Chapter I

Introduction
1.1. Introduction on dyes

A dye can generally be described as a coloured substance that has an affinity to the substrate to which it is being applied. One of the classification methods of the dyes is according to the method of dyeing process. Synthetic dyes may be categorized into 16 classes [1]. They are of Basic-cationic, Oxidation-bases, Acid-anionic, Acid-milling, Acid-premetallized, Neutral-premetallized, Mordant-chrome, Direct-substantive, Direct-developed, Direct-azoic, Disperse, Sulfur, Vat, Reactive, Pigment and Optical Brightener types. The classification can also be based upon the particular type of chemical composition of the dye.

The era of the dyes and dyeing began as earlier as 331 B.C. The discovery by Sir William Perkin (an English chemist in 1836) that a mauve colouring matter capable of dyeing silk could be prepared by the oxidation of aniline started a vast chain of events. It resulted in production of approximately 8,000 distinctly different dyestuffs being manufactured all over the world and sold under 40,000 trade names.

Synthetic dyes that are used in the textile industry can be broadly classified as follows;
BASIC DYES: Mauve, the first to be discovered by Perkin, was a basic dye and most of the dyes, which followed including magenta, malachite green and crystal violet, were of the same type. Basic dyes dye wool and silk from a dye bath containing acid but dye cotton fibres only in the presence of a mordant, usually a metallic salt that increases affinity of the fabric for the dye. Basic dyes include the most brilliant of all the synthetic dyes known, but unfortunately they have very poor light and wash fastness. Basic dyes will dye wool and silk from an acid bath and are used where brightness is of prime consideration. With the introduction of cotton dyes possessing higher fastness properties, their use for dyeing cotton has diminished.

DIRECT DYES: These are soluble in water and have direct affinity for all cellulosic fibres. Some will also dye silk and wool. By continuous research this group of dyes has been supplemented with dyes of good fastness to light and washing. As these dyes, when dyed without additives, do not exhaust well, an addition of salt is required to improve the yield of the dye and obtain deeper shades. Generally, the wash fastness of these dyes is inferior but there are a number of after-treatments available to improve the wash fastness of the dyeing. Most direct dyes can be stripped of the use of stripping salts (sodium hydrosulphite) without harmful effects on the fibres. Direct dyes dye all cellulosic fibres, viscose rayon, and most of them also dye wool and silk. They do not dye acetate rayon and synthetic fibres. Direct dyes can be applied well at low
temperatures and are therefore suitable for tie-dyeing and batik work. Generally these dyes are used where high wash fastness is not required.

VAT DYES: Indigo, probably the oldest dye known to man, is one of the most important members of this group. In 200 BC, the Egyptians used natural indigo extracted from the plant ‘Indigofera tinctorie’. The first synthetic indigo was introduced to the textile trade in 1897 and had the effect of completely replacing the natural product. Although the vat dyes may be divided into three chemical groups, they are similar in that they are insoluble in water and become water soluble when reduced in the presence of an alkali. After dyeing, the fabric is oxidized and the dye again becomes water insoluble. Because of the time consuming and costly procedure in reducing vat dye into a water-soluble complex, dye manufacturers have produced a stabilized water-soluble vat dye. This dye can be applied to cotton and viscose rayon by the methods used by applying direct cotton dyes. After the dyeing, a simple treatment restores the vat dye to its normal insoluble state. Solubilized vat dyes have an affinity for cellulosic and animal fibres. Vat dyes are used in cotton dyeing where high wash and boil fastness required. Because of the high alkali concentration in the dye bath, pure vat dyes cannot be used on animal fibres, (wool, natural silk, and various hairs). Bright red is absent in vat dye range. Solubilized vat dyes, not requiring the presence of alkali, can be used for dyeing on animal fibres.
REACTIVE DYES: These dyes have been introduced to the market in 1956. They react chemically with the fiber being dyed and if correctly applied, cannot be removed by washing or boiling. The main feature of the dyestuff is its low affinity to cellulose; therefore large amounts of salt are required to force its deposition on the fabric. After this has been achieved, addition of alkali causes the deposited dyes to react with the fiber. Only a successfully concluded reaction guarantees a fast dyeing. Basically there are two types of reactive dyes: the cold dyeing and hot dyeing types. Reactive dyes are used where bright dyeing with high light and wash fastness is required. Cold dyeing is used extensively in batik work. Although some reactive dyestuffs have been specially modified to dye wool, their main usage is in dyeing cotton linen and viscose rayon.

