CHAPTER 1

INTRODUCTION

1.1 GENERAL

There is an ever increasing demand for fabric in the world due to population growth. More than 7,00,000 tonnes of ten thousand different synthetic dyes are produced and used for dyeing of fabric annually worldwide (Prakash 1996).

Textile industry plays an important role in the industrial development of India and is the second largest sector of Indian economy, next to agriculture. A large number of textile mills have mushroomed in India to meet the demand for fabric. These mills are located mainly in Gujarat, Maharashtra, Delhi, Tamil Nadu and Karnataka. These mills consume large volumes of water for various processes. It is estimated that 100 to 200 liters of water is required for processing one kilogram of fabric. The wastewater of the dyeing process is highly coloured by the release of unfixed dye. It is estimated that 10-15 percent of the dye is lost during dyeing process (Jiantuan and Jiuhui 2003).

The textile dyeing wastewater contains dyes of various intense colours. The coloured wastewater of dyeing processes is not merely aesthetically objectionable. Extremely high doses of colour can interrupt photosynthesis and lower the dissolved oxygen content of receiving waterways / water bodies, which may lead to killing of fish. Dyes having
functional group of alkenes, aromatic,-c-n, -s = o-, -n=n- are responsible for colour development in wastewater.

1.2 STATUS OF TEXTILE DYEING INDUSTRY

Textiles exports contribution is 16.63% of India’s total exports earnings, and the country’s share in the global textiles and apparel market is 3.9% and 3% respectively.

1.2.1 Status in India

The Indian Textiles Industry has an overwhelming presence in the economic life of the country. Apart from providing one of the basic necessities of life, the textiles industry also plays a pivotal role through its contribution to industrial output, employment generation, and the export earnings of the country. Currently, it contributes about 14 percent to industrial production, 4 percent to the GDP, and 16.63 percent to the country’s export earnings. It provides direct employment to over 35 million. The textiles sector is the second largest provider of employment after agriculture. Thus the growth and all round development of this industry has a direct bearing on the improvement of the economy of the nation. The close linkage of the industry to agriculture and the ancient culture and traditions of the country make the Indian textile sector unique in comparison with the textile industries of other countries.

1.2.2 Status in Tamil Nadu

Tamil Nadu is one of the major textile exporting regions in the country. The total number of units in Tamil Nadu is 2267. In places like Tiruppur (729), Erode (694), Coimbatore (60), Karur (487), Salem (254), Namakkal (270) and Kanchipuram (68) where the dyeing units are located in clusters, Common Effluent Treatment Plants (CETPs) and Individual Effluent Treatment Plants (IETPs) are provided for the treatment of wastewater. The
Tamil Nadu Pollution Control Board (TNPCB) insists that all the textile processing units provide zero liquid discharge system so as to avoid further contamination of fresh water resources and also to avoid ground water exploitation.

1.2.3 Textile Dyeing Wastewater

Textile dyeing industry is one of the major industries consuming large amount of water for its various operations and also discharges vast quantity of wastewater. The dyeing wastewater is strongly coloured due to the utilization of various dyestuffs. Colour is imparted to the dyeing effluents by the spent dye bath and unfixed dyes wash off during the washing process. The discharge of effluent contaminates the ground water and the soil (CPCB 2000).

1.2.4 Wastewater Discharge Standards

In India, the Water (Prevention and Control of Pollution) Act was enacted in the year 1974 to control and prevent water pollution. Under this Act, tolerance limits have been set for the discharge of industrial wastewater. The textile dyeing industries are classified as highly polluting industries. For the purpose of protecting and improving the quality of the environment and preventing pollution, the standards for discharge of environmental pollutants from the industries, operations, or processes are specified in schedule I to IV (Rule 3 of the Environment (protection) Rules 1986).

