



# *Review of Literature*

## **2. REVIEW OF LITERATURE**

Review of literature for the present study "**Removal of Color and Odor from Textile Dye Effluent Using *Bacillus Subtilis* and *Thiobacillus Bacteria***" is discussed under the following headings.

- 2.1. Textile Effluent**
- 2.2. Textile Effluent Treatment Methods**
- 2.3 Reused of Decolorized Effluent**
- 2.4 Cotton**
- 2.5 Weaving**
- 2.6 Dyeing**
- 2.7 Use of Biotechnology for Decolorization**
- 2.8 Dye Decolorization**
- 2.9 Odor Biodegradation**
- 2.10 Thiobacillus- Sulphide Oxidizing Bacteria**

### **2.1. TEXTILE EFFLUENT**

Textile waste water includes a large variety of dyes and chemical additions that makes the environmental challenge for textile industry not only as liquid waste but also in its chemical composition. Main pollution in textile waste water came from dyeing and finishing processes. Normally textile effluent is alkaline in nature and has BOD from 900 – 2000 mg/l and high COD at two to five times the BOD level, states Sivaramakrishnan (2008). These processes require the input of a wide range of chemicals and dyes stuffs, which generally are organic compounds of complex structure, reports Sivakumar and Sundar (2006).

### **2.1.1. Causes of Textile Effluent**

Generally the textile effluent is thrown out from various processes such as desizing, sizing, scouring, bleaching, mercerization, dyeing, printing, finishing and washing, views Das (2007).

Effluent generated at various stages of textile dyeing differs in its composition, strength as well as volume. The high pollution load of dye effluent arises from spent dye bath composed of unexhausted, hydrolysed and surface deposited dyes as well as chemicals and auxiliaries, say Lal and Nishkam (2005).

Wash water from desizing unit contain 70% of the total COD load in the effluent because of the starch in that effluent, reports European Commission (2005). Bleaching releases chemicals like peroxides and hypo chlorides into the effluent which contributes ten percent of the total pollution load in effluents, inform Asolikar and Abhyankar (2000). Effluent from scouring operation contains predominantly oil and greases, view Chilekar and Satam (2000).

In reactive dyes residual color is a major problem compared to other dyes, because 50% of dyes are lost in the effluent. Color in aquatic environment is an escalating problem, review Pearce *et al.*, (2002). It has been estimated that more than 90% of the pollution load of textile mill waste is the result of processed chemicals, especially in the dyeing unit, observe Verma *et al.*, (2001).

### **2.1.2. Environmental Hazards Due to Textile Effluent**

Effluents from the textile industries containing dyes are highly colored and are therefore visually identifiable, review Kilic *et al.*, (2007). Color is usually the first contaminant to be recognized in wastewater, report Wong and Yu (1999) and thus, the color present in dye effluents gives a straight forward indication of water being polluted, and the discharge of these highly colored effluents can damage directly the receiving waters, review Chen *et al.*, (2003).

Effluent causes many water-borne diseases like nausea, haemorrhage, ulceration of skin and mucous membrane, dermatitis, perforation of nasal septum and severe irritation of the respiratory tract because of the presence of toxic dyes and chlorolignin residues, report Iyer and Saxena (2000).

Due to large scale production and extensive application, synthetic dyes can cause considerable environmental pollution and are serious health-risk factors, report Forgacs *et al.*, (2004). The untreated dyeing effluents that are straightly used in agriculture have a serious impact on environment and human health, explain Pourbabaee *et al.*, (2006). Disposal of the untreated dyeing effluent, without any treatment in water bodies causes serious environmental and health hazards, remark Shedbalkar *et al.*, (2008). Industrial effluents containing synthetic dyes reduce light penetration in receiving water bodies and thus affect the photosynthetic activities of aquatic flora, thereby badly affecting the food source of aquatic organisms. The thin layer of discharged dyes formed over the surface of a receiving water body also decreases the amount of dissolved oxygen in the water, thereby affecting the aquatic fauna. Furthermore, dye-containing effluents increase Biochemical Oxygen Demand of the contaminated water, state Annur *et al.*, (2009). Many dyes are visible in water at concentrations as low as one mg L<sup>-1</sup>, view Pandey *et al.*, (2007). Thus, apart from affecting the health of plants and animals, synthetic dyes are also undesirable in water bodies from aesthetic point of view. The fast colored dyes are a major source of concern to environmentalists, since such pollutants, besides causing aesthetic damage to sites, are also toxic and carcinogenic, views Meyer (1981).

