washing of most of the dyed samples was in the range of 2-3 to 3. Colourfastness to light of the dyed samples varied with the change of mordant and the substrate. Highest rating for cotton was found to be 3 and that for silk and wool was around 4.

Sharma *et al*. (2005) discussed the ecological and health hazards associated with the chemical dyes especially for food, cosmetic and pharmaceutical industries. Therefore, the demand and search for new and novel sources of natural colour is increasing. The rich biodiversity of Himalayan ecosystem has not been assessed for their natural colour yielding potential. Hence, to identify the newer sources of colouring matters, surveys of NW Himalaya were carried out and 24 plant species belonging to 19 families were screened for the presence of colouring matter. The UV-Vis spectral characteristics suggested that most of the colouring extracts contain flavonoids, anthraquinone, chlorophyll and carotenoids: however, tannin was also dominating in certain species. Therefore, we suggest that the Himalayan species were a rich source of natural colours and analyses based on extraction of colouring matter in ethanol coupled with UV-Vis spectra can be of immense value in screening the plant species for identification of new and novel sources of natural colours.

Singh *et al*. (2005) studied to test some natural dyes as inherent anti-microbial activity with a view to develop protective clothing from these. Five natural dyes *Acacia catechu*, *Kerria lacca*, *Quercus infectoria*, *Rubia cordifolia* and *Rumex maritimus* were tested against common pathogens *Escherichia coli*, *Bacillus subtilis*, *Klebsiella pneumoniae*, *Proteus vulgaris* and *Pseudomonas aeruginosa*. *Quercus infectoria* dye was most effective and showed maximum zone of inhibition thereby indicating best antimicrobial activity against all the microbes tested. Minimum inhibitory concentration (MIC) was found to be varying from 5 to 40 μg. The textile material impregnated with these natural dyes, however, showed less antimicrobial activity, as uptake of these dyes in textile material was below MIC.

Ukalkar and Karanjkar (2005) optimized dyeing variables of silk by using forest flowers. The petals were selected as a dye source and were removed when the flowers were fresh and dried under shade. Optimization of dyeing silk comprised of optimization of dye material concentration, dyeing time and concentration of mordant. Based on percent dye absorption and visual appearance, aqueous medium was found to be most suitable for extraction of dye.

Das *et al*. (2006) studied the application of dye obtained from *Punica granatum* fruit rind on wool and silk fabric in the presence and absence of environment-friendly mordanting agents. The dyeing of silk and wool with pomegranate solution was found to be effectively accomplished at pH 4.0. Pre- and post-mordanting employing ferrous sulphate and aluminium sulphate improve the colour uptake, light fastness and colour retention repeated washing. The use of such mordants, however, does not improve wash fastness property of dyed substrates.

Kavitha *et al*., (2006) studied the antimicrobial properties of eleven natural dyes against three types of Gram-negative bacteria experimentally. Results demonstrated that certain dyes were able to reduce microbial growth almost completely in the case of *Escherichia coli* and *Proteus vulgaris*. The dyes examined also exhibited good wash fastness and the antibacterial effect was therefore likely to be durable. Overall, study shows that these dyes can impart multifunctional properties to fabrics and can therefore be applied for various industries.

Mahale *et al*. (2006) selected mahogany leaves for dye extraction and optimization of dyeing conditions by using different textile materials including cotton, silk and wool. A neutral non-bitter principle, Swietenine and a bitter hygroscopic component, Sweitenoide were isolated from the seeds. Melianone was found to be present in the dried leaves of the tree. In addition to optimizing the dye ingconditions, an attempt was made to assess the colourfastness properties of the textile materials. It was observed that cotton dyed with ferrous sulphate, post-mordanted, has the highest dye absorption. Silk and wool showed the highest dye absorption for stannous chloride under the post-mordanting method.

Mukherjee (2006) standardized the strength of dyes and dose of mordants, which were interrelated to each other, were extremely necessary for shade reproducibility as well as for the prevention of serious water pollution. Natural dyes were mostly obtained from vegetable sources which yield dyes according to their maturity, climate and soil. Hence the fact cannot be denied that a natural dye manufacturer will feel the difficulties in controlling the dye strength as well as tone apart from the brightness which was inherent to natural dyes in most of the colorants. But strength approximation after dye manufacture for each batch can be done in terms of a standard metallic mordant from which the doses of other mordanting salts can be correlated.