1.3 WASTEWATER GENERATION DURING TEXTILE PROCESSING

Textile dyeing process cycle involves de-sizing, scouring, bleaching, washing, dyeing, fixing, washing, finishing and drying of fabric/yarn. Out of these processes, bleaching and dyeing process generate large quantities of wastewater.
1.3.1 Description of Bleaching Process

A schematic chart of the bleaching process is shown in Figure 1.1. Bleaching is carried out to remove the natural colouring material from the fabric and to whiten the cloth. There are two types of bleaching:

1. Hypochlorite bleaching
2. Peroxide bleaching

In hypochlorite bleaching, the material is loaded in a winch and water (10 to 12 times its weight) and wetting oil (0.35% by weight of material) are added. This is allowed to run for half an hour for uniform wetting, followed by addition of 3% caustic soda by weight. The temperature is raised to 80°C by passing steam. After allowing a process time of 30 minutes, a 10% (by weight) solution of bleaching powder is added to the bath and it is run for two more hours. The material is then washed with fresh water and then treated with sodium bisulphite solution for half an hour. This process is followed by washing and draining and addition of 8% hydrochloric acid (by weight of material) for neutralization. Finally, the material is washed twice or thrice as per the quality requirement and is set for dyeing.

In peroxide bleaching, after the initial wetting, the material is treated with 3% caustic soda and 0.75% stabilizing agent for about 30 minutes. This is washed and hydrogen peroxide (3% by weight of material) is added. The temperature of the bath is maintained at 80°C and bleaching is carried out for two and half-hours. Post peroxide bleaching, the material is washed and neutralized with 8% hydrochloric acid. Finally the material is washed twice or thrice as per the quality requirement and is set for dyeing.

Alkaline hypochlorite or chlorine bleaching is the predominant bleaching process. Peroxide is normally used for bleaching good quality fiber.
The chemicals used in peroxide bleaching are sodium peroxide, caustic soda, sulphuric acid and certain soluble oils. Water required to bleach the cloth fluctuates between 40-48 liters/kg of yarn bleached, but can vary marginally depending on the type of operation and the material (yarn/cloth) to be processed. The wastewater from yarn or fabric bleaching would contain all the above mentioned inorganic chemicals.

**Figure 1.1  General Bleaching Operations** (Source: Comprehensive Industry Document on Textile Industries (COINDS), CPCB, 2010)
1.3.2 Description of Dyeing Process

Dyeing is the application of colour to the cloth. There are many classes of dyes: Reactive dyes, vat dyes, napthol dyes, acid dyes, basic dyes and natural dyes (which include vegetable dyes). The water requirement for dyeing (for different types of dyes and shades) varies between 36 – 176 liters/kg, with an average of 106 liters/kg. The effluent generation during dyeing process is slightly lower than the water intake and is between 35 to 175 liter/kg, with an average of 105 liters/kg.

The dyeing process is as follows: The bleached material and water are loaded into the winch along with the required quantity of dyestuff (varying from 0.001% to 10% as per the colour and quality required). Common salt (about 40 to 120% of the weight of material is added to dye bath) depending on the shade required. Sodium carbonate (4-22% of the material weight) and caustic soda (1-3% of the material weight) are also added and the winch is operated at 80°C for 1-3 hours. The material is then washed with fresh water for half an hour and the whole process is repeated. Next, detergent is added to the winch and followed by 5-10% hydrochloric acid treatment for neutralization. The material is washed twice before adding dye-fixing agent (about 1% of the weight of material). The material is washed after each operation. The characteristics of the effluent vary depending upon the type of dyes used. However, almost all the industries use reactive dyes. The flow diagram of dyeing process and the steps releasing effluents are shown in the Figure 1.2.
**Figure 1.2** General Dyeing Operations  
(Source: Comprehensive Industry Document on Textile Industries (COINDS), CPCB, 2010)
1.4 ENVIRONMENTAL PROBLEMS DUE TO DISCHARGE OF EFFLUENT

The discharge of effluent contaminates the ground water and the soil. Discharge of effluent into water bodies can upset the penetration of sunlight and biological activity in the water body. It affects photosynthesis of the phytoplankton, retarding the self-purification capacity of the water body. The dye is visible even at small concentrations and the transparency of streams would also be reduced. Colour being an indicator of pollution, hampers the use of water for certain industrial and recreational purposes. Coloured industrial wastewaters are considered to be toxic. Most of the dyes are non-biodegradable and toxic. Azo dyes are considered to be carcinogenic. Many amino substituted azo dyes have been found to be mutagenic as well as carcinogenic. Sulphated azo compounds, which are used as dyes for textiles are reported to be xenobiotic in character (Kanmani 2003).