### **2.1.3. Water Consumption in Textile Wet Processing Sector**

Water is the basic requirement of life and textile processing accounts for the major water consumption, views Lal (2003). Water consumption of textile mill is presented in (Table I) as reported by Choudhary (2006).

**TABLE I****WATER CONSUMPTION IN TEXTILE MILL**

<b>Processes</b>	<b>Total water consumption (%)</b>
Bleaching	38
Dyeing	16
Boilers	14
Weaving	9
Printing	8
Spinning	6

**2.2. TEXTILE EFFLUENT TREATMENT METHODS**

Textile effluent from various textile processing units contains various classes of dyes and chemicals such as acids, alkalies, surfactants, salts and sequestrants. An average sized textile mill having daily cloth production of 8000 kg/day can produce one million liters of effluent per day. This polluted water is harmful to flora and fauna in the environment. Special treatment is needed before they are let out in the drain to reduce pollution, explains Shenai (2003).

Color released from textile dyeing processes is a major pollutant of textile effluent which is not only aesthetically unpleasant but also adversely affects the aquatic life. Therefore color has to be removed from effluent prior to discharge. Various decolorization processes can be used to remove color before discharged or prior to reuse. They are Physical, Chemical and Biological methods, describe Parthiban and Kumar (2005).

### 2.2.1. Physical Methods

- In screening method coarse suspended matters such as rags, pieces of fabric, fibers, yarns and lint are removed. Bar screens and mechanically cleaned fine screens remove most of the fibers. The suspended fibers have to be removed prior to secondary biological treatment, otherwise they may affect the secondary treatment system. They are reported to clog trickling filters, seals or carbon beads.
- The suspended solids in polluted water are too fine to be screened out and heavy to be skimmed off. These can be removed by settling down under the influence of gravity. This technique is called sedimentation, defines Sodhi (2006).
- Effluent streams are collected into 'sump pit'. Sometimes mixed effluents are stirred by rotating agitators or by blowing compressed air from below. The pit has a conical bottom for enhancing the settling of solid particles.
- The dye house effluents are generally alkaline in nature. They have to be neutralized to the proper pH ranges (6.5 – 7) to make them amenable for secondary biological treatments, reports NIIR Board.
- Adsorption mechanism is a solid surface in contact with solution tends to accumulate a surface layer of solute molecules because of unbalance of surface forces. Activated carbon is frequently used for adsorption of dyes and heavy metals from effluent, reports Shukla (2006). Adsorption techniques have gained favour, recently due to their efficiency in removal of pollutants. Decolorization is a result of two mechanisms, adsorption and ion exchange. It is influenced by many physico – chemical factors such as dye sorbent, interaction, sorbent surface area, area size, temperature, pH and contact time, states Shanmugasundaram (2006). Apart from activated carbon, some other adsorbents are silica gel, chitin and chitosan. Peats are used as cheap adsorbents, describe Shukla and Jawale (2007).

- Membranes are the best available technology for water and waste water treatment. They are simple to operate and require minimal chemical use. Different types of membranes are available which are classified according to size of the particle that can pass through the pores. Types of membrane filtration are Micro filtration, Ultra filtration, Nano filtration and Reverse osmosis (Asian dyer 2007).

## **2.2.2. Chemical Methods**

### **2.2.2.1. Coagulation**

It is a physico – chemical method which is used most frequently to treat effluent, say Perkowski and Kos (2004).

### **2.2.2.2. Oxidation**

A variety of oxidizing agents can be used to decolorize wastes. Sodium hypochlorite decolorizes dye bath efficiently. Though it is a low cost technique, but it forms absorbable toxic organic halides (AOX). Oxidative process results in aromatic ring cleavage of the dye molecules to get small colourless organic compounds. To ease the stated problems, advanced oxidation process (AOPS) have been developed to generate hydroxyl free radicals by different techniques. These oxidants effectively decolourize the dye, but do not remove COD completely, describe Alimet *et al.*, (2003) and Stanislaw *et al.*, (2001).

The treatment of synthetic dye house effluents is normally combined by ozonisation and hydrogen peroxide in combination with ultraviolet light, view Arslan *et al.*, (1999). The main disadvantage of these techniques is it requires an effective sludge producing pretreatment plant.

### **2.2.2.3. Ion Exchange Process**

Purification of effluent by ion exchange takes place by passing water first through an cation exchanger where cation are exchanged for hydrogen

ions followed by passage through an anion exchanger where acid radicals are replaced by hydroxyl ions, review Chatwal and Sharma (2004).

