1. INTRODUCTION

All the living and nonliving things including human beings are interdependent in the Global Environment. Environment is defined as “The sum of all external conditions and influences affecting the development and life of organisms”. The Environment performs three basic functions in relation to mankind. First, it provides living space and other amenities that made life qualitatively rich for man. Second, the Environment is a source of agricultural, mineral water and other resources that are consumed directly or indirectly. Third, the Environment is a sink, where all the waste produced by man and manmade activities are assimilated. As the relationship of man with the Environment is necessarily symbiotic the equilibrium between the two must be maintained at all costs (Masters, 2004).

Now a day’s population growth coupled with industrialization and urbanization has resulted in increasing demand for water and land thus leading to water crisis and serious consequences on the Environment. These consequences include the disposal of all kinds of byproducts and waste products into the biosphere in large quantities. It affects not only the functioning of microorganisms but also the growth of plants, activities of animals, human and functioning of Ecosystem. They are collectively called as pollutants (Sharma, 2005). Industrial effluents are the major source of pollutant that pollutes not only the water bodies, but also the entire biosphere. The persistence of toxic metals and organic pollutants in the surroundings causes pollution and deteriorate the Environment. Contamination of heavy metal to the Environment is the major global concern because of their toxicity and threat to human life (Sharma, 2005).
1.1 TEXTILE INDUSTRY:

The growth of World textile industry has followed an interesting pattern over the years. Originating in the UK, the center of textile production first moved to the USA, then to Japan and finally to the Asian countries. Having already passed through several stages of modernization and rationalization, India’s spinning and weaving industries are now comforted with the need to higher standard product categories. Textile sector is one of the large exporting and the most important industrial sector of India. It is estimated that every year, Indian Textile industry produces roughly about 3.35 million tons of textile fabrics and consumes in chemical process about 250 cubic meters of water (Gandhi, 2001). The textile processing includes sizing, desizing, bleaching, dyeing, printing, finishing etc. The structure of the industry varies widely and this gives rise to marked differences in pollution characteristics (Porter 1970, and Tunay et al., 1990).

1.2 CHARACTERISTICS OF TEXTILE DYEING EFFLUENT:

Textile industries consume large amount of water and chemicals for wet processing of textiles. The chemical reagents used are very diverse in chemical composition, ranging from inorganic compounds to polymers and organic products (Banat Nigam et al., 1996). Textile effluents are mostly discharged in to the Environment after minimal pretreatment with a high amount of pollutants.

In general dye house effluent is grey (in pretreatment process) or coloured (in coloured treatment), high in temperature, chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids and at times highly alkaline. Dye wastes and other effluent from textile processing can cause problems like foaming colour persistence have abnormally high pH, temperature and heavy metal concentrations and
variations in the hydraulic flow rates. The pollutants aggravated by the presence of free chlorine and toxic heavy metals cause rapid depletion of dissolved oxygen leading to depletion of oxygen in the receiving water. These pollutants are known to destroy microorganisms that lead to a reduction in the self-purification capacity of the stream. The metals and some other contaminants tend to persist indefinitely, circulating and eventually accumulating throughout the food chain (Mc Mullan et al., 2001).

Dyeing industry effluent that alters the colour and quality of the water bodies has been proved to be hazardous to Aquatic Ecosystem (Khan and Jain., 1995). It reduces the sunlight penetration which is essential for photosynthesis, which leads to toxicity of fish and mammals. They also inhibit the activity and growth of micro-organisms (Murugesan et al., 2003). Dyes having higher stability under sunlight and resistance to microbial attack and temperature were identified. The presence of dyes or their degraded products in water will also cause human health disorders such as nausea, haemorrhage, ulceration of skin and mucous membranes. The presence of such toxic compounds also resulted into severe damage to kidney, reproductive system, liver, brain and central nervous system. The Environment and health concern of these potentially carcinogenic pollutants present in textile waster waters has drawn the notice of many workers.

Many dyes are known as carcinogens such as benzidine and other aromatic components all of which might be reformed as a result of microbial metabolism. It has been already well documented that azo and nitro-compounds were reduced in the sediment and intestinal Environment, resulting in the regeneration of parent toxic amines this compound was not readily removed by typical microbial based waste treatment process. The highest rate of toxicity was observed for basic, diazo and direct dyes
Some algae and higher plants exposed to effluent rich in disperse dyes at higher concentration have a tendency to bio accumulate the heavy metal ions from textile effluents. They contaminate not only the Environment but also transform the toxicity through the entire food chain, leading to bio magnifications. Government legislation was becoming more stringent in most developed countries regarding the removal of dyes from industrial effluents, which in turn is becoming an increasing problem for the textile industries. Most textile industries are developing onsite or implant facilities to treat their own effluent before discharge was fast forth coming reality.