AZOIC DYES: The word 'azoic' is the distinguishing name given to insoluble azo dyes that are not applied directly as dyes, but are actually produced within the fiber itself. This is done with impregnating the fiber with one component of the dye, followed by treatment in another component, thus forming the dye within the fiber. The formation of this insoluble dye within the fabric makes it very fast to washing. The deposition of the free pigment on the surface of the dyed fabric produces poor rub fastness, but once the loose pigment is removed by boiling the fabric in soap, the dyeing becomes one of the fastest available.
SULPHUR DYES: The first sulphur dye was discovered in France in 1873, and further work done by Raymond Videl enabled the manufacture of 'Videl black'. Its outstanding fastness to light, washing and boiling far surpassed any cotton black known at that time. The general disadvantage of the sulphur dyes that they produce dull shades and lack a red. The main advantage lays in their cheapness, ease of application and good wash-fastness. In their normal state, sulphur dyes are insoluble in water but are readily soluble in the solution of sodium sulphide. In this form they have high affinity to the all cellulosic fibres. The use of sulphur dyes is restricted to dull brown, khaki and navy shades, where a good wash but not boil-fastness is required. Most khaki and navy overalls are dyed with sulphur dyes. An outstanding member of this family is sulphur black. It dyes all cellulosic fibres, but particularly linen and jute, to a lustrous and deep black with excellent wash and light fastness. Sulphur dyes are dyed from a dye bath containing sodium sulphide and common or Glaubers salt, and are oxidized by airing or with some oxidizing agents (sodium bichromate or hydrogen peroxide) in a fresh bath.

MORDANT DYES: Mordant dyes are so called because to apply them necessitates the use of mordant. This group of dyes includes natural dyes (derived from logwood, fustic and madder) and a large group of synthetic dyes with a widely differing constitution. The mordant dyes can be applied to fibres by three different methods; (i) by mordanting the fiber with a suitable metallic salt and then applying the dye, (ii) by dyeing the fiber and subsequently after-treating
it with a suitable metallic salt so as to form an insoluble lake. This is the basis of 'after-chrome' method used in particularly fast dyeing of black and brown colour on wool, (iii) by the simultaneous application of the dye and mordant. In wool dyeing 'metachrome' or 'monochrome' process is extensively used for dyeing of brown and khaki colours. Since the dyes used in this process vary widely, not only by the methods of application and dyeing of different fibres, reliable recipes and instructions are to be followed carefully.

ACID DYES: These dyes comprise a large number of dyes used for the dyeing of wool, silk and nylon. They vary considerably in their basic chemical structure, but have one common feature (they dye from an acid dye bath). All acid dyes can be grouped in three broad sub groups; (i) level dyeing acid dyes - these dyes produce bright dyeing. The main feature is their good leveling properties. They are dyed from a dye bath containing strong acids (sulphuric or formic acid). These dyes exhibit low wash and light fastness. (ii) Acid milling dyes- they have high light fastness and are extensively used for dyeing woolen fabrics that are subsequently milled. These dyes require great care in application because uneven dyeing are difficult or impossible to rectify. The dye bath requires the presence of weak acid (acetic acid) or acid releasing salts (ammonium sulphate or ammonium acetate) from which acid is liberated during dyeing; (iii) premetalized dyes- the metal component being already incorporated in the dye during manufacturing process. They have very good light fastness
even in pale shades. The family of acid dyes is very large and diverse, varying widely in their methods of dyeing, application and end use of the dyed fabric.