1.4.1 Environmental Issues of Textile Units at Tiruppur

Tiruppur is one of the largest and fastest growing city in Tamil Nadu. It is the seventh largest city in Tamil Nadu. It has grown as a ‘Municipal Corporation’ and is the headquarters for the newly formed Tiruppur District. It is the 32nd District of Tamil Nadu and one among the ten well industrialized and economically developed districts of Tamil Nadu. It had attracted the attention of both the policy makers and businessmen at the national and international levels, mainly because of its continuous business growth and its outstanding performance. It is popularly known as “Banian City” of Southern India. The knitwear industry, which is the soul of Tiruppur, has created lakhs of jobs for all class of people. Tiruppur is the knitwear centre of India. As a predominant export niche, the town gains its significance for its updated technology and the quality of its macro-economic environment. Buyers from more than 50 countries frequently come to
Tiruppur. More than 80 per cent of India’s total knitwear exports originates from here.

1.4.2 Environmental Problems

Tamil Nadu’s textile city, Tiruppur, which has nearly 729 dyeing units, is ranked topmost in terms of generating hazardous waste. The bleaching and dyeing units use large quantities of water, but most of the water used by these units is discharged as effluent, containing a variety of dye and chemical (acids, salts, wetting, agents, soaps, oil etc.). These units discharge nearly 90 mld of effluents on land or into the Noyyal River, leading to contamination of the ground and surface water and soil in and around Tiruppur and downstream. A number of mechanical, thermal and chemical processes are involved in the textile industry and each process has a different impact on the environment. This impact starts with the use of pesticides during the cultivation of natural fibers. During the past few decades, there has been growing awareness of the environmental problems which have become an important issue in the textile trade, thanks to the various environmental and health legislations. Environmental policy is increasingly dictated by market forces.

Many chemicals use in the textile industry cause environmental and health problems. These problems may occur during the production process, with respect to emission or occupational health problems. Other problems caused by these chemicals manifest due to their presence in the final product. However, worldwide environmental problems associated with the textile industry are typically those associated with the water pollution caused by the discharge of untreated effluent, particularly due to these of toxic chemicals during processing. These chemicals can harm end consumers, if retained in the fabric. The textile industry is facing challenges due to social and environmental compliance issues from US and European buyers.
Textile processing is a water intensive process. The wastewater generated by the industry is high in BOD, COD, pH, temperature, colour, turbidity and toxic chemicals. These effluents need to be treated chemically to remove the hazardous material and chemicals so that the wastewater will comply with the prescribed limits and can be discharged into the public sewer or into aquatic bodies.

1.5 DYESTUFFS

Dyes are large structured polymers which are used to impart the desired colour to the fabric. The colour causing groups are called chromophore. The colour of chromophore is due to the presence of bonds of unsaturation (Venkatraman 1972).

1.5.1 Classification of Dyes

Dyes are classified based on the chemical composition and method of application. From a marketing and utilization point of view, dyes are classified as presented in Table 1.1.

Table 1.1 Classification of Dyes

<table>
<thead>
<tr>
<th>Class</th>
<th>Properties</th>
<th>Chemical Structure</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid dyes</td>
<td>Water-soluble anionic</td>
<td>Azo, Anthraquinone</td>
<td>Wool, polyni, silk</td>
</tr>
<tr>
<td>Basic dyes</td>
<td>Water-soluble anionic</td>
<td>Triphenylmethane modified azo, anthraquinone</td>
<td>Polyacrylnitril modified synthetics</td>
</tr>
<tr>
<td>Direct dyes</td>
<td>Water-soluble anionic</td>
<td>Azo stilbene, phthaloeyanine</td>
<td>Cotton, viscose, linen</td>
</tr>
<tr>
<td>Reactive dyes</td>
<td>Water-soluble anionic</td>
<td>Sulphonic acid group</td>
<td>Cotton, viscose</td>
</tr>
<tr>
<td>Pigments</td>
<td>Water-soluble nonionic</td>
<td>Azo, anthraquinone, phthaloeyanine, quinacridone</td>
<td>All</td>
</tr>
<tr>
<td>Disperse dyes</td>
<td>Water-soluble anionic forms covalent bonds with substrate</td>
<td>Azo, anthraquinone, phthaloeyanine</td>
<td>Cotton, Viscose linen, wool, silk</td>
</tr>
<tr>
<td>Sulphur dyes</td>
<td>Temporarily solubilized with alkali sulphide</td>
<td>Sulphur</td>
<td>Cotton, viscose</td>
</tr>
<tr>
<td>Vat dyes</td>
<td>Temporarily solubilized as leuco ester with alkaline sodium hydrosulphate</td>
<td>Anthraquinone indigo</td>
<td>Cotton, Viscose linen, silk</td>
</tr>
</tbody>
</table>