1.3 HEAVY METALS IN DYEING EFFLUENT:

The term “Heavy metal” commonly refers to metals either with a specific weight higher than 5g/cubic cm or an atomic number above 20. All of them may not be toxic at relatively low concentrations, classified as heavy metals. So, the heavy metals are a very heterogeneous group of elements, which greatly differ in their chemical properties and biological functions. For this reason, the term “Heavy metal” is discredited and terms “trace elements” are preferred by numerous authors (Phipps, 1981). Heavy metals are non-biodegradable pollutants on Environment and some are even hazardous to human and animals. Heavy metals in excessive quantity cause toxicity and death to most living organisms. Contamination of soil and soil water results from the presence of undisturbed metal near the soil surface or from the actual mining of ores. The heavy metals are often used as fungicides, pesticides or disinfectants which are responsible for toxicity. As the metal pollutants are non-degradable and are readily taken by plants, these are likely to enter easily in to food chain (Prasad, 1995).
Dyes are one major source of metals like Cd, Cr, Co, Cu, Hg, Ni, Mg, Fe, and Mn (Wagner et al., 1986). Sediments and suspended solids particles are important restores for trace metals in waste water. Heavy metals are non-biodegradable pollutants on Environment and some are even hazardous to human and animals. Among the heavy metals, chromium is abundantly available in nature. It enters the ecosystem through the industrial activities causing water pollution. The trivalent chromium compounds are less toxic, mobile and available for biological uptake, while hexavalent chromium compounds are 100-fold more toxic than trivalent compound due to their higher solubility in water, rapid permeability through biological membranes and subsequent interaction with intracellular proteins and nucleic acids (Safe, 1984). Nickel is ubiquitous in nature. It occurs in form of sulfide and silicate minerals. Human exposure may occur through inhalation, ingestion and dermal contact. It is mainly discharged from dyeing industry effluent and thus causing the pollution to the Environment.

Industries are significant points of pollutional sources from an Environmental point of view and pollution characteristics are different from one another. Most of industries use water in varying proportions. It may be directly used as a solvent and as a medium for chemical reactions or for cooling, washing product etc. The waste water discharged carries with it a number of dissolved and suspended impurities, the composition of which varies with industries and the process used. Industries such as coating, electric battery, manufacturing, paint, dyeing, lead smelting, internal combustion engines and mining generate large quantities of heavy metal to the Environment. Heavy metal concentration has linked to birth defects such as cancer, skin lesions, retardation leading to disabilities of liver and kidney. The center for disease control (CDC) and the
agency for toxic substances and disease registry (ATSDR) estimate that 15-20% of U.S children have lead levels greater than 15 mg/dl in blood, which is considered potentially toxic. Change in the trace element profile of the soil causes physiological and genetic changes in various diseases in human beings and also disturb their metabolic functions. The recognition of toxic effects from minute concentrations of some metal ions has resulted in regulation of laws to reduce their presence in the Environment (Cernigila 1985). The number of heavy metal is about 65 and is defined with respect to number criteria such as the cationic hydroxide formation, specific gravity greater than 5g/mL, complex formation, hard soft acids and bases and association with eutrophication and Environmental toxicity.

1.3.1 Chromium

Chromium is an element which is abundantly available in nature. It is mostly used in metallurgical, electroplating, leather, tanning, pigment, glass ceramic and photography industries. It enters through the industrial activities causing water pollution. In trace amounts Cr (VI) plays an important role in different physiological functions through its involvement in a number of metabolic activities like glucose, lipids, amino acids and nucleic acid synthesis. Cr (VI) is toxic when present in higher concentration. Its presence beyond permissible limit causes mutation and carcinogenicity in human beings by penetration through cell membrane. Hence the removal of Cr (VI) from Environment is essential to control the pollution.