DISPERSE DYES: The introduction of regenerated cellulose acetate fibre in 1920 led to the necessity to develop an entirely new range of dyes. It was found that cellulose acetate fibre had hardly any affinity for water-soluble dyes. A new dyeing principle (dyeing with water dispersed coloured organic substances) was introduced. These finely coloured particles are applied in aqueous dispersion to the acetate material and actually dissolved in the fibres. Basically developed for dyeing of acetate fibres, disperse dyes are also used for dyeing of polyamide and acrylic fibres. With the addition of 'carriers' or swelling agents, these dyes are also used in dyeing of polyester.

OXIDATION DYES: These are not dyestuffs in the same sense as other soluble or disperse dyes, but because of their exceptional fastness to light and washing are of great importance. The most important member of this group is produced by oxidation of aniline and is much used in dyeing of fur and leather goods. In addition to fur and leather dyeing, aniline black was almost exclusively used to dye luster black umbrella fabric.

MINERAL AND PIGMENT DYES: Although it is preferred to use water-soluble dyes in textile dyeing for two reasons namely ease of application and greater softness of the fabric, there are two processes where pigment colouration
is used; (i) mineral khaki - cotton army equipment where it is used because of its cheapness and renders fabric resistant to rotting and attack by insects in damp conditions, and (ii) synthetic resin printing - the introduction of heat setting synthetic resins has opened new fields in textile printing. Mineral and organic pigments, as used in paint manufacture, can now be applied to any fabric and rendered wash fast after heat treatment. Whilst the formation of mineral pigment on the fabric is used less and less as a dyeing process, the use of pigment printing is continuously increasing. The reason for this is the development of soft and flexible synthetic resins, available as binders (or adhesives) to secure the pigment to the fabric without inducing a harsh or stiff finish.

Following are some of the names in each dyestuff category;

Reactive      : Drimarene-K, Drimalan-F, Procion, Levafix, Hostalan, and Cibacron
Vat           : Synthetic Indigo, Indanthreen, Calendon, and Indigosol
Disperse      : Polysol, Resolin, Foron, Dispersol, Cibaset
Modified basic: Astrazon, Maxilon, Sandocryl, Synacryl
Azolic        : Naphtol, Naphtanilide, and Diazoo Fast salts
Direct        : Solar, Diamin, Solophenyl, and Durazol
Acid          : Lanasy, Nylosan, Sandolan, Irgalan, Lissamine
Chrome        : Eriochrome, Solochrome

**Disperse Dyes**

Disperse dyes are organic colouring substances which are free from ionizing groups, are of low water solubility and are suitable for dyeing hydrophobic fibres from colloidal dispersion. Disperse dyes are essentially low molecular weight derivatives of azo, anthraquinone diphenylamine and other compounds. They melt at above 150°C and are crystalline materials, which are
ground with dispersing agents to produce a stable dispersion in the dye bath. Sodium lignine sulphonate is mainly used as dispersing agent. The structure of lignine is given below;

About 50% of all the commercial disperse dyes belong to monoazo and 25% is provided by anthraquinonoid dyes. Diazo contributes 10% of the total while methine, styryl, acrylene benzimidazol, and quinonaphthalone dyes amount to 3% each.

The disperse dyes are mainly used for colouring hydrophobic fibres such as cellulose acetate, triacetate, polyamide, polyester, polyacrylonitrile etc. These are especially important for polyester fibres as they are widely used as a component of blends with cotton, wool or any other man-made fibre.
The dispersion process involves the conversion of large particles of the dye into a uniform and very fine form to ensure uniform and trouble free dyeing with maximum colour value. This is achieved by milling the dye paste in the presence of a large excess of dispersing agent and then drying in a spray dryer in which the paste is sprayed into a stream of hot air when water present is rapidly evaporated.

The dispersing agents also help in increasing the solubility of the dye in water. The dyeing applications of disperse dyes on polyester fibres are considerably accelerated by the addition of "carriers". It helps to reduce the intermolecular forces operating in the fibre thus allowing the dye molecule to diffuse more rapidly. This is known as "carrier" dyeing. The other method of application of disperse dyes on polyester fibres is the "Thermosol" process. Polyester fibres being thermoplastic soften and their internal structure is opened up when heated to around 200-230°C. The fibre macromolecule can vibrate vigorously so that the dye molecules can diffuse in the fibre with ease. This method has the advantage of being a continuous one and having excellent dye utilization of about 75-90%.