(Source: Booth 1998; Schulze Rettmer 1999)
1.6 TREATMENT OF TEXTILE DYEING WASTEWATER

Textile industry is a leading industry for many countries, such as India, China, Singapore, UK, Bangladesh, Italy and Turkey. Environmental pollution is one of the main concerns of this industry. Besides being users of huge amounts of water and chemicals, the textile dyeing and finishing industry is one of the major polluters among industrial sectors, in terms of volume and the chemical composition of the discharged effluent (Pagga and Brown 1986). Textile industry effluents can be classified as dangerous for receiving waters, and commonly contain high concentrations of recalcitrant organic and inorganic chemicals, characterised by high chemical oxygen demand (COD) and total organic carbon (TOC), high amounts of surfactants, dissolved solids, fluctuating temperature and pH, possibly heavy metals (e.g. Cu, Cr, Ni) and strong colour (Grau 1991 and Akal Solmaz et al 2006). The presence of organic contaminants such as dyes, surfactants, pesticides, etc., in the hydrosphere is of particular concern for the freshwater, coastal, and marine environments because of their non-biodegradability and potential carcinogenic nature of the majority of these compounds (Demirbas et al 2002; Fang et al 2004; Bulut and Aydin 2006; Mahmoudi and Arami 2010; Amini et al 2011). The major concern with colour is its aesthetic character at the point of discharge with respect to the visibility of the receiving waters (Slokar and Le Marechal 1998).

The main reason for colour in textile industry effluent is the usage of large amounts of dyestuffs during the dyeing stages of the textile-manufacturing process (O’neil et al 1999; Georgiou et al 2002). Inefficient dyeing processes often result in significant dye residuals being present in the final dye house effluent, in hydrolised or unfixed forms (Yonar et al 2005). Apart from the aesthetic problems relating to coloured effluent, dyes also strongly absorb sunlight, thus impeding the photosynthetic activity of aquatic plants and seriously threatening the whole ecosystem. Stricter
regulatory requirements along with an increased public demand for colour-free effluent necessitate the inclusion of a de-colourisation step in wastewater treatment plants (Kuo 1992).

Well known and widely applied treatment method for the treatment of textile industry wastewater is the activated sludge process and its modifications. Combination of activated sludge process with physical and chemical processes can be found in most applications. These traditional treatment methods require large spaces and are affected by wastewater flow and characteristic variations. Moreover, activated sludge process modifications themselves or combinations of this process with physical or chemical processes are inefficient in the treatment of coloured waste streams (Venceslau et al 1994; Willmott et al 1998; Vendevivere et al 1998; Uygur and Kok 1999).

On the other hand, in the advanced physico-chemical treatment technologies such as, membrane processes, ion exchange, activated carbon adsorption etc., only transfer pollutants from one phase to the other phase rather than eliminating the pollutants from effluent body. Recovery and reuse of certain and valuable chemical compounds present in the effluent are under investigation by most scientists (Erswell et al 2002). At this point, Advanced Oxidation Processes (AOPs) show specific advantages over conventional treatment alternatives because they can eliminate non-biodegradable organic components and avoid the need to dispose of residual sludge. AOPs, based on the generation of very reactive and oxidizing free radicals, especially hydroxyl radicals, have been used with an increasing interest due to the their high oxidant power (Kestioglu et al 2005).

1.6.1 Treatment Technologies Adopted in Textile Dyeing Industries

The various physical, chemical and biological processes used for the removal of colour from the wastewater fall into two categories viz.,
separation of the colour components and decomposition of the colour component. Chemical precipitation falls in to the first category and the biological processes and chemical oxidation (AOP) methods fall into the second category (Kanmani 2003).

