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Review Article

POLLUTION MINIMIZATION POTENTIALS IN DYEING INDUSTRY: ENVIRONMENTAL ISSUES AND ITS IMPACTS

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ABSTRACT
Dyes are coloured substances which impart colour to the object. The colour giving property of dyes can be attributed to chromospheres which is one of the major components of dye. First synthetic dye was discovered by William Henry perkin in 1856. Dyes are used for various applications but most extensively used in textile dyeing. About 10,000 different textile dyes with an estimated annual production of 7.105 metric tonnes are commercially available worldwide; 30% of these dyes are used in excess of 1,000 tonnes per annum, and 90% of the textile products are used at the level of 100 tonnes per annum or less. The paper deals with the classification of dyes based on application and chemical composition of dye. It also discusses water consumption in dye industry and the characteristic of wastewater along with the brief idea of treatment methods available for treating wastewater from dye industry.

Keywords: *Chromospheres, Synthetic Dye, Metric Tonnes, Wastewater*

INTRODUCTION
Dyes and Dye Intermediates industry occupies an important place in the sector of Indian Chemical Industry. After independence this sector has grown at a very fast rate. Dyes stuff are produced over 700,000 tons annually estimated from more than 100,000 commercially available dyes Bhatia SC. and applied in many different industries, including the textiles, paper, cosmetic, leather, food and pharmaceutical industries. At present nearly half of its production is being exported. Most of the industries manufacturing dye and dye intermediate are in the small and medium scale sector. Dyes are complex compounds with a big complicated molecular structure and toxic properties.

Thus, it can affect aquatics life, human health and ecological system when Dye wastewaters are extremely discharged wastewater into water sources. It eventually makes changes of ecological system and other serious pollution problems (Honda and Yamamoto, 2000). The major components of a dye molecule are chromophores and auxochrome. Chromophores (chroma = colour; phore = bearer) are basic group, primarily responsible for colour while auxochrome(auxo = augment) intensify the colour of dye and it also helps in improving the affinity of dye to substrate.

Classification Systems for Dyes
Hunger (2003) mentioned, dyes are classified in two methods. First of all, is the classification according to the chemical structure of dyes particularly considering the chromophoric structure presents in the dye molecule and the second classification is based on their usage or applying.

Classification of Dyes by Usage or Application Method

The classification of dyes by usage or application is the most important system adopted by the Color Index (CI).

- *Acetate Rayon Dyes:* developed for cellulose acetate and some synthetic fibers
- *Acid Dyes:* used for coloring animal fibers via acidified solution (containing sulfuric acid, acetic acid, sodium sulfate, and surfactants) in combination with amphoteric protein
- *Azoic Dyes:* contain the azo group (and formic acid, caustic soda, metallic compounds, and sodium nitrate); especially for application to cotton.
- *Basic Dyes:* amino derivatives (and acetic acid and softening agents); used mainly for application on paper.

• *Direct Dyes:* azo dyes, and sodium salts, fixing agents, and metallic (chrome and copper) compounds; used generally on cotton-wool, or cotton-silk combinations.
• *Mordant or Chrome Dyes:* metallic salt or lake formed directly on the fiber by the use of aluminum, chromium, or iron salts that cause precipitation in situ.
• *Lake or Pigment Dyes:* form insoluble compounds with aluminum, barium, or chromium on molybdenum salts; the precipitates are ground to form pigments used in paint and inks
• *Sulfur or Sulfide Dyes:* contain sulfur or are precipitated from sodium sulfide bath; furnish dull shades with good fastness to light, washing, and acids but susceptible to chlorine and light.
• *Vat Dyes:* impregnated into fiber under reducing conditions and reoxidized to an insoluble color [dye ppah]

Classification of Dyes Based on Chemical Composition

Dyes can be classified into different groups depending on the type of functional group present in dye molecules. For example dye molecule containing –NO- group are called as nitroso dye, having -N═N- are called as azo dye and so on. The following table shows the classification of dyes based on chemical composition (Lee *et al.*, 2006).

Table 1: Classification of Dyes Based on Chemical Composition

S.N.	Type of dye	Structural unit	Examples	Remarks
1	Indigoid dyes	Indigo	Indigo caramine	Oldest known dye, earlier isolated from plants of indigofera group but now prepared synthetically.
2	Nitro dyes	$-NO_2$ group	Picric acid	Oldest known synthetic dye, but not commercially important.
3	Nitroso dyes	-NO group	Naphthahol green B	Generally possess –OH group at ortho position to the nitroso (-NO) group
4	Azo dyes	-N=N- group	Aniline yellow	Largest class of synthetic dye. Other exaples include congo red, ethyl orange, ethyl red.
5	Phthalein dye	Phthalein group	phenolphthalein	Obtained by treating phenol with pthalic anhydride.
6	Triarylethane dyes	Triphenyl ethane	Elachite green	Prepared by introducing one or ore $–NH_2$ or -OH groups into the triphenyl methane rings.
7	Anthraquinoid dyes	Anthraquinoid group	Alizarin	

Source: Toor MK (2010).

***Water Consumption and Wastewater Generation in Dye Industry*:**

The water usage in the industry is mainly for the following purposes:
• Synthesis of the dyes and dye intermediates.
• Steam generation and cooling system.
• Washing and rinsing of reaction kettles, filter press, floor, etc.
• Domestic and other miscellaneous activities.

The water consumption pattern varies widely from one industry to another. In the same industry rate of water consumption often changes due to frequent changes of the feed material synthesis action and desired products. The change of product pattern needs cleaning and washing which consumes a substantial quantity of water. Thus water requirement of a dye and dye intermediate industry depends on the following factors:
• Type of dye produced.
• Number of produced.
• Gross production.
• Pattern of working of factory i.e. continuous or in one shift only.