Murthy (2006) featured an audio-visual representation of antique natural dyes obtained from nature, and modern Laser dyes made by academia at an event held on 9 December, 2005. The topics discussed highlighted the developments and applications of natural dyes such as Ajrakh, and synthesis and structure of laser dyes. Mrs. Hundekar, a student from textiles division of UICT highlighted techniques of Ajrakh printing, which mainly focused on indigo blue dyeing from nature. Dr. Sekar, a co-investigator of project entitled Development of Dye Dope Polymeric Sol Gel Laser Materials, gave a presentation on dye lasers, focusing on the functioning, evolution, properties, ad dyes used for these lasers. It was suggested that both laser dyes or synthetic dyes should not be compared with natural dyes as both target different designs for unique niche marketing.

Rawat *et al*. (2006) studied the application of poinsettia leaf dye, an environmental friendly natural dye, on silk fabric. The fastness properties were found satisfactory. A silk fabric, which was degummed using a solution of genteel and water, was dyed with poinsettia leaves and the dyed fabric was subjected to colour fastness testing. The dye may be useful imparting number of fast shades on silk using common mordants such as $FeSO_4$ and $CuSO_4$ with good fastness properties except alkaline perspiration.

Sarkar *et al*. (2006) applied the portion of extracted natural dye on hydrophilic substrate like bast fibre. The hydrophilic textile substrate like 100% flax were chosen and prepared for the application of dye to obtain true shades of natural dye. Four chosen flowers were Marigold, Butterfly pea, China rose and Balsam. Use of acid dye bath choice of acid showed a definite improvement in the substantivity. Result showed good substantivity on flax fibre. There was also improvement in the fastness property.

Sudhakar *et al*. (2006) extracted natural dye from the nuts of *Areca catechu* grown abundantly in India and utilized for coloration of silk fabric. Different mordants at varying concentrations were used on silk for pre-mordanting to study their effect on the colour value and fastness properties of the dyed samples. Silk fabrics were also dyed with different mordanting techniques using lowest concentration of mordants. Colour values with respect to K/S, L* a* b* and fastness properties were found to be influenced by the type of mordant and technique of mordanting with very low concentrations of the mordant.

Teli and Paul (2006) discussed the creative potential, non-pollutant nature, and soft lustrous colours of natural dyes enable them to be used in eco-friendly methods of dyeing textiles. An attempt has been made to extract a natural dye from the coffee-seed for its application in dyeing textiles like cotton and silk. The dyeing was carried out by pre-mordanting, meta-mordanting and post-mordanting, using several mordants including myrobolan and ferrous sulphate. The result indicated that coffee-seed extract develops a range of shades with good fastness properties on cotton and silk and give different tones and higher depth of dyeing.

Alam *et al*., 2007 reported that henna plant leaves (*Lawsonia inermis*) contain dye along with other ingredients. The dye component was extracted and applied on silk fibre in order to investigate the dyeing characteristics, e.g. dyeability, fastness etc. It was found that the dye up take by silk fibre was decreased with the increase of dye concentration.

Gupta and Laha (2007) treated cotton fabric with tannin-rich extract of *Quercus infectoria* plant in combination with alum, copper and ferrous mordants and then tested for antimicrobial activity against Gram- positive and Gram-negative bacteria. The study also shows that the cotton textiles can be successfully treated with *Q. infectoria* to produce bioactive textiles from natural eco-friendly material. It was a viable alternative to synthetic antimicrobial agents for use in hospital textiles and an effective anti-odour agent for use in sports and household textiles.

Kale *et al*. (2007) analyzed the optimization of dye extraction time, dye material concentration and mordant concentration were also discussed. The right mordant selection, colour fastness properties and the fastness grades were described.

Punjani and Goel (2007) documented 29 species of natural dye-yielding plants and gather information on indigenous knowledge system associated with extraction and use of natural dyes for preparation of Patiola by one of the Salvi families in Patan city of north Gujarat.

Shanker and Vankar (2007) extracted natural dye of *Hibiscus mutabilis* which has been used for dyeing textiles. Aqueous extract of the flowers yield shades with good fastness properties. The dye has good scope in the commercial dyeing of cotton, silk for garment industry and wool yarn for carpet industry. In the present study dyeing with *H. mutabilis* has been shown to give good dyeing results. Pre-treatment with 2-4 % metal mordants and keeping M:L ratio as 1:40 for the weight of the fabric to plant extract is optimum showing very good fastness properties for cotton, silk and wool dyed fabrics.