The trivalent chromium compounds are less toxic, mobile and available for biological uptake, while hexavalent chromium compounds are 100-fold more toxic than trivalent compounds due to their higher solubility in water, rapid permeability through
biological membranes and subsequent interaction with intracellular proteins and nucleic acids (Sultan and Hasnain, 2005). Though trivalent is impermeable to biological membrane but the trivalent generated inside the cell, bind stably to protein and interacts with nucleic acid (Ohtake and Silver., 1994). Accordingly, chromium and its compounds can be easily reacts with nucleic acids. Hence, Cr (VI) poses a greater threat to public health, the Environment and Ecosystems, compared with Cr (III) (Casadevall and Kortenkamp, 2002; and Sedman et al., 2006).

In biological system hexavalent chromium passes easily through the cellular membrane and then is reduced to trivalent chromium in the mitochondria, nuclei as well as in cytoplasm (Mujeep Ur Rahman et al., 2000). The reduction of chromium(VI) to Chromium(III) is therefore an attractive and useful process for remediation of Chromium(VI) pollution and the technologies focusing on transformation of Chromium(VI) to Chromium(III) have accordingly received much more attention by Konopka et al., (1999), Ganguli and Tripathi, (2002), and Faisal and Hasnain, (2004).

**1.3.2 Nickel**

Nickel is ubiquitous in nature. It occurs in form of sulfide and silicate minerals. Ambient air as a result of industrial activity, combustion of fossil fuels and waste incineration is known to contain very low level of nickel. Human exposure may occur through inhalation, ingestion and dermal contact. Deposition, absorption and elimination of nickel particles in respiratory tract largely depend on the particle size and concentration of nickel. The rate of dermal absorption depends on the rate of penetration in the epidermis, which differs for different forms of Nickel. Nickel compound are carcinogenic to human risk were highest for lung and cancer among workers heavily
exposed to nickel sulfide, nickel oxide and to metallic nickel. Blood nickel levels provide a guideline as to the severity of exposure. A nickel binding metalloproteinase—nickeloplasmin identified in plasma. It is an alpha-glycoprotein complex that plays an important role in extracellular transport, intracellular binding and urinary and biliary excretion of nickel.

Industries generally produce wastes containing toxic heavy metals along with organic and inorganic effluents that contaminate the ground water. The industrial waste waters can be broadly classified as nonfermentable and fermentable in organics and toxic wastes. The effluents discharged by metal industries, steel mills and machine tool factories are nonfermentable wastes and are generally characterized by low pH and high concentration of trace metals. The effluents from tanneries, food and meat packing plant effluents contain mostly fermentable wastes. Effluents discharged from textile dying and chemical industries are highly toxic. Hence they should be treated properly before disposal to the Environment.

1.4 TREATMENT OF DYEING INDUSTRY EFFLUENT:

Various physical, chemical and biological pretreatment, main treatment and post treatment techniques can be employed to remove colour from dye containing waste waters. Several factors that determine the technical and economic feasibility of each single dye removal includes dye type and its concentration, waste water composition, operation costs (energy and material), Environmental fate and handling costs of generated waste products. In general each technique process may often not be sufficient to achieve complete depolarization. Dye removal strategies consist therefore mostly of a combination of different techniques (Grau 1980 and Cooper, 1993). In past years studies
dealing with treatment of textile waste water, several high rate anaerobic/aerobic reactors (Biological and non-biological) including, Baffled reactor (Chanaka et al., 1992). Two stage up flow anaerobic sludge blanket combined sequential batch reactors (El-Mansi et al., 2004) and filter reactor for different dye due to their own limitations.

1.4.1 Physico-chemical treatment

Different physico-chemical techniques including coagulation, flocculation, precipitation, flotation; adsorption, ion exchange, ion pair extraction ultrasonic mineralization electrolysis, advanced oxidation (chlorination, bleaching, ozonation, fenton oxidation and photocatalytic oxidation) and chemical reduction were previously used in the treatment of different industrial effluents. These physico-chemical techniques are of great value specifically when effluents from industries contain chemical compounds hazardous to biological resources like bacteria and fungi which play a vital role in nourishing other biotic sources by providing basic nutrients after mineralization of organic contaminants in soil and water. Besides different advantages, physico-chemical techniques have also some major disadvantages due to which they are still not seen as permanent answers for the treatment of dye wastewater of industries. (Robinson et al., 2001).