### **2.2.3. Biological Methods**

Biological processes such as aerobic, anaerobic and facultative digestions are extensively in operation for the treatment of industrial effluent. In recent years, anaerobic treatment has received more attention. Main advantage of anaerobic systems over aerobic is cost savings, remark Ansari and Thakur (2002).

#### **2.2.3.1. Trickling Filters**

This oldest form of biological waste water treatment is also known as biofiltration or percolating filters. It is efficient next to activated sludge process. In trickling filtration method, materials with large surface area are packed in the form of a bed and the waste water is sprinkled over it with the help of sprinkler. A microbial film is formed over the surface of the packed material and the biological reaction takes place. These bacterial slimes oxidize the organic matter present in the water. The effluent emerging out of the filter contains suspended matter although free from degradable matter. The effluent is allowed to settle and then discharged, remarks UNEP (2003).

#### **2.2.3.2. Activated Sludge**

This is the most versatile biological oxidation method employed for the treatment of waste water containing dissolved solids, colloids and coarse solid organic matter. In activated sludge process, the waste water is aerated in a reaction tank in which some microbial floc is suspended. The aerobic bacterial flora bring about biological degradation of the waste into carbon dioxide and water molecule, while consuming some organic matter for synthesizing bacteria. The bacteria flora grows and remains suspended in the form of a floc, which is called “Activated Sludge”. The effluent from the reaction tank is separated from the sludge by settling and discharged. A part of the sludge is

recycled to the same tank to provide an effective microbial population for a fresh treatment cycle. The surplus sludge is digested in a sludge digester, along with the primary sludge obtained from primary sedimentation. An efficient aeration for 5 to 24 hours is required for industrial wastes. BOD removal to the extent of 90-95% can be achieved in this process.

### **2.2.3.3. Aerated Lagoons**

This method is also called as stabilization or oxidation ponds. This process consists of a shallow pond of two – four feet in depth designed to allow algal growth on the textile effluent. Effluent in oxidation ponds can stand for several days to weeks while the biological activity of bacteria and algae under sunlight destroys most of the organic waste. Sludge will be removed from the lagoon periodically and disposed of as in other treatment, observe Bailey *et al.*, (2005).

## **2.3. REUSE OF DECOLORIZED EFFLUENT**

In the twentieth century, it was realized that environment needs to be protected from pollution. Color in the textile effluent cannot be removed by simple operation. Hence, decolorizing the dye effluent before its use for further dyeing is the only practical way to reduce pollution, views Bardhan and Sule (2004). An additional cost required for effluent treatment incurred, simply for legitimate disposal, this creates the concept of revising the treated effluent. The water which is suitable for return to the environment is acceptable for reuse in preparation and dyeing. Appropriate treatments such as ultra filtration, reverse osmosis and adsorption make the effluent suitable for reusing, reports Singh (2004).

## **2.4. COTTON**

Cotton the “white gold” is the most precious gift of nature to the mankind contributed by the genus “Gossypium”, states Mishra (2000). Cotton known as “king of fibre” has a prime position as the principle clothing fibre, which is not able to meet the growing demand due to deforestation and increase of population, denotes Ranganathan (2005). Cotton is the most commercially

significant fibre in the world. It is a hygroscopic material, hence it easily adapt to the atmospheric air conditions, say Jindal and Jinday (2007). Cotton is produced in over 50 countries worldwide; averaging 20 to 24 million metric tons per year, remain Ghorashi *et al.*, (2007). Cotton accounts for more than 75% of the total fibre consumption in the spinning mills and 56% of the total fibre consumption in the textile, says Malik (2007).

Cotton plays a vital role in the Indian economy. Cotton enjoys an extremely positive image due to its naturalness and gentleness to the human skin, says Shriveleela (2004). The cotton industry provide a largest number of jobs and livelihood opportunities in rural and urban. India is a second largest cotton textile manufacturing countries in the world, denotes Swaminathan (2005). Cotton fiber grows from the surface of seeds in the pods and balls of a bushy mallow plant. It is composed basically of a substance called cellulose. Variation among cotton fibres also occur because of growth conditions including such factors as soil, climate, fertilizers and pests, remains Naresh (2005). Cotton is the strong and reasonably low in price and it posses so many interesting properties like good absorbency and strength. It can be washed with strong soaps and detergents. It has good affinity for dyes and prints, views Shukla (2005).