**General properties of disperse dyes**

- Disperse dyes are essentially low molecular weight derivatives of anthraquinone and diphenylamine.
- Disperse dyes have no charged groups and contain polar sites.
• Disperse dyes are low molecular weight crystalline solids melting at 150-250°C and subliming without decomposition.

• Disperse dyes have low solubility and increasing with rising temperature and by the addition of a dispersing agent. Solubility is complete at 130°C.

• Salubrity value of these dyes is high with the range of 30 to 200 mg/g of fibres.

• Particle size of marketed dyes is low (about one micron) which accelerates rate of dyeing.

1.2. German Ban

In Germany, it was found that symptoms of cancer occurred among workers who handled benzidine in the production of azo dyes. Due to this, several European dye manufacturing companies stopped producing and marketing azo dyes based on benzidine in the 1970's. Later, several tests were conducted on azo dyes and it was found that azo dyes could be split under certain physiological condition to form carcinogenic amines.

In July 1994, Germany amended two laws that were significant for textile processing industries; (i) The Fourth Federal Emission Protection Ordinance (its aim being to protect the environment from effluent of textile industry) and (ii) The Ordinance of Material and Articles (its aim being to protect the consumer). This ban prohibits the use of certain azo dyes, which could split and give 20 arylamines proven or suspected to be carcinogenic. As per the German Legislation Consumer Goods Ordinance, "No articles of clothing or items which
regularly come in contact with the human body may be put into circulation if they can release harmful amines due to the use of azo dyes, which are either known or suspected to be allergic, poisonous or carcinogenic. These dyes should not henceforth be used by any supplier of textiles or leather goods" [2].

Red and Green lists have been prepared in most of the European countries. Green listed items are labeled as ecofriendly. Red listed items are either being banned or phased out. The list prepared by German Committee for testing the carcinogenic materials is called MAK list and is updated every year. The banned (red listed) dyes spread over six classes of dyes, viz., acid, azoic, basic-cationic, direct, disperse, oxidation bases and developers. These six classes are termed as "affected" classes of dyes. None of the dyes from the remaining classes of dyestuffs is banned, i.e., dyes belonging to reactive, vat, sulfur and natural dyes. These are termed as "unaffected" classes.

The amines obtained after dye reduction are electrophilic and are covalently bonded to the nucleic acid of DNA resulting in DNA damage and hence induce cancer. Scientifically found evidence proves that four aromatic amines have carcinogenic effect on human. These are benzidine, 2-Naphthylamine, 4-Aminobiphenyl and 4-Chloro-o-toluidine. These four amines are listed as definitely carcinogenic and placed in group III A1 of German MAK list. The other listed amines are also carcinogenic under optimum condition of splitting and placed in group III A2 of MAK list.
Conditions that can cause reductive splitting of azo dyestuffs are (i) a reductive chemical medium and (ii) the human organism as a result of the action of intestinal bacteria or azo reductase in the liver on any azo dyestuffs in the body. The mechanism of reduction cleavage and further action may be represented as follows:

**Reductive Cleavage:**

\[
R - N = N - R' \xrightarrow{\text{reductive condition}} \xrightarrow{\text{azo cleavage}} R - NH_2 + R' - NH_2
\]

(Azo dyestuff) \hspace{1cm} \hspace{1cm} Aromatic amines

**Covalent bonding to the nucleic acid bases of DNA**

\[
R-NH_2 \xrightarrow{\text{Oxidation}} R-NHOH \xrightarrow{\text{pH < 7}} R-NOH_2 \xrightarrow{\text{(covalent bonding)}} R-NH^+
\]

(Amine)

List of forbidden dyes based on benzidine type is as follows:

<table>
<thead>
<tr>
<th>Acid Orange 45</th>
<th>Direct Red 37</th>
<th>Direct Brown 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Red 85</td>
<td>Direct Acid 44</td>
<td>Direct Brown 25</td>
</tr>
<tr>
<td>Acid Black 29</td>
<td>Direct Violet 1</td>
<td>Direct Brown 27</td>
</tr>
<tr>
<td>Acid Black 94</td>
<td>Direct Violet 12</td>
<td>Direct Brown 31</td>
</tr>
<tr>
<td>Azoic Diazo Comp 112</td>
<td>Direct Violet 22</td>
<td>Direct Brown 33</td>
</tr>
<tr>
<td>Direct Yellow 1</td>
<td>Direct Blue 2</td>
<td>Direct Brown 51</td>
</tr>
<tr>
<td>Direct Yellow 24</td>
<td>Direct Blue 6</td>
<td>Direct Brown 59</td>
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<td>Direct Green 1</td>
<td>Direct Brown 79</td>
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<tr>
<td>Direct Orange 8</td>
<td>Direct Green 6</td>
<td>Direct Brown 95</td>
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<tr>
<td>Direct Red 1</td>
<td>Direct Green 8</td>
<td>Direct Brown 101</td>
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<tr>
<td>Direct Red 10</td>
<td>Direct Green 8:1</td>
<td>Direct Brown 154</td>
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<tr>
<td>Direct Red 13</td>
<td>Direct Brown 1</td>
<td>Direct Black 4</td>
</tr>
<tr>
<td>Direct Red 17</td>
<td>Direct Brown 1:2</td>
<td>Direct Black 29</td>
</tr>
<tr>
<td>Direct Red 28</td>
<td>Direct Brown 2</td>
<td>Direct Black 38</td>
</tr>
</tbody>
</table>
The list of banned azo dyes is as follows [3-5].

| Acid Red 4 | Basic Red 111 | Direct Blue 10 |
| Acid Red 5 | Basic Red 42 | Direct Blue 14 |
| Acid Red 24 | Basic Brown 4 | Direct Blue 15 |
| Acid Red 26 | Oxidation Base 20 | Direct Blue 22 |
| Acid Red 73 | Direct Yellow 48 | Direct Blue 25 |
| Acid Red 114 | Direct Orange 6 | Direct Blue 35 |
| Acid Red 115 | Direct Orange 7 | Direct Blue 53 |
| Acid Red 116 | Direct Orange 10 | Direct Blue 76 |
| Acid Red 128 | Direct Orange 108 | Direct Blue 151 |
| Acid Red 148 | Direct Red 2 | Direct Blue 160 |
| Acid Red 150 | Direct Red 7 | Direct Blue 173 |
| Acid Red 158 | Direct Red 21 | Direct Blue 192 |
| Acid Red 167 | Direct Red 22 | Direct Blue 201 |
| Acid Red 264 | Direct Red 24 | Direct Blue 215 |
| Acid Red 265 | Direct Red 26 | Direct Blue 295 |
| Acid Red 420 | Direct Red 39 | Direct Green 85 |
| Acid Violet 12 | Direct Red 46 | Direct Brown 222 |
| Acid Brown 415 | Direct Red 62 | Direct Brown 91 |
| Acid Black 131 | Direct Red 67 | Direct Yellow 154 |
| Acid Black 132 | Direct Red 72 | Disperse Yellow 7 |
| Acid Black 209 | Direct Violet 21 | Disperse Yellow 23 |
| Azoic Diazo Comp11 | Direct Blue 1 | Disperse Yellow 56 |
| Azoic Diazo Comp12 | Direct Blue 3 | Disperse Yellow 149 |
| Azoic Diazo Comp48 | Direct Blue 8 | Disperse Red 151 |
| Azoic Diazo Comp113 | Direct Blue 9 | |

After the prohibition of import and marketing of textiles (or allied articles containing azo dyes which on reductive cleavage release any of the twenty carcinogenic amines) by Germany, other countries also imposed similar restrictions [6]. These include Holland, Turkey, France and India. However, the approach in enforcing ban varied from one to another. The European union has banned around 300 textile dyes of suspected carcinogen [7].
1.3. Industrial Pollution Problems relating health, safety and environment

We must recognize that all sectors (industry, government, agriculture, mining, energy, transportation, construction and consumers) of our society generate waste. Wastes contain pollutants, which are discarded process materials or chemicals. Pollutants, releasing into the environment beyond the assimilation capacity of the environment create pollution. Among those sources, industry is the primary target of all waste generators because of its quantity and toxicity. Industrial activities such as production, distribution, transport, storage, consumption of goods and services have known to be the most critical sources of environmental pollution problems.