1.6.1.1 Chemical precipitation

The chemical coagulation consists of adding small amounts of certain chemicals like alum, ferrous sulphate, ferric chloride etc., to wastewater, which form flocculent precipitates. Use of coagulant aids like polyelectrolyte can improve the efficiency of coagulation (Metcalf and Eddy 2004). Chemical coagulation of textile dyeing effluents produces considerable amounts of recalcitrant, toxic dye bearing sludge, the quantity of which is a function of influent suspended solids content and dosages of chemicals. It is undesirable that large amounts of sludge is formed, which results in high costs (COINDS/2010). The coagulation treatment alone may not be sufficient for complete decolourization.

1.6.1.2 Biological treatment

Biological degradation, the traditional method is inadequate since most dyes are recalcitrant. It becomes difficult to apply this technique since the dyeing wastewater requires longer period of acclimation and is slow to degrade; also, it requires a larger area and consumes more energy besides continuous monitoring.

1.6.1.3 Oxidation methods

The oxidation methods can be carried out using chemical such as chlorine or using advanced oxidation processes. Chlorine is often used to decolorize the wastewater. It can be applied in the form of liquid or gas, chlorine water or hypochlorite. The drawback of this method is that it has a
potential for generating chlorinated organics that are harmful to both lives and the environment.

1.7 ADVANCED OXIDATION PROCESSES

A lot of research has been directed at a special class of oxidation technique known as Advanced Oxidation Processes (AOPs), pointing out its potential prominent role in the wastewater treatment (Legrini et al. 1993; Bahnemann et al. 1994; Hoffmann et al. 1995; Robertson 1996). These treatment processes are considered as very promising methods for the remediation of ground and surface waters that are polluted by non-biodegradable organic industrial effluents. The AOPs were defined by Glaze et al. (1987) as near ambient temperature and pressure water treatment processes which involve the generation of highly reactive hydroxyl radicals (OH*) in sufficient quantity to effect water purification. The hydroxyl radical is a powerful, nonselective chemical oxidant which reacts very rapidly with most organic compounds. Table 1.2 shows the oxidation potential of some well known oxidants, where hydroxyl radical has the highest thermodynamic oxidation potential next to fluorine.

**Table 1.2 Oxidation Power of Selected Oxidants**

<table>
<thead>
<tr>
<th>Oxidant</th>
<th>Oxidation potential(eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorine</td>
<td>3.03</td>
</tr>
<tr>
<td>Hydroxyl radical</td>
<td>2.80</td>
</tr>
<tr>
<td>Atomic oxygen</td>
<td>2.42</td>
</tr>
<tr>
<td>Ozone</td>
<td>2.07</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>1.77</td>
</tr>
<tr>
<td>Potassium permanganate</td>
<td>1.67</td>
</tr>
<tr>
<td>Chlorine dioxide</td>
<td>1.50</td>
</tr>
<tr>
<td>Hypochlorous acid</td>
<td>1.49</td>
</tr>
<tr>
<td>Chlorine</td>
<td>1.36</td>
</tr>
<tr>
<td>Bromine</td>
<td>1.09</td>
</tr>
</tbody>
</table>

(Source: Carey 1992; Munter 2001)
The versatility of AOPs is also enhanced by the fact that they offer different possible ways for hydroxyl radical production, thus allowing a better compliance with the specific treatment requirement. The AOPs are usually classified of different ways according to the reaction phase (homogeneous or heterogeneous) or to the hydroxyl generation methods (Gogate and Pandit 2004a, 2004 b). The classification of AOPs is shown in Figure 1.3.

Figure 1.3 Classifications of Advanced Oxidation Processes
1.7.1 Ozonation

Ozone or ozone based technologies are chemical oxidation processes applied to water treatment for the degradation of individual pollutants or the reduction of organic load and improved biodegradability of wastewaters (Reynolds et al 1989; Rice 1997). Ozone is a powerful oxidizing agent that is able to participate in great number of reactions involving organic and inorganic compounds. Ozone decomposition in water is a radical chain process in which decomposition intermediates will further catalyze depletion of molecular ozone. In addition, ozone molecules can directly react with organic compounds which have high electronic density sites. Such direct reactions are usually very selective. In contrast, hydroxyl radical reactions are non selective and will virtually react with almost all the organic compounds by the either H-atom abstraction or direct electron transfer (Zhou and Smith 2002). The major drawbacks are the operating cost, the mass transfer limitations during the transfer of ozone into the pollutant.