Cotton, the most widely used fiber in the world has a long and fascinating history. Cotton was used in India thousands of years ago and has been traced to ancient Egypt, Greece, Rome and Pre-columbian American. It was introduced to Europe by Arab traders. Its use spread widely in 17<sup>th</sup> century as trade with India also increased, says Malik (2007).

#### **2.4.1. History of Cotton**

Cotton is appreciated for its naturalness. Demand for cotton is as strong as ever with new developments appearing constantly and its consumption has increased at an average annual growth rate of 2 per cent. Since World War II attention has shifted to developing countries, more to China, where

manufacturing is concentrated (Textiles, 2008). Cultivation of cotton in Europe and other parts of the world was started around 17th Century. America and Russia produce 40 percent of the world total production. According to Thomas (2006), cotton cultivated in India, Pakistan, Mexico and Peru 5000 years ago. The early Greeks and Romans used cotton for awnings and sails as well as for clothing, states Collier (2001). Cotton has been cultivated for more than 5000 years and archeological finds indicate that cotton was grown and used for textile purpose in the Indus Valley well before 2100 B.C. The oldest known “cotton yarn” was produced in Mohanjo-Daro in Pakistan 3000 years ago, explains Kaplan (2002).

The first reference in literature to cotton is found in a “Hindu Rig-Veda Hymn”. The hymn was written fifteen centuries before “Christ and mentions” threads in showing that cotton was already being used in weaving, say Brown *et al.*, (2001). Thousands of years ago humans came across a un preprocessing short plant growing in India that had bits of soft and fluffy on it. A closer examination showed them that in the tangled fibers were the seeds of the plant, remarks Raghavan (2002). The advent of manmade fiber is a serious challenge to the supremacy of cotton, which had held undisputed away over the textile world from time immemorial, denotes Kulkarani (1999).

It had its patriotic associations far it was spun on his “charka” by “Father of Our Nation”. Cotton had been regarded as the common man’s fibre and clothes of the masses in India.

#### **2.4.2. Properties of Cotton**

##### **Physical properties**

Cotton fibers are made up of cellulose, which constitutes approximately 90%. In addition to this water is 5-8% and the rest weight is contributed by other natural impurities, say Gupta *et al.*, (2005). If the cotton fibers are seen through the microscope, they show a formation of the shape like a fine braid.

If the cotton is fine, the number of strands is more, explains Nakamura (2005). The strength of the fiber increases at higher humidity or at higher moisture. In general, the tensile strength increases upto a relative humidity of 60% and then it remains mostly constant. Mostly cotton fibers have 8.5% of the moisture but it has ability to absorb 15-20% of the moisture. Due to this property it takes time while drying, say Gupta *et al.*, (2005). When cotton fiber is wet, it tends to contract or shrink as it dries. As a result, cotton yarns and fabrics can shrink considerably, particularly those that are loosely constructed. However, preshrinking finishing processes minimize shrinkage in cotton fabrics, explains Singh (2004). Cotton fibers have the ability to conduct heat energy, minimize and destructive heat accumulation. Thus they can withstand hot ironing temperature. Excessive application of heat energy causes the cotton fiber to char and burn, without any prior melting, view Gohl and Vilensky (1999).

### **Chemical properties**

Cotton fibers are weakened and destroyed by acids. Acidic conditions hydrolyze the cotton polymer at the glucoside oxygen atom, which links the two glucose units to form the cellobiose unit mineral or in organic acids being stronger than organic acids, will hydrolyse the cotton polymer more rapidly. Cotton fibers are resistant to alkalis and are relatively unaffected by normal laundering. The resistance is attributed to the lack of attraction between the cotton polymers and alkalies. Exposure to air in presence of sunlight for a long period will have an effect on cotton like that of heat, describes Mishra (2000). Cotton fabrics should therefore be shaded from direct sunlight, explains Singh (2004). Many organisms attack cotton. Numerous fungi cause mildew discolors rots and weakens the fibre. Most fungi reproduce by means of spores, largely present in air and are attracted to cotton, says Mishra (2000).

### **2.4.3. Importance and Uses of Cotton**

Today, the textile industry world used more cotton than any other fibre. This is the backbone of world's textile trade. It is also number one value added

crop, says Thomas (2006). Cotton is sustainable renewable and biodegradable making to it an excellent choice as an environmental friendly fiber throughout its entire production of life cycles, explain Kang and King (1997). It is a natural vegetable fiber and it has great economic importance in the world. Today cotton is an interesting part of textiles in India. India is the home of cotton, says Nimkar (2006).