Sharma *et al*. (2007) explored the herbaceous plant *Eupatorium adenophorum* as a very good green colour source for dyeing of silk yarn with excellent fastness properties. The concentration of dye material was optimized by taking seven concentration prepared by boiling.

Tiwari and Vankar (2007) carried out standardisation and optimisation of dye extraction of *Terminalia arjuna* bark. The dyeability of aqueous extract was evaluated for dyeing cotton fabric. Dyed cotton fabric shows good fastness properties and evaluated as commercially viable natural dye source.

Vankar *et al.* (2007) used *Bischofia javanica* for natural dye production for textile dyeing. In the present study innovative sonicator dyeing with *B. javanica* has been shown to give good dyeing results. Pre-treatment with 1-2 % metal mordant and using 5% of plant extract (owf) was found to be optimum and shows very good fastness properties for cotton, wool and silk dyed fabrics.

Vankar *et al*. (2007) studied two step ultrasonic dyeing of cotton and silk fabrics with natural dyes, *Terminalia arjuna*, *Punica granatum* and *Rheum emodi* have been developed in which an enzyme was complexed with tannic acid first as a pre-treatment. This was found to be comparable with one step simultaneous dyeing. The effectiveness of three enzymes protease-amylase, diasterase and lipase was determined. The enzymatic treatment gave cotton and silk fabrics rapid dye adsorption kinetics and total higher adsorption than untreated samples for all the three dyes. The CIELab values also showed improvement by enzymatic treatment. The tannic acid-enzyme-dye combination method offers an environmentally benign alternative, 'soft chemistry' to the metal mordanted natural dyeing.

Vankar *et al*. (2007) discussed on the study of cotton fabric using *Eclipta* as natural dye in both conventional and sonicator methods. The effects of dyeing showed higher colour strength values obtained by the latter. Dyeing kinetics of cotton fabrics were compared for both the methods. The time/dye uptake reveals the enhanced dye uptake showing sonicator efficiency. The results of fastness properties of the dyed fabrics were fair to good. CIELAB values have also been evaluated.

Vankar *et al*. (2008) studied the production of anthraquinone reddish orange dyes in roots stem and leaves, which has been used for dyeing textiles since ancient times from *Rubia cordifolia*. Commercial sonicator dyeing with *R. cordifolia* showed that pre-treatment with biomordant, *Eurya acuminata* DC vareuprista Karth. (Theaceae family) in 2 % showed very good fastness properties for dyed cotton using dry powder as 10 % of the weight of the fabric was optimum. Use of biomordant replaces metal mordants making natural dyeing eco-friendly.

Kar and Borthakur (2008) reported 44 dye yielding plant species for dyeing handloom textile products of different communities of Assam like Bodo, Karbi, Dimasa, Mishing, Rabha, Deori, Garo, Khasi, Jaintia, Tiwa, Kuki, Hmar, Zeme, Nagas, Rengma Nagas etc.

Sivakumar *et al*. (2009) reported the influence of process parameters for ultrasound assisted leaching of colouring matter from plant materials. They studied the extraction of natural dye from beetroot using ultrasound and compared with static or magnetic stirring as a control process at 45°C. The influence of process parameters on the extraction efficiency such as ultrasonic output power, time, pulse mode, effect of solvent system and amount of beetroot has been studied. The use of ultrasound was found to have significant improvement in the extraction efficiency of colorant obtained from beetroot.

Kulkarni *et al*. (2011) used pomegranate peel for dyeing cotton cloth using two mordants- copper sulphate and ferrous sulphate in the ratios 1:1, 1:3, 3:1. Large range of shades was obtained because of varying mordant ratios and combinations. The production cost of the pomegranate peel dye was estimated to be cost-effective as compared to the cost of dyes in local market.

Samanta *et al*. (2011) studied on the selective (single and double) and natural dyeing of 6% H_2O_2 (50%) bleached jute fabric have been carried out using myrobolan (harda) and metallic salts (potash alum and aluminium sulphate) as mordants and aqueous extract of tesu (palash flower petals) as dyeing agent under varying dyeing condition to optimize the dyeing process variables.