Environmentalists have been controlling the releases of pollutants and neglecting the production of harmful products and services that also caused environmental pollution. DDT, CFCs, asbestos, leaded gasoline, certain kinds of plastics, medicines, cosmetics, fertilizers, pesticides, herbicides, discarded by-products and used-products are known to cause environmental and health risks. The increase of toxic chemicals and hazardous wastes in our environment has become man’s most urgent environmental pollution problem both now and in the future. In order to solve this urgent problem, one has to take immediate action.

The scale of industrial production worldwide seems set for inexorable growth. Ecosystems have declined severely worldwide. We are witnessing the
evolution of a fully industrialized world, with global industrial production, global markets, global transportation, global telecommunication and global prosperity. This prospect brings the realization that current patterns of industrial production will not be adequate to sustain environmentally safe growth on such a scale and are therefore all but obsolete.

Millions of people are concerned about pollution, waste, garbage and trash. There are over 6 billion people living on the planet. Many people see severe environmental problems, but still many others do not. Even those who see pollution problems may not know and understand all the impacts on what happens to waste and pollution, and what the impacts are on public health and the environment. Waste seems natural both biologically and socially. If waste is inevitable, then all forms of waste have to go somewhere. Pollution exists because the environment can absorb only a limited amount of pollutants and wastes. Some hazardous or toxic by-products and chemicals are termed hazardous pollutants because they have toxic characteristics and the environment cannot assimilate them. Many wastes or pollutants will have multiple adverse effects. There may also be synergistic interactions and cumulative exposures from different wastes and pollutants in the environment. A toxic chemical may be in drinking water, food, household and workplace air, and consumer products.
The human behavior for change in pollution prevention needs new knowledge and education, with creative and probing personalities. It is no longer acceptable to rest on environmental experiences gained decades ago in wastewater treatment or air pollution control systems. The future factory may consider the environmental implications of a new product or service. It may design pollution management strategies into its research experiments.

1.4. Waste Treatment and Disposal

In air pollution control systems, contaminants are removed from the waste air-stream and transformed into wastewater or solid waste. Only in emission that meets legally established standards is emitted into the environment. In principle, the same happens in the wastewater treatment system; contaminants are removed from the wastewater, collected as solids, and disposed of as waste. Air pollution control technologies include filtration, electric precipitation, cyclone, combustion for solid pollutants; absorption, adsorption, condensation, incineration for gaseous pollutants. Water pollution control technologies include; sedimentation, filtration, combustion for inorganic pollutants; vaporization, absorption, adsorption, biodegradation for organic pollutants. Solid waste pollution control technologies include landfill and incineration. The end-of-pipe technology involve the danger that noxious pollutants may merely be shifted from one medium to another and in the end a huge waste problem will be created. As many as 1,00,000 chemical substances are used commercially around the world, and for many produced in very high volumes.
Some common household hazardous chemicals are:

(i) Hair dyes and bleaches are highly toxic if ingested
(ii) Ammonia is toxic and an irritant if inhaled or skins contacted
(iii) Drano contains sodium hydroxide
(iv) Fingernail polish remover contains acetate solvents
(v) Polyurethane wood finish contains isocyanates
(vi) Fertilizer causes nitrate poisoning
(vii) Pesticides can be lethal to all living organisms
(viii) Others include carburetor cleaner, paint thinner, glue or epoxide, varnish, anti-freezer, brake fluid, rust remover and lead paint.