Cotton has hundreds of uses, from blue jeans to shoe strings, clothing and household items are the largest uses, but industrial products account from many thousands of bales. It is one of the most commonly abundant natural fibres having many advantageous especially related to textiles. The uses of cotton as the prime textile materials, entirely due to cheapness and easy available and good laundering properties. Cotton used for virtually in every type of clothing. Garments made of cotton are very soft, comfortable and weather friendly. They are either 100% or blended with some natural or a synthetic fibre, says Nelson (2003). In apparel, cotton garment range from jackets, jeans, shirts, pants, salwar and kameez, sari, tops, gowns, coat, lining, mattresses, upholsteries, stuffing purposes, toys, drapes, curtains, slip covers, bedspreads, towels, bags and others, states Phyltis *et al.*, (2001).

Cotton also finds special applications in medical and surgical products like hydropillic fibers. Cotton (cotton wool), compress, gauze bandages, tampons or sanitary towels, cotton swap, gloves and caps, explains Kothari (2001) Angappan and Gopalakrishnan (2006). Cotton has many versatile industrial qualities that make it a fiber for all masses and occasions, views Britannica (2000). Many of our everyday textile fabrics are made from cotton, states Lapere (2009). Cotton is the number one fiber used for apparel in the United States. It traps air with in the fabric structure and help for a thermal insulation process, resulting protection from heat in summer and cold in winter. ([www.fabrics.manufactures.com](http://www.fabrics.manufactures.com)).

All types of Apparel made in 100% cotton and in blend or mixture with other fibers. Industrial abrasives, book bindings, handbags, luggage shoes, tobacco clothes and wiping clothes are also made using cotton fabrics, denote Kumar *et al.*, (2002).

## **2.5. WEAVING**

Weaving is one of the most important discoveries in the history of man, organized from basketry prevailed during some age hunters period, woven fabrics in the prehistoric period were used as waist cloth, tubular, shirts, rugs, scarves etc, in addition they were also used during the religious ceremonies of primitive people. Several variations have been introduced in the modern process of weaving, which add to the number of the cloth products, remarks Parvathi (2007).

Weaving is primarily characterized by the possibility of forming at least two separate sheds in the tensioned warp by mechanical or automatic means; it is thus possible to obtain at least two distinct interlacing of warp which are separated by the weft thread. Secondary features, which are not always present, are the interlacing at right angles of the essentially passive warp usually active continuous weft and use of several warp and weft systems, remarks Mullick (2004).

Woven structure can vary in density in interlacing and this can make them differ in appearance. But in their simple forms they represent a very stable material. It does not extent a great deal in warp and weft directions because of the interlacings, which resist an attempt to pull warp and weft straight, states Mahadevan (2001). The shuttleless technologies have many advantages over the conventional weaving system. Excellent quality fabric with high productivity, versatility, consistency and reliability of the machines. Better fabric engineering and creative weave patterns are possible, remains Siva Sankar (2010). The structure of the fabric and its appearance are affected by the pattern of interlacing to a large extent. As a result, fabrics made of the same yarns may differ greatly in appearance and properties, if the interlacing pattern is different, says Adanur (2001). Fabric is used as decoration for the idols in the temples.

### **2.5.1. Types of Weaving**

The fundamental weaves are such weaves in which every warp and weft thread within the repeat overlaps or is overlapped only by one thread of the opposite system. There are three kinds of fundamental weaves. They are plain, twill, satin and sateen weaves. One to lift the odd numbered warp yarns and a second lift the even numbered warp yarns, reports Singh (2004). More than two harnesses are required for advanced weaves, and as many as forty for figured weaves. The three basic weaves in common use for the majority of fabrics are plain, twill and satin with some variations. Important constructions are also obtained from the following weaves. They are pile, double cloth, gauze, swivel, lappet, dobby and Jacquard, says Shenai (1999).