Arora and Rastogi (2012) used Ratanjot (*Arnebi anobilis* Rech. f) to extract dye for its application on various textile substrates such as cotton, wool, silk, nylon, polyester and acrylic. The sensitivity of the dye extract to pH and temperature is studied.

Bose and Nag (2012) attempt to isolate natural dyes from the flower of *Hisbiscus rosa-sinensis*. In the result, three different colours like blue, purple and green were prepared from the *H. rosa-sinensis* flower and they were well stable on cotton cloths after washing by hot water and soap too. The intensity of the three colours were also high, they were bright and really eco-friendly to the human skin.

Chandravanshi and Upadhyay (2012) studied the interaction of two Indian natural dyes, namely madder (*Rubia cordifolia*) and mallow (*Punica granatum*), with cationic surfactant cetyltrimethyl ammonium bromide and anionic surfactant sodium lauryl sulphate. The critical micelle concentration of the surfactants, determined by measurement of specific conductance and surface tension, was found to decrease on the addition of natural dyes in an aqueous solution of surfactants. The thermodynamic and surface parameters for the interaction have been evaluated.

Das and Mondal (2012) highlights the uses of dye yielding plants by the local people in two famous handicraft- ‘Patchitra’ in Pingla and ‘Mat craft’ in Sabang areas of Paschim Medinipur district and deliberation their act of living. The indigenous knowledge of using the natural dye from plants has been carried out their tradition from generation to generation without any transformation. In this investigation there are 15 dye yielding plants belonging to 11 families have been recorded and collected information about few plant species which used largely in medicine by local vaid’s and local ethnic people. This study was to focus about the usefulness of natural dye in the traditional job in the district and to make a conscious of actual need of conservation of indigenous knowledge through natural dye yielding plants.

Despande and Chaturvedi (2012) effort to yield a natural dye from different parts of *Ricinus communis*. With different mordant green, brown and yellow shades were obtained on clothes. Excellent fastness property of the dye was observed. A smart green shade was observed on cotton cloth with $CuSO_4$ as mordant.

Keka *et al*. (2012) demonstrates the microwave irradiation as a new technique to extract colorants from a selected flower, i.e. butterfly pea which can be found abundantly in India. Colorant from this flower was extracted at different elevated times, from 10 sec up to 2 min using microwave technique and the extracts obtained were compared to those obtained by aqueous extraction method at 30 min to 3 h. The colour strength and yield of dye extracts was analyzed using UV-Visible spectrophotometer. It was observed from the experimental results that the extraction using microwave techniques gives better results than the conventional aqueous extraction methods.

Singh and Mathur (2012) reported that the local weavers and ethnic communities of Firozabad, U.P. use plant dyes for imparting different shades to their clothes, hands, hairs and food items. About 19 plant species belonging to 17 families of Dicots, mostly trees and herbs have been identified as traditional dye yielding plants.

Singh and Purohit (2012) studied on the colour fastness properties of the flowers of *Erythrina suberosa* dyed on wool using combination of mordants such as lemon juice : ferrous sulphate and lemon juice : stannous chloride in the ratio of 1:3, 1:2 and 3:1. Dyeing along with mordanting techniques which included pre-mordanting, simultaneous mordanting and post mordanting was carried out. Large range of shades was obtained because of varying mordant ratios and combinations. The washing, rubbing, light and perspiration fastness of the dyed samples was also evaluated, giving fair to excellent fastness grades.

Teron and Borthakur (2012) conducted a study of traditional Karbis knowledge dye and dyeing techniques in Karbi Anglong District, Assam. The use of dyes for imparting specific colour or colour combinations was found to play an important role in the social and religious life of the Karbis. Yarn, fibres and garments were often dyed (e.g., black, blue, indigo, yellow, red, pink) with plant extracts, animal products and even minerals.

Upadhyay and Choudhary (2012) enumerated 100 plant species for dye, out of these 15 species belonging to 12 genera and 12 families. Different shades of colours were obtained using different plant parts and different mordant.

Alwa *et al*. (2013) reported the used of dyes for making specific colour or colour combinations play an important role in the social and religious life of the tribals. Eighteen dye yielding plants have been observed in the study area which was used by tribal. Indigenous knowledge of ethno-herbal dye was facing threats from synthetic dyes and needs attention for conservation.