In addition, some common industrial hazardous chemicals are:

(i) Chlorinated solvents such as trichloroethane
(ii) Non-chlorinated solvents such as benzene, acetone
(iii) Waste oils such as hydraulic oils, cutting oils and machine lubricants
(iv) Acids and alkalis such as sulfuric acid, caustic soda, lime
(v) Developers, fixers, and inks contain formaldehyde, cyanide, acetic acid from textile manufacturing, print and photo and X-ray processing
(vi) PCB's contain polychlorinated biphenyls from insulating equipment
(vii) Asbestos used for insulting ducts and buildings
(viii) Paint wastes and lacquers from metal maintenance manufacturing processes
(ix) Resins such as urea formaldehyde, epoxy from chemical, rubber and plastic manufacturing.
The difference between waste management and pollution management is that the former emphasizes controlling pollutants in the wastes and minimizing waste generation at the sources. While pollution management is not just to prevent and control pollutants and wastes, but also the search for better answers for manufacturing and consuming environmental friendly products and services in a broader sense. Pollution prevention is the logical extension of pollution control. Environmental management needs to upgrade beyond waste management to a broad approach of pollution management.

- The first principle of pollution is that pollution from human activities is unavoidable. Pollution is created by releasing pollutants and wastes into the environment as well as by producing environmental harmful products and services as a result of careless human activities related to social and economic development.

- The second principle of pollution is that prevent pollution whenever possible. As a result of the first principle, pollution needs to be cost-effectively managed. Pollution can be prevented or minimized, but not completely eliminated. The remaining residual pollution from human activities must be properly treated and disposed in order to protect human health and the environment.

- The third principle of pollution is that minimal pollution is acceptable. Ecosystems can safely handle and assimilate minimal amounts of
pollution. If pollution is within the environmental standards of quality, its impacts to human health and the environment can be acceptable. One must work within the confines of the natural laws to prevent pollution problems in a wise and economically feasible fashion [8].

From industrial pollution practices viewpoint, pollution prevention and cleaner production can be generalized into six categories: improved plant operations, in-process recycling, process modification, materials and product substitutions, materials separations and precision fabrication. It is important to realize that pollution prevention is a very broad term and applies beyond industrial sectors to a variety of economic sectors and institutional settings. Methods of controlling the use of toxic chemicals include (i) increasing knowledge of chemicals, (ii) improving information, (iii) substituting toxic chemicals by less toxic ones, and (iv) for those chemicals that cannot be replaced, ensuring that handling does not result in exposure that may damage public health or the environment. Interest in biodegradable materials has increased recently, as they offer potential for reducing the cost of waste handling and the increasing problem of littering, due to faster decomposition of the disposed materials. Degradation mechanisms include biodegradation, photodegradation, chemical degradation and environmental erosion.

The ABCs of Pollution Prevention [9] can be listed as given;

1. Avoid chlorinated organic solvents, cyanide compounds and petroleum-based compounds when water-based substitutes exist.
2. Buy drain boards and drip pans to enhance drip reuse in process baths.
3. Choose closed-loop recycling designs to reduce wastes and worker exposures.
4. Decrease the frequency of painting and paint removal to minimal levels.
5. Ensure a neat work environment to prevent spills of toxic chemicals.
6. Foster a regular program of pollution prevention planning and auditing.
7. Give employees incentives to find new pollution prevention ideas.
8. Have and use covers for all containers holding fluids that evaporate.
9. Instruct employees in pollution prevention.
10. Just use storage tanks with secondary containment.
11. Keep track of toxic chemical inventories to ensure fewer containers on-site, thus minimizing spills, spoilage and evaporation.
12. Label containers to prevent mistakes that could result in wastes requiring disposal.
13. Monitor and maintain the appropriate temperature for heated materials.
14. Never allow leaks to persist.
15. Only use sprays when absolutely necessary, since they waste chemicals through dispersion.
16. Pre-clean parts with physical methods before using solvents.
17. Quit disposing of baths without checking bath quality and restore quality through the use of non-toxic additives.
18. Reformulate or redesign products so fewer toxic chemicals are used in production processes.
19. Select continuous rather than batch processes whenever possible, to avoid start-up wastes.
20. Try redesigning processes so they require fewer toxic chemicals.
21. Use machines instead of manual methods where toxicity concerns exist and process precision would reduce wastes significantly.
22. Varnish and other coatings that are not essential should be avoided.
23. Wash parts only when absolutely necessary.
24. Xerox double-sided as often as possible.
25. Yield maximization is one goal, and
26. Zero waste is the other goal.