Frequency of change of product pattern etc (Bhatia)

Table 2: Water consumption and wastewater generation during production of various types of dye products

S.No	Type of product	No. of units	Range Water consumption	lit/kg, of product Wastewater generation
1.	Direct dyes	15	*2.5* - 667	1.0-644
2.	Reactive dyes	11	2.0-186	2.0-157
3.	Basic dyes	4	60 - 4200	50 - 200
4.	Azo dyes	8	90 - 400	8.0-213
5.	Vat dyes	2	1528-10345	1389-7980
6.	Dye intermediates	6	36-230	9.0-74
7.	Naphthol dye	2	6.0 - 17	5.0-8.0
8.	Pigments	3	93 - 923	7.0-7.85
9.	Indigosol colours	1	529	429
10.	Disperse dyes	1	70	12-42.5
11.	All varieties of dyes/intermediates	10	13-2300	11-1146

Source: Bhatia S.C.

Waste Water Characteristics

The process waste water is mainly the mother liquor left over after the product is isolated and separated by filter press. This waste water is of smaller volume and highly concentrated in terms of pollutants. The vessel washings also contain similar type of pollutants but with lower concentration. It has been identified that the waste waters of the industries have the following characteristics:

i. High levels of BOD and COD
ii. High acidity.
iii. High TDS.
iv. Deep colour of different shades.
v. High levels of chlorides and sulphates.
vi. Presence of phenolic compounds.
vii. Presence of heavy metals, e.g., copper, cadmium, chromium, lead, manganese, mercury, nickel and zinc
viii. Presence of oil and grease.

The dye industry waste-waters, if derived from naphthalene and anthracene bases are resistant to biodegradation. The colour removal is also not adequate by the conventional chemical and biological treatment Toor MK (2010).

Table 3: Dyes for cotton dyeing and the compositions of the wastewater (Honda and Yamamoto, 2000)

S.No.	Type of dye	The compositions of the wastewater
1	Reactive dye	Dye, caustic soda, soda ash, interfacial active agent, salt cake
2	Developed dye	Dye, sodium chloride, sodium nitrate, peneirant, sodium sulfide, chlorine or sulfate, developer (B-NapMliol). interfacial active agent, soap or sulfated soap or fatty alcohol
3	Direct dye	Dye sodium carbonate, salt or salt -cake, interfacial active agent. Sodium salfate.
4	Naphthol dye	Dye, caustic soda, interfacial active agent, alcohol, soap, soda ask. salt, bases, sodium acetic, sodium sulfide, sodium nitrate, sodium nitrite.
5	Sulfide dye	Dye. sodium sulfide, sodium carbonate, salt
6	Vat dye	Dye, caustic soda, interfacial active agent, sodium hydrosulfite, potassium dichromate, perborate or hydrogen peroxide

Source: Honda and Yamamoto (2000).

Treatment Technologies

Composition of waste water from dye and dye intermediate manufacturing is highly variable. It varies from industry to industry depending on the type of dye manufactured in a particular industry. Treatment method employed for treating waste water coming from dye industry depends on the type of chemical components present in effluent. The structure of dye is complex and influences its degradability. Various methods have been studied for treating waste water from dye industry. However these treatment methods and technologies have several advantages & disadvantages as presented in the table below.

Table 4: Summary of the advantages and disadvantage of methods for treating dye wastewater

S.No	Method	Advantages	Disadvantages
1	Activated carbon adsorption	- Suspended solids and organic substances well reduced.	- Blocking filter
2	Coagulation— Flocculation	- Effective for all dyes - Elimination of insoluble-water dyes	- High cost - High sludge production
3	Advanced chemical oxidation	- Non-hazardous end products	- High cost
4	Electrochemical oxidation	- Removes small colloidal particles - Low sludge production - Breakdown compounds are non-hazardous - No chemicals use	- High cost-Iron hydroxide sludge -Not effective for all dyes
5	Photo-oxidation	- No sludge production	- Releases aromatic amines
6	Ozonation	- No sludge production - No alteration of volume	- High cost -Short half life
7	Supported liquid membrane	- Minimal loss of extractants - Simple to operate - Low energy consumption - Easy to scale up - Low cost	- Emukificatiott may occurs
8	Liquid - liquid extraction	- Low cost - Low energy consumption - Variety of solvents available - Easy to scale up	- Emulsificatioa may occur - Effluent must be treated
9	Biological process	- Environmentally friendly - Rates of elimination *by* oxidizable substances about 90% - Economically attractive	- Low biodegradability of dyes - Needs adequate nutrients - Narrow operating temperature range - Cost
10	Nanofiltraiion	- Removes all dye types - High effluent quality - Easy to scale *up*	- High investment costs membrane fouling-Influent must be pre-treated
11	Reverse osmosis	- Removal of all mineral salts, hydrolyzes reactive dyes and chemical auxiliaries	- High pressure
12	Ultrafiltration- Microfiltration	- Low pressure	- Insufficiency quality of treated wastewater

Source: Mahmoud *et al.*, (2007).

CONCLUSIONS

Dyes may be natural or synthetic depending on the origin. These coloured compounds make the world more beautiful by imparting colour to the objects. Unfortunately these are considered as the most problematic group of pollutant when present in industrial effluent. Dye removal from industrial effluent is extremely important as most of them are non-biodegradable and highly toxic in nature. Due to their toxicity they poses substantial threat to the aquatic life. Efficient dye removal can be achieved by the application of adequate treatment methods such as adsorption, coagulation-flocculation, membrane processes, biological processes etc., depending on the availability and feasibility of the method.

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