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Textile Dyes: It's Impact on Environment and its Treatment

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Dyes are complex aromatic molecular structures which are intended to be stable and consequently are difficult to degrade. At present, there are more than 100,000 dyes available commercially (of which azo dyes, represent about 70% on weight basis), and over 1 million tons dyes are produced per year, of which 50% are textile dyes [1]. In India alone, dyestuff industry produces around 60,000 metric tons of dyes, which is approximately 6.6% of total colorants used worldwide [2]. The largest consumer of the dyes is the textile industry accounting for two third of the total production of dyes [3].

The dyes intended to be used for a specific application must conform to the quality criteria set for the commercial acceptability of the end product. For applications in textile coloration, the features such as depth of the shade, chromophoric strength and brightness of the hue are of prime importance in addition to the restrictions on colored waste disposal imposed by environmental enacting agencies.

Textile industry consumes a large volume of water and chemicals during wet processing stages and delivers considerable quantities of colorants along with other chemicals. Dyes being tinctorially stronger are visible in water at concentrations as low as 1 ppm. One of the major factors responsible for release of water-insoluble as well as water-soluble dyes in the wastewaters is the improper dye uptake as well as the degree of fixation on the substrate which is governed by several factors such as depth of the shade, application method, material to liquor ratio and pH etc. For almost all dye-fibre combinations, exhaustion and degree of fixation of dye decreases with increasing depth of the shade. Due to high composition variability and high colour intensity, wastewater from textile dyeing facilities is difficult to treat satisfactorily. It is estimated that approximately 2% of the dyes produced are discharged directly in aqueous effluent, and 10% is subsequently lost during the coloration process. It is reasonable to assume that approximately 20% of the colorants enter the environment through effluents from the wastewater treatment plants. The presence of such compounds in the industrial wastewaters may create serious environmental problems due to toxicity to aquatic life and mutagenicity to humans. Inspite of resistance to biodegradation under aerobic conditions, dyes (in particular azo dyes) undergo reductive splitting of the azo bond relatively easily under anaerobic conditions releasing corresponding aromatic amines. Anaerobic decolorization is considered to be microbiologically a non-specific process.

Thus both dyeing technologists as well as colour chemists face the ever growing challenge of achieving maximum exhaustion and fixation levels by modifying the dyeing recipes and dye design, respectively. The textile industry is challenged by the requirement to satisfy the demands of increasingly stringent legislation and controls introduced by governments and regulatory agencies to ensure compliance with environmental issues. A significant source of complexity is the fact that the requirements vary globally and substantially, in detail as well as in severity.

In view of these facts, efforts have been made for the removal of colour from textile industrial wastewaters by adopting the treatment techniques like physical, physico-chemical chemical, and biological with the aim to completely mineralize colour to species such as CO_2, H_2O, NO_3^-, SO_4^{2-}, and Cl^- etc. as applicable. The physical methods as well as the chemical methods have shown encouraging trends but the task of complete removal has thus far been formidable owing to the diversity and complexity of the dyes coupled with the associated toxicological aspects. Biological treatment methods on the other hand, have often been visualized as an economically viable option. The treatment technologies for the removal of textile dyes from the textile wastewater has been critically reviewed [4] and it has been found that over the past two decades interest has been focused on biodegradation methods such as fungal decolorization, microbial degradation, adsorption by microbial biomass (living