1.5. Treatment system for textile wastewater

Increasing concern for environmental friendly processing, which necessitates the use of new materials / methods and reduced pollution load in effluent discharge has left the textile processors in the lurch. The state-of-the-art technology for textiles has to come to the rescue by providing a range of innovative materials and methods. Any process or activity may not consume the entire output. A large percentage is returned as wastewater. Rough estimate is that 70% of water becomes waste. Wastewater originating from textile wet processing operations destroys the quality of water-body in which they are disposed affecting the sewage system, agricultural land, marine life etc. It is therefore necessary that the materials and methods used in textile operations
should result in a meaningful solution to tackle the problem of environmental pollution.

Wastewater is treated to remove and decompose substances that are harmful to the natural environment. Textile production can be roughly divided into the following four processes.

(i) Preparation: Prior to dyeing, impurities are removed from raw fabrics. Then the raw fabrics are "desized, refined and bleached" at the same time. Starch or other natural adhesive paste is mainly used as the glue in raw fabrics. However the spread of high-speed textile machines has made chemicals such as PVA (polyvinyl alcohol) the mainstream. PVA is a refractory substance because it is a polymer. And it is difficult to purify wastewater including PVA. In this process, chemicals such as surface active agents, oxidative desizing agents, sodium hydroxide, hydrogen peroxide, sodium hypochlorite, acetic acid and auxiliaries are used. So these refractory chemicals are highly concentrated in the wastewater from this process.

(ii) Mercerization: This process gives products a luster. Mercerization gives cotton a silk-like shine, using high concentration sodium hydroxide. A high alkaline waste solution is discharged and requires neutralization.
(iii) Dyeing: Textile material is dyed using various classes of dyes. The process is grossly divided into reactive, disperse, sulfur, indanthrene, and naphtnol dyeing according to product use and raw fabric materials. Chemical substances concentration in the wastewater always fluctuates because of compound chemical reactions in it. Moreover, the diversity of pigments makes them hard to identify. Therefore, the wastewater discharged from this process is coloured with compound reactions.

(iv) Finishing: This process finishes products for the intended use. It includes any number of treatments such as softening, water-proofing, antibacterial, insect repelling, flame-retarding, durability improvement, etc. The objective of this process is to give products an appropriate look and function. Therefore a various kind of resins and chemicals are used such as silicon, acrylic, urethane and fluorine. Most of these chemicals and resins do not readily decompose. So they react with one another in the wastewater from this process.

Various methods can be employed for the treatment of textile mill wastewater. The mostly used treatments are drying, evaporation, chemical treatment (precipitation, oxidation, reduction), thermal treatment, biological treatment (aerobic and anaerobic), membrane processes (ultrafiltration, reverse osmosis), adsorption, distillation, electrochemical and composting. They can be classified as follows;
<table>
<thead>
<tr>
<th>Separation</th>
<th>Filtration</th>
<th>Screening</th>
<th>Dehydration</th>
<th>Filter press</th>
<th>Decanter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sand filtration</td>
<td></td>
<td></td>
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<td>Oxidation - reduction</td>
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<td>Suspended Biology</td>
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<td>Anaerobic</td>
<td>Digestion process</td>
<td>Obligate aerobe</td>
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**Summary**

In textile industries, different classes of dyes are used for the dyeing of different substrates. Disperse class of dyes are normally used in dyeing of polyester. The wastewater originating from such disperse dyeing should be treated properly. Considering the wastewater originating from disperse dyeing and environmental pollution issues discussed, it has been planned to study the disperse dye effluent treatment by various physicochemical methods. The literature details on dye effluent treatments are presented in the next chapter.