### **2.5.2. Plain Weave**

The plain weave is sometimes referred to as the tabby, homespan, or taffeta weave. It is the simplest type of construction and is consequently inexpensive to produce. On the loom, the plain weave requires only two harnesses. Each filling yarn goes alternately under and over the warp yarns across the width of fabric. On its return, the yarn alternates the pattern of interlacing, if the yarns are close together, the plain weave has a high thread count and the fabric, states Smith (2006). Plain weaves include muslin, cheesecloth, lawn, organdy, taffeta, linen, toweling, chiffon etc. These fabrics are given a variety of finishes and have a wide range of texture, hand and appearance, denotes Hasmukhrai (1996). The appearance of the plain weave may be varied by differences in the closeness of the weave by different thickness of yarn or by the use of colors in the warp and filling. In addition two variations of the plain weave afford simple decorative effect, the basket weave and the ribbed or corded weave, state Garg *et al.*, (2005).

The basic characteristics of plain weaves are

- It has the maximum number of binding points.
- The threads interlace on alternate order of one up and one down.
- The threads density is limited.
- The cloth thickness and mass per unit area are limited.
- It produces a relatively stronger fabric that is obtained by any other simple combination of threads, excepting that of “gauze” or “cross weaving”, remarks Gokarneshan (2005).

Plain weave fabrics are usually reversible. The yarns can be packed loosely or compactly. The warp threads may equal the filling threads in number but unequal arrangement can be produced by variation in the yarn size and by unequal spacing of warp or filling yarns.

## **2.6. DYEING**

### **2.6.1. History of Dyes**

Dye stuffs and dyeing are as old as textiles and predate written history, reveals Smith (2006). Frequently dyeing processes involved treating the fibres with mixtures of "dyes" of animal or vegetable origin and varying proportion of clay, earth, ashes, slate dust, powdered brick and various gums, all with the objective of achieves were made from natural materials, mainly vegetable and animal matter. Latter slum and other metallic salts and mordant dyeing were born. Dyeing is a complex, specialized science. Today nearly all dyestuffs are synthetically produced compounds and in most instances surpass natural dyes, says Thomas (2006).

### 2.6.2. Natural Dyes

Natural dyes are those which are obtained from nature without chemical processing, report Khan *et al.*, (2006). Primitive people obtained natural dyes from flowers, nuts, berries, other form of vegetable, plant life, minerals and animal sources, view Kumar *et al.*, (2002). Natural dyes can be applied on all kinds of both synthetic and natural yarns, fabrics and knitted fabrics. Natural dyes comprise of many chemical classes such as erithocyanins, flavanoids, quinines, dihydrophyrane, indigoids, carotenoids and chlorophylls.

### 2.6.3. Synthetic Dyes

In 1855 William Perkin, a chemist working in London, discovered a purple dye while he was trying to develop synthetic quine from aniline. He found that it would dye silk and although it was not particularly fast. This was the first synthetic dye and it generally influenced the development of the dye industry. Thus a new wide range of cheap, colorful textiles become widely available. Some prominent types of dyes are Acid, Basic, Direct, Mordant, Reactive, Sulphur and Vat dyes.

Acid dyes are best when applied in an acid bath and they provide variety of colors, fairly fast to light and to washing. It is mainly used on nylon, silk and wool. Direct dyes are applied directly to cellulosic fibres in the presence of electrolytes. Disperse dyes are non ionic and have very low water solubility. Reactive dyes contain reactive group that forms a covalent bond with a group on the substrate usually hydroxyl or amine, explain Shenai (2003).

Reactive Dyes are the most important class of colors for the dyeing of cotton, state Patel *et al.*, (2005). The term reactive dye means, the dye that chemically react with fibre. As the name suggests they actually react with the hydroxyl groups of cellulose through a reactive system. Hence they will have good washing fastness when applied to cotton, states Singh (2002). The first coal-tar dyes are called basic dyes. They give many bright shades for silk and wool.

Disperse dyes were developed because other dyes would not work with acetate. It is also used on different manmade fibres, including acrylic, acetate and polyesters (<http://hubpages.com/>).

Disperse dyes are colored organic substance with very low solubility in water, but they can interact with the polyester chains by forming dispersed particles, the general structure of disperse dyes is small, planar and non-ionic, with attached polar functional groups like  $-\text{NO}_2$  and  $-\text{CN}$ . The shape makes it easier for the dye to slide between the tightly-packed polymer chains, and the polar groups improve the water solubility, improve the dipolar bonding between dye and polymer and affect the color of the dye. (<http://www.chm.bris.ac.uk/>) Dyes vary in chemical composition, but share a common feature they are highly stable to external agents such as exposure to sweat, light, water, many chemicals including oxidising agents and microbial attack, studies Choudury (2006).

Pillow (2001) remarks that the dye should have the following features namely,

- Intense color
- Solubility in water
- Substantivity to the fibre
- Durability of wet treatments
- Safe, easy to handle and reasonably priced.