2.3 Review works on local context

Sharma *et al*. (2005) discusses 34 plant species belonging to 30 families used in the extraction of dyes by the Meitei community of Manipur. The plant parts used in the extraction of dyes along with the method of extraction and their uses have also been described in detail. Another 19 plant species belonging to 14 families used as dye mordants have also been included.

Lunalisa *et al*. (2008) reported more than 50 plant species in Manipur, which is used as dyes right from ancient times, before chemical dyes were introduced in the state. *Parkia timoriana*, *Melastoma malabathricum*, *Solanum nigrum*, *Bixa orellana*, *Tectona grandis*, *Strobilanthes cusia* etc. were common plants used by the Meitei community and many tribes of Manipur. The compound isolated from these plants and the indigenous knowledge on dye preparation was also reported.

Singh *et al*. (2009) reported varieties of plants and its parts as source of dye. Also reported that the use of *kum* (*Strobilanthe scusia*) was more significant than any other type of vegetable dyes because of its superior quality than the others.

Ningombam *et al*. (2012) done a case study with the *kum* dye [*Strobilanthes cusia* (Nees) Kuntze] used by the Meitei community in Manipur, northeast India. The study focused on economic activities and feedback that could revive the *kum* dye and *kum dye phanek* cultural traditions.

2.4 Review works on bacterial identification and isolation from dyes

Padden *et al*. (1999) isolated a gram positive, anaerobic, moderate thermophile strainWv6T (*Clostridium isatidis*), capable of reducing indigo dye from a fermenting woad vat prepared essentially as in medieval Europe.

Kenji *et al*. (2005) isolated an alkaliphilic bacteria, *Alkalibacterium iburiense* sp. nov., an obligate alkaliphile that reduces an indigo dye. For phenotypic characterization of the bacteria, alkali-RCA or alkali-RCB was used as the basal medium. The 16srRNA gene sequence was also analysed.

Nakajima *et al*. (2005) isolated three indigo-reducing obligately alkaliphilic strains, M3(T), 41A, 41C. The isolates grew at pH 7-8. They were Gram-positive, facultatively anaerobic, straight rod-shaped strains with peritrichous flagella. The isolates grew in 0°-14°C, with optimum growth at around 30°-37°C. They did not hydrolyse starch or gelatine. DL-lactate was the major end-product from D-glucose.

Yumoto *et al*. (2008) isolated indigo-reducing, obligately alkaliphilic strains A11^T, F11 and F12 from indigo fermentation liquor obtained from Tokushima Perfectine, Shikoku Japan. The isolates grew at pH 9.0-12.3, but not at pH 7.0-8.0. The optimum pH range for growth was 9.5-11.5. They were Gram -ve, facultatively anaerobic, rod-shaped strains with peritrichous flagella. Phylogenetic analysis based on 16S rRNA gene sequence data indicated that the isolates belong to the genus *Alkalibacterium*.

Aino *et al*. (2010) characterized the bacterial community and dynamics of indigo fermentation in Japan. Bacterial community structure associated with indigo fermentation using denaturing gradient gel electrophoresis and clone library analyses of a PCR-amplified 16S rRNA gene in the early phase of fermentation was carried out. A marked substitution of *Halomonas* spp. by *Amphibaccilus* spp. was observed corresponding to the marked change in the state of indigo reduction. Novel indigo-reducing strains, *Amphibacillus* spp. strain C40 and *Oceanobacillus* spp. strain A21, were isolated from fermentation liquor aged for 10 months and from liquor aged for 4 days, respectively.

Park *et al*. (2012) identified *Alkalibacterium* sp. and *Pseudomonas* sp. as the indigo reducing bacteria of the fermented liquor of *Polygonum tinctorium* (indigo plant) aged for 6 years. Based on the concentrations of leuco-indigo reduced from indigo *Alkalibacterium* sp. and *Pseudomonas* sp. showed alkaliphilic and thermotolerant characteristics, optimally functioning at pH 10.0 and temperature 50°C. It was also concluded that isolation of alkaliphilic and thermotolerant bacterial strains, which can reduce insoluble indigo into leuco-indigo, from Korean traditional fermentation liquor could provide a biological tool to enhance efficiency in the traditional indigo dye by an environmentally friendly manner.