1.4.2 Biological Treatment

Biological dye removal techniques are based on microbial biotransformation of dyes in the effluent. Many researches have demonstrated partial or complete biodegradation of dyes by pure and mixed cultures of bacteria, fungi and algae. In the 1950’s there was a strongly held view amongst microbiologists, often called the “Principle of microbial infallibility, that all chemicals were susceptible to microbial
degradation if the right organisms and conditions could be provided”. The metabolic capabilities of microbes are “all powerful”. The growing realization that many chemicals like dyes which finds their way into the Environment were not being degraded and were persistent for many years. To put an end to such thinking, bioremediation has evolved as the most promising one because of its economical, safety and Environmental features, since organic contaminants become actually transformed and some of them are fully mineralized. Bioremediation technologies offer a cost effective, permanent solution to clean up soils contaminated with Xenobiotic compounds. According to Alper (1983), bioremediation is at least six times cheaper than incineration and three times cheaper than confinement. It is a new and exciting field and its multidisciplinary nature is a challenge for those interested in the remediation of contaminated sites. Bioremediation can be performed off-site when contamination is superficial, but it will have to be in-situ when the contaminants have reached the saturated zone.

1.4.3 Bioremediation

Biotechnology through the study of micro-organisms which are capable of resisting and surviving in polluted Environment provides the knowledge for bioremediation. Bioremediation is a pollution control technology that uses biological systems to catalyze the degradation or transformation of various toxic chemicals to less harmful forms. Bioremediation is defined as the manipulation of living systems to bring about desired chemical and physical changes in a confined and regulated Environment (Cernigila 1985). This natural process includes bioremediation biodegradation, mineralization and co-metabolism.
1.4.3.1 Bioremediation Approaches

Bioremediation is an organic approach to the reclamation of waste materials at the site. It is simply a new application of very old technology once primarily used in waste water treatment. Now this technology is routinely applied to solids, sludges, ground water and surface water contaminated with chemicals such as crude oil, petroleum hydrocarbons, fuels, industrial solvents etc. Detoxification and mineralization of the pollutants to biomass, carbondioxide and water make it an attractive, Environment friendly, safe and cost effective alternative technology to conventional methods. It is a strategy on a process that uses microorganisms, plants or microbial or plant enzymes to detoxify the contaminant in soils and other Environment. The concept includes biodegradation, mineralization and co-metabolism. Three important basic principles have to be considered before selecting the most appropriate strategy to treat specific contaminations. The amenability of the contaminants to biological transformation to less toxic products, the accessibility of the contaminant to microbes (Bioavailability) and the opportunity for optimization of biological activity.

1.4.3.2 Bioremediation Mechanisms

The chief ways by which remediation may be accomplished include biosorption, bioaccumulation, reduction, solubilization, precipitation and methylation (Alexander 1999). Some of the technologies are fully developed and are being practised.

➢ Biosorption

Biosorption is defined as a nondirected physico-chemical interaction occurs between metal or radionuclide sps and microbial cells (Shumate and Stranberg, 1985). It is a biological method of Environmental control and can be an alternative to conventional
contaminated water treatment facilities. Metals interact with microbial cells and accumulate as a result of physico-chemical mechanisms and transport systems of varying specificity, independent on or directly and indirectly dependent on metabolism. These processes are of biotechnological importance relevant to metal removal and recovery from mineral deposits and industrial effluents for industrial use or Environmental bioremediation. The biosorption process depends on pH, temperature, agitation rate and metal concentration. It offers several advantages over conventional treatment methods such as cost effectiveness, high efficiency and minimization of additional nutrients and regeneration of biosorbent with possibility of metal recovery. The biosorption process involves a solid phase (sorbent or biosorbent) usually a biological material and a liquid phase containing dissolved species to be sorbed. Due to the higher affinity of the sorbent for the sorbate, the metal is attracted and bound with different mechanisms. The process continues till equilibrium is established between the amount of solid-bound sorbate and its portion remains in the solutions. During the preponderance of solute molecules in the solution, the uptake of metal does not occur. The imbalance between the two environments creates a driving force for the solute. The heavy metals adsorb on the surface of biomass thus, the biosorbent becomes enriched with metal ions in the sorbate.