## **2.7. USE OF BIOTECHNOLOGY FOR DECOLORIZATION**

Conventional waste water treatment are feeble at removing dyes and involve high cost, formation of hazardous by-products and intensive energy requirements, explains Stolz (2001). Moreover, complete dye removal is unfeasible. This has impelled result into alternative methods like bio technological processes.

Microbial degradation and decolorization of dyes is an environment friendly cost competitive alternative to chemical decomposition process, observe Swamy and Ramsay (1999), He *et al.*, (2004), Rodriguez couto *et al.*, (2006). The effectiveness of microbial decolorization depends on the adaptability and the activity selected micro organisms. Wide range of micro organisms including bacteria, fungi, yeasts, actinomycetes and algae capable of degrading azo dyes have been reported by Chen *et al.*, (2003).

Use of enzymes is also an attractive option for waste water treatment for numerous reasons, which include their bio-compatibility as well as the ease and simplicity of process control, review Karam and Nicell (1997). Most of the work related to lignolytic enzymes and decolorization of dyes has been concentrated on selected white rot basidiomycetes, views Modi (2008). Laccase enzymes offer attractive solutions because of its potential to degrade wide spectrum dye having diverse chemical structure, reports Thurston (1994).

### **2.7.1. Microorganism in Decolorization**

*Bacillus subtilis* is a Gram-positive, rod-shaped and endospore-forming aerobic bacterium. It is found in soil and rotting plant material and is non-pathogenic. It is one of the most studied gram-positive bacteria. One feature that has attracted a lot of interest in *Bacillus subtilis* is its ability to differentiate and form endospores.

Several strains related to *Bacillus subtilis* are used in the commercial production of extracellular enzymes, such as *Bacillus amyloliquefaciens* alpha-amylase. Other strains produce insect toxins, peptide antibiotics and antifungals, some of which have been used in agricultural crop protection.

*Bacillus subtilis* forms colonies that are dull and may be wrinkled, cream to brown in colour and when grown in broth have a coherent pellicle, usually with a single arrangement.

*Bacillus subtilis* bacteria secrete enzymes, "such as amylase, protease, pullulanase, chitinase, xylanase and lipase. These enzymes are produced commercially and this enzyme production represents about 60% of the commercially produced industrial enzymes", states Morikawa (2006).

## **2.8. DYE BIODEGRADATION**

The success of a biological process for color removal from a given effluent depends in part on the utilization of microorganisms that effectively decolorize synthetic dyes of different chemical structures. Many bacteria, actinomycetes, yeast and mitosporic fungi are able to decolorize dyes, with color removal by these microorganisms being mainly attributed to adsorption of the dyes. Biodegradation is the chemical dissolution of materials by bacteria or other biological means. Biodegradable matter is generally organic material such as plant and animal matter and other substances originating from living organisms, or artificial materials that are similar enough to plant and animal matter to be put to use by microorganisms

Bioaugmentation is a process in which various microorganisms including indigenous, wild type, or genetically engineered are introduced to the bioreactor or the polluted sites/matrices to accelerate the desired biological processes and achieve more consistent results. Bioaugmentation refers to the use of selected strains of bacteria as opposed to the use of nonspecific microbial cultures such as those that are contained in activated sludge. Although activated sludge is used in the process of treating the contaminants, the microbial species that are contained in this material are uncharacterized and the system is a "black box". This may lead to inconsistent results, such that in some cases, up to 90% of the dyes in an effluent can remain untreated after an activated sludge process. On the other hand, activated sludge can provide a useful starting medium from which individual strains or consortia can be isolated and cultured for use as inoculants. The microbial species and consortia

can then be studied to determine the environmental factors that affect their growth and the rate of degradation.

Biodegradation is a cost-effective method to remove the residues of wastewater streams from dye product industries. The treatment of effluents from dye-based industries can introduce additional water resource for agricultural irrigation purposes. Moreover, the maintaining of natural water resources from pollution by the toxic residues can help to preserve the agricultural environment from these hazardous pollutants. Treatment of dye-contaminated wastewater discharged from the textile and other dye-stuff industries is necessary to prevent contamination of soil and surface and ground water. Currently, there are several physicochemical and biological methods for the removal of dyes from effluents. Among these, biotechnological approaches are receiving increased attention worldwide as environmental-friendly methods that are becoming increasingly efficient and cost-effective for the remediation of dye-contaminated wastewater, report Khalid *et al.*, ( 2010).