1.7.2 TiO$_2$ Photocatalysis

During the past two decades, photocatalytic oxidation of organic contaminants with TiO$_2$ has become attractive as a promising chemical procedure for water purification (Legrini et al 1993; Hoffmann et al 1995). Under near UV irradiation, TiO$_2$ is photo-activated and active oxygen species such as hydroxyl radicals are formed on the surface of the TiO$_2$. Among several semiconductors, TiO$_2$ has proven to be the most suitable for widespread environmental applications. TiO$_2$ is nontoxic, stable to photo and chemical corrosion, and inexpensive. However, the rates of photo catalytic chemical transformations are limited by the rays of electron hole recombination in the bulk of TiO$_2$ or at the surface which are not easily controlled and the slow attainment of mineralization limit the application fields of photocatalysis (Gogate and Pandit 2004a).
1.7.3 Fenton Process

The Fenton reaction discovered by Fenton (1894) has been applied to the degradation of a wide range of contaminants, predominantly persistent organic pollutants. Production of hydroxyl radicals by Fenton reagent occurs by means of addition of hydrogen peroxide to ferrous salts as shown in equation (1.1). This is a simple way of producing hydroxyl radicals where neither special reactants nor special apparatus is required.

\[ \text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \text{OH}^- + \text{OH}^{'}, \quad (1.1) \]

The primary benefits of the Fenton reagent are its ability to convert a broad range of pollutants to harmless or biodegradable products, its benign nature, and the relatively low cost. The main advantage of the photo-Fenton process is the light sensitivity up to a wave length of 600 nm which covers nearly 35% of the solar radiation (Safarzadeh amiri et al 1997). The depth of light penetration is high and the contact between pollutant and oxidizing agent is close, as homogeneous solution is used (Bauer et al 1999; Fallmann et al 1999). The commonly mentioned disadvantage of the photo-Fenton method is the necessity to work at low pH because at higher pH, ferric ions would begin to precipitate as hydroxide. Furthermore, the added iron has to be removed after the treatment.

Among the different AOPs, the Fenton and, especially, the photo-Fenton processes are considered to be the most promising for the remediation of highly contaminated wastewaters (Bossmann et al 1998). They constitute an attractive oxidative system since they do not require either expensive reagents or sophisticated instrumentation for pollutants destruction (Andreozzi et al 1999). Iron is the fourth most abundant element on the earth, as well as nontoxic and safe, whereas hydrogen peroxide, compared with other bulk oxidants, is reasonably priced, easy to handle and environmentally benign.
At the same time, the Fenton reagent is considered a “clean” reagent (Huston et al. 1999). Once the treatment is over, dissolved iron can be removed by precipitation just by increasing the pH of the media (Malato et al. 2003). Moreover, if the employed catalyst amount is small enough (in the order of few mg/L), it could remain dissolved without affecting the quality of the resulting water. Likewise, any residual hydrogen peroxide readily decomposes to O₂ and H₂O, posing no lasting environmental threat (Pignatello et al. 2006).

Fenton type processes are capable of carrying out a deep mineralisation of pollutants with, in many cases, oxidation effectiveness clearly superior than other AOPs (Pignatello et al. 2006; Bauer et al. 1997). Additionally, from an economic and environmental point of view, photo-assisted Fenton process may also surpass most of them. It makes use of photons with wavelengths from the near UV up to visible (~ 550 nm), with the possibility of being driven under solar irradiation (Bauer et al. 1997; Pignatello et al. 1999). Even so, the high operational costs derived from chemical reagents consumption are the main handicap of this technology.

Other associated drawbacks are the instability of the reagent mixture, the necessity of pH changes, the interference by some substances that complex iron ions and the possible iron oxide sludge generation and subsequent disposal (Pignatello et al. 2006).

1.8 COUPLING SOLAR PHOTO-FENTON AND BIOLOGICAL TREATMENT PROCESSES

Coupling of solar photo-Fenton and biological processes is a good alternative in order to minimize the treatment cost of wastewater containing bio-recalcitrant, non-biodegradable and toxic pollutants. Due to the high cost of photocatalytic treatment, it must be confirmed that target pollutants are
definitely non-biodegradable. Since, for biodegradable compounds, classical biological treatments are at present the cheapest and most environmentally compatible. In coupled systems, the photo-Fenton pretreatment is meant to modify the structure of pollutants by transforming them into less toxic and easily biodegradable intermediates, which allows the subsequent biological treatment to be achieved in a shorter time and in a less expensive way. The wastewater resulting from photo-treatment stage is considered to be biologically compatible after the elimination of the initial bio-recalcitrant compound, the inhibitory and/or non-biodegradable intermediates and the residual H$_2$O$_2$ or other inhibitory electron accepters, whenever they are utilized for photo-treatment.

Biological and kinetic studies must always be conducted to ensure that the photo-Fenton pre-treatment induces beneficial effects on the biocompatibility of the treated wastewater. Lee et al (2001) described the advantages of coupled wastewater treatment as 1) synergistic effects as photo-Fenton and biological methods complement each other, 2) protection of biological culture from inhibitory or toxic compounds by photo-Fenton pretreatment, 3) reduction in chemical dosage by the use of cost-effective biological treatment, 4) flexibility in total residence time as a result of different choices that are possible, with photo-Fenton and biological reactor residence time in a constant efficiency and 5) cost-effectiveness in achieving complete pollutant mineralization.

1.9 NEED FOR THE STUDY

Degradation of dyes especially reactive dyes, which contribute to about 70% of all used dyes, is difficult due to their complex structure and synthetic nature. Due to the complex polyaromatic structure and recalcitrant nature, dyes cannot be degraded by means of biological methods. Aromatic amines which are formed as metabolites of reductive cleavage of azo bond
under anaerobic conditions are more toxic than intact dye molecules and hence need further treatment.

Many researchers have focused on only one method of treatment; either biological process or AOP for treating recalcitrant compound. The use of a combination of processes has been a recent development in the treatment of textile dyeing effluents. In line with this development, the present study was planned to evaluate solar photo-Fenton oxidation process with steel scrap as a catalyst to achieve complete decolourization of reactive dye and partial cleavage of aromatic amines to make them easily biodegradable. Further degradation was planned by treating effluent of photo-Fenton’s treatment by aerobic SBRs. Solar light intensity in the study location is quite suitable and is an ideal light source in photo-Fenton oxidation process.

1.10 SCOPE OF THE STUDY

The scope of the research study was to evaluate a coupled treatment system consisting of solar photo-Fenton process with steel scrap as the catalyst and a biological treatment process namely sequential batch reactor for the treatment of textile dyeing effluents.

1.11 OBJECTIVES OF THE PRESENT STUDY

- To study the characteristics of three reactive dyes namely Reactive Blue, Reactive Black and Reactive Yellow.
- To study the characteristics of the textile dyeing effluent.
- To study the characteristics of steel scrap used as a catalyst in Fenton oxidation process.
- To conduct laboratory scale feasibility studies on the degradation of reactive dyes in a conventional Fenton process.
under room light, UV light and solar light conditions, and to evaluate the effects of various operating variables.

- To conduct laboratory scale feasibility studies on degradation of dyes in the textile dyeing effluents in a Fenton process with steel scrap as a catalyst under room light, UV light and solar light conditions and to evaluate the effect of various operating variables on Colour and COD removal.

- To conduct feasibility studies on a bench scale solar photo-Fenton reactor with steel scrap as a catalyst and to study the performance in terms of colour and COD removal.

- To evaluate the biodegradability of solar photo-Fenton with steel scrap as a catalyst treated effluent in the sequential batch reactor (SBR).

1.12 ORGANIZATION OF THE THESIS

Chapter 1 is a general introduction about textile industry, waste water generation, environmental problems due to discharge of effluents, classification of dyes, treatment technologies adopted in textile dyeing industries, advanced oxidation processes, coupling photo-Fenton and biological treatment processes, need for the study and the scope and objectives of the present study.

Chapter 2 provides an overview of literature related to treatment methods for degradation of dyes by Fenton related processes, degradation of dyes in the textile dyeing effluent by Fenton related processes and degradation of dyes in the textile dyeing effluent by coupled Fenton and sequential batch reactor processes.
Chapter 3 discusses the materials and methods adopted for characterization of dye solutions, characterization of textile dyeing effluent and Characterization of steel scrap. In addition, the details of the treatability studies conducted are presented.

Chapter 4 presents the results of experiments and detailed discussion on degradation of three reactive dyes and degradation of reactive dyes in the textile dyeing effluent.

Chapter 5 covers the summary and conclusion of the thesis by highlighting the salient features of the studies carried out.