Biosorption is a property of certain types of inactive, dead, microbial biomass to bind and concentrate contaminants from even very dilute aqueous solutions, e.g., heavy metal. Biomass that exhibits this property acts as a chemical substance of biological origin. The cell wall structure of certain algae, fungi and bacteria is responsible for this phenomenon, which is a passive process that requires no energy. Biosorption often results from the formation of metal-organic complexes with constituents of microbial cell walls,
capsules or extra cellular polymers synthesized and excreted by the organisms. It may result from the positively charged metallic cation retained electrostatically by negatively charged functional groups in the walls, capsules or polymers. The mechanisms of sorption and the cell constituents involved in sorption are usually unknown although considerable research has been developed to trace the possible mechanisms. It involves mechanisms like ion exchange, chelation and complexation. Inorganic precipitation may occur by hydrolysis. Inorganic deposition occurs via adsorption by physical forces and ion entrapments in inter and intra fibular capillaries and spaces of the structural polysaccharides network as a result of diffusion through cell constituents like acetamido group of chitin, structural polysaccharide of fungi, amine sulphahydral and carboxyl groups in protein, phosphodiester and phosphate and hydroxyl in polysaccharides. (Ahlya et al., 2003)

- **Bioaccumulation**

  The active mode of accumulation of contaminants by living cells is usually referred to as bioaccumulation. The mechanisms by which bacteria actively accumulate include precipitation intracellular accumulation and oxidation or reduction (Ahmad et al., 2004)

- **Precipitation**

  Contaminants react with a product of microbial metabolism to yield water in soluble derivative. The removal of such precipitate constitutes remediation.

- **Reduction**

  Microbes can bring about the reduction of a wide array of organic anions and cations. The reduction changes the toxicity, water solubility and mobility of the element.
Solubilization/Oxidation

The oxidation reaction that has practical use is associated with the oxidation of sulfides. This process can be used in a beneficial way under a controlled or managed process known as bioleaching (Ehrlich and Brienly, 1990)

1.4.3.3 Metabolic Process involved in Bioremediation

Microbes that live virtually everywhere are the vital components for bioremediation. Microbial enzymes act as catalysts in degradative reactions that provide energy and material for synthesis of additional microbial cells. In general, the biochemical process can be divided into two groups: fermentation and respiration. These can be distinguished by the nature of the redox reaction on the basis of the terminal electron acceptor (Bailey and Ollis 1987). Two types of metabolism exist, depending on the type of electron acceptor. If it has an organic origin, fermentation occurs whereas for inorganic origin, fermentation occurs whereas for inorganic compounds, the process will be respiration. In turn, there are two kinds of respiration: aerobic, when the molecular oxygen becomes the electron acceptor and anaerobic, when inorganic compounds such as nitrates, sulphates or carbon dioxide are used.

1.5 MICROBES IN DYEING EFFLUENT TREATMENT:

Biological degradation is a natural process in which microorganisms make use of pollutants for growth and other cellular processes. Bioremediation process offer several advantages over physico-chemical options. Microorganisms are selfgenerating catalysts operating under ambient temperature and pressure conditions. Their reaction specificity permits selective enrichment of microorganisms for a target compound. Microbes have revolutionized the biosorption technology due to their selectively, short generation time,
cost effectiveness, ease in handling and amenability for repeated use. Elevated concentrations of heavy metals discharged into waste water treatment installations may inhibit the sludge biomass from performing its primary function of carbon and nutrient removal (Atkinson et al., 1998). It is therefore of utmost necessity that such nocuous effluents are treated at the source before being discharged into the sewer system.

1.5.1 Bacteria in dyeing effluent treatment

Most studies on the metabolism of organic contaminants have been performed with bacteria especially in the context of bioremediation (Abhijit Chatterjee and Laliatagauri Ray., 2008). Bacteria generally are easier to culture and they grow more quickly than fungi. They are more amenable to molecular genetic manipulations. They are able to metabolize chlorinated and other organic contaminants such as oil and mineralize chemicals using them as carbon or energy source (Heitzer and Sayler, 1993).

Member of the genus *Pseudomonas*, a soil bacterium is the most predominant microbe that degrades xenobiotic compounds. Different strains of *Pseudomonas* that are capable of detoxifying more than 100 organic compounds have been identified eg, hydrocarbons, phenols, biphenyls, PCBs, polycyclic aromatics and naphthalene. About 40-50 strains of *Pseudomonas* capable of degrading xenobiotics have been isolated. Some times for the degradation of single compound, the synergetic action of a few microbes i.e., a consortium or cocktail of microbes may be efficient. For example, the insecticide parathion is more efficiently degraded by the combined action of *Pseudomonas aeruginosa* and *Pseudomonas stutzeri*. 
1.5.1.1 Mechanism of Bacterial Action

Gram Negative bacteria are widespread in metal contaminated soils than gram positive bacteria. The anionic nature of bacterial surface enables them to bind metal cations through electrostatic interactions. Because of their thickness and anionic character which is mainly due to peptidoglycan, teichoic acid and teichuronic acid, the cell wall of gram positive bacteria have high capacity for metal binding. Among bacteria, Bacillus and Pseudomonas has been identified as having potential for metal sequestration and has been used in commercial biosorbent preparation.

1.5.2 Fungi in dyeing effluent treatment

Among micro-organism fungal biomass offers the advantage of having a high percentage of cell wall material which shows excellent metal binding properties. Many fungi and yeast have shown an excellent potential of metal biosorption, particularly the genera Rhizopus, Aspergillus, Streptoverticillium and Saccharomyces. Biosorption is a process in which solids of natural origins are employed for binding heavy metals. It is a promising alternative method to treat industrial effluent mainly because of its low cost and high metal binding capacity. Fungi, virtue of their aggressive growth, greater biomass production and extensive hyphal reach in the Environment, fungi has been seen to perform better than bacteria. The high surface to cell ratio of filamentous fungi makes them better degraders under certain niches (Ashwani et al., 2008).

1.6 ROLE OF ENZYMES IN DYEING EFFLUENT TREATMENT:

Enzymes are catalytic proteins which plays a major role in various metabolic activities. A large number of enzymes from different plants and microorganisms have been reported to play an important role in array of waste treatment applications. The
enzymatic decolourisation of industrial dyes was a big challenge due to large diversity of chemical structures (Wesenberg et al. 2002., Akhtar et al., 2005). Enzymes can act on specific recalcitrant pollutants to remove them by precipitation or transformation to other products (Akhtar and Husain, 2006). Enzymes offered several advantages such as greater specificity, better standardization, easy handle and store and independence of bacterial growth rates (Rojas-Melgarejo et al., 2006). White rot fungi were able to degrade dyes using lignin peroxidase (LiP) and manganese dependent peroxidase (MnP) (Muragesan et al., 2007). Other enzymes used for this purpose include Hydrogen peroxidase producing enzymes, such as glucose-2-oxidase along with laccase and phenoloxidase enzymes (Husain., 2009). Similarly enzymes are also involved in the biodegradation of peroxidase, lignase (Prabhune et al., 1992). The characterization of enzymatic reduction of Hexavalent chromium by Escherchia coli. (Haishen and Yi-Tin-Wang.1993).

Fungi are capable of breaking down the chromophore bearing polymers into coloured and soluble volatile low molecular weight products (Mittar and Khanna, 1992). (Nikhgath Kousar et al., 2000), reported the isolation of Aspergillus niger and its application in decoloursation of industrial effluents. (Vyas and Moliitories 1995), (Mala and Saravana Babu 2004) reported that enzymes which are involved in the degradation of dyes also participate in the decolourisation of the effluent.

1.6.1 Peroxidase

Peroxidase are heme-containing enzymes that are widely distributed in plants, microorganisms and animals. Duarte-vazquez., et al., (2003), and Yang et al., (2003) stated that decolourisation of dye by manganese peroxidase from fungi of different
species namely *Debaryomyces polymorphus*, *Candida tropicalis* and *Umblelopsis isabellin*. The organisms are tested against the degradation of reactive blue 5 dye it showed effective decolourisation. The significance of the manganese peroxidase was proved by *Lentinula edodes* showing decreased activity in the absence of maganase ions and hydrogen peroxide. The manganese peroxidase produced by *Phanerochaete sordida* showed higher range of 90% decolourisation of azo and anthrax quinone dye (Harazono and Nakamura 2005).

1.7 ROLE OF BIOADSORBENTS IN TEXTILE EFFLUENT TREATMENT:

Raw agricultural solid wastes and waste materials from forest industries such as saw dust and bark have been used as adsorbents. These materials are available in large quantities and may have potential as sorbents due to their physico-chemical characteristics and low-cost. Sawdust is an abundant by-product of the wood industry that is either used as cooking fuel or as packing material. Sawdust is easily available in the countryside at zero or negligible price. It contains various organic compounds with polyphenolic groups that might be useful for binding dyes through different mechanisms. The role of sawdust materials in the removal of pollutants from aqueous solutions have been reviewed recently (Shukla *et al*., 2002). Sawdust has been proven to be a promising effective material for the removal of dyes from waste water (Ozacar and Sengil 2005). The sorption mechanisms can be explained by the presence of several interactions, such as complexation, ion-exchange due to a surface ionization and hydrogen bonds. Chemical pretreatment of saw dust has been shown to improve the sorption capacity and to enhance the efficiency of sawdust adsorption (Garg *et al*., 2003). Adsorption offers the best prospect for overall treatment of effluent and it is effective in colour removal.
Mayer *et al.*, (1989) has evaluated the ability of several low cost natural adsorbents materials including saw dust, maize stalks, sand, rice husks and peat moss. Gupta *et al.*, (1990) studied the impact of clay as an adsorbent for mordant blue. Namasivayam and Kadirvelu, (1994) also has studied the adsorption of dye by waste coir.

### 1.8 HEAVY METAL REMOVAL BY IMMOBILIZATION:

One of the major problems in the use of microorganisms for the biological treatment of waste water is the recovery from treated effluents. Immobilization technique is the best to solve this problem. Cell immobilization can be defined as the confinement of whole cells in an insoluble phase, which permits the free exchange of solutes from and towards the biomass but at the same time, isolates the cells from their surroundings medium. Free biomass is not advantageous over the immobilization counterpart in bioremediation processes. During the biosorption processes, free biomass malfunctions because pressure drops across a fixed bed column during down-flow operation. This is due to cell clumping and excessive hydrostatic pressure is required to generate a suitable flow-rate. Free cells are suitable only for a limited number of applications such as discontinuous reactors (*Balanco et al.*, 2003). The above constrains can be overcome by using an appropriate immobilization method for the selection biomass. Thus the biomass immobilization provides good handling and operation characteristics to biomass. Application of biosorption is based on adsorption on inert supports and entrapment in polymeric matrix.

Immobilization of biomass in a matrix that is too dense can significantly reduce contaminant loading. Aggressive immobilization leads to beads with lesser porosity and the contact time between the immobilized biomass and the water with contamination
must be increased to allow for the increased diffusion time. Contamination especially metals adsorbed on to the immobilization biomass can be eluted in the same way as in case of free biomass i.e. by means of the common eluents (Gupta, et al., 2005). Metals such as Au, Ag and Hg can be desorbed using chelating compounds such as EDTA or complexing agents such as thiourea.

The regeneration of the biosorbent is important for keeping the process cost down. The possibility of recovering the metal occurs in liquid phase. The desorption process yield the metal in the concentrated form and restore the biosorbent close to the original state for effective reuse with undiminished metal uptake. Dilute mineral acids are used for metal removal which causes health hazard and metal accumulation in plants.

1.9 UTILIZATION OF TREATED EFFLUENT FOR IRRIGATION:

Recycling of treated wastewater for irrigation seems to be an appropriate solution for land degradation, salinization and eutrophication of water bodies. Effluents could serve as a source of water and nutrients for crop production, thereby reducing the demand for potable water for irrigation water and fertilizer inputs. Crop irrigation with treated effluent is a technically sound, Environmentaly safe recycling programme, which need of the industries and farmers of the neighbourhood at a single stroke (Rekha, 2000). The treated effluents can be a dependable water source for the farmers in the neighbourhood. Irrigation with paper mill effluents has shown encouraging results in oat and orchard grasses (Hashimoto and Yokoto, 1965).

Singh et al., (1990) and Azov and Shelef, (1991) reported that lack of high quality of fresh water has stimulated the search for alternative non- conventional water resources. The treated effluent application by irrigation simultaneously solves water
shortage and waste water disposal problem. Marten (1978) reviewed the literature on the use of municipal waste water as a source of irrigation for crop production, on feed quality of forage crops, forage legumes and grain crops. Day (1973) has showed that effluent from activated sludge treatment plant contained nitrogen, phosphorus and potassium that could be utilized for irrigation. Biologically treated textile effluent improved the germination percentage of tomato seeds. Diluted and biologically treated effluent produced higher yields than control. Saravana Babu et al., (1992) studied the effect of tannery effluent on germination and seedling height in some cereals. Mala and Saravana Babu (2005) reported the impact of untreated textile dyeing effluent on germination of Bhendhi, Green gram, Maize. Irrigational utilization of treated tannery effluent and biochemical characteristics of ground nut was studied by Swamiantahan and Vaidheeswaran (1991).