## **2.9. ODOR BIODEGRADATION**

Odor is one of the most important concept, considered in industries. The odor left back in the waste, by products or product themselves has to be checked and removed to retain quality standards, working conditions and reduce pollution.

The determination of odor has become increasingly important, as the general public has become more concerned with the proper operation of wastewater treatment facilities. The odor of fresh wastewater is usually not offensive, but a variety of odorous compounds are released when wastewater is decomposed biologically under anaerobic conditions. They constitute health problems as some are known to be toxic to both man and animals at very low concentrations. The different unpleasant odors produced by certain textile industrial wastewater by means of phenolic compounds present in the effluent.

Presently the natural gas constitute as potential energy source in the world. The availability of natural gas reserve is higher than the reserve of crude oil. The quality of natural gas can interfered with the presence of sulphur compounds. Sulphur is malodorous compounds which exceed the odor threshold at low concentrations, view Leonardos *et al.*, (1969).

The presence of sulphur compounds in natural gas must be reduced to preserve the quality of natural gas. Commonly, sulphur compound in natural gas is removed by chemical treatment, but this method has many disadvantages including the high cost of equipment, toxic chemical usage and secondary contaminations. On the other hand, the biological treatment can be reduced sulphuric compound without high cost equipment report, Sri Astuti Rahayu *et al.*, (2007).

### **2.9.1. Odor Compounds in Waste Water**

Odor substances that are emitted from effluent treatment plants include both organic and inorganic gases and vapours. Inorganic gases include hydrogen sulphide and ammonia. Many of these odorous substances result from the anaerobic decomposition of organic matter containing sulphur and nitrogen. Gases commonly referred as sewer gas usually include hydrogen sulphide, ammonia, Carbon dioxide and Methane, of this hydrogen sulphide and ammonia are odorous .Depending upon the types of chemicals present in the effluent, other odorous compound may also include such as organic acids, aldehydes and ketones, Views Sivaramakrishnan (2009).

Odor may be caused by a variety of odorous compounds that are released or generated by various waste water processes. The major types of odors generated in waste water treatment facilities are:

- Acetaldehyde : pungent but fruity
- Allyl mercaptan : garlic smell
- Amines : fishy odor quality
- Ammonia : pungent and irritating
- Chlorine : pungent and suffocating
- Diamines : decayed flesh odor quality
- Dimethyl amine : pungent ammonical
- Hydrogen sulfide : rotten eggs odor quality
- Mercaptans : skunk odor quality
- Pyridine : pungent and irritating
- Ozone : pungent and irritating
- Organic sulfides : rotten cabbage odor quality
- Sulfur oxide : pungent and irritating
- Skatole : fecal odor quality

## 2.10. THIOBACILLUS - SULPHIDE OXIDIZING BACTERIA

The genus *Thiobacillus* is also known under the name of *Acidithiobacillus*. This genus is thermophilic, preferring temperatures of 45-50 degrees Celsius. It is thermophilic, acidophilic, strictly aerobic bacteria. *Thiobacillus Bacteria* is more effective than the other sulfide oxidizing microorganisms in terms of their required growth conditions and the utilization of various types of substrates. The protein composition of the bacterium cell surface changed according to the culture substrate. Sulphur-grown cells showed greater adhesion to sulphur than iron-grown cells. The thio l groups of the 40-kDa protein formed a disulfide bond with elemental sulfur and mediated the strong adhesion between *Thiobacillus* and elemental sulfur. Bacterial adhesion to mineral surfaces plays an important role in biodegradation.

Water treatments are generally based on inoculation of wastewaters with *Thiobacillus thiooxidans* or other unspecified sulphur bacteria followed by aeration. *T. thiooxidans* has been used to remove sulphur from a gas that is bubbled through culture. *T. ferrooxidans* has been used as the basis of two gas treatment aerobic process in which H<sub>2</sub>S gas is first precipitated as sulphides. Desulphurization of a fuel gas would require anaerobic conditions to avoid oxygen contamination of gas. *T. denitrificans* a strict autotroph and facultative anaerobic bacteria can be utilized for biodesulphurization of natural gas containing H<sub>2</sub>S gas. *T. denitrificans* can grow anaerobically on sulphide (Na<sub>2</sub> gas) as an energy source if sulphide is used as growth limiting factor in chemostat, in which case sulphide is oxidized to sulphate, express Prasad *et al.*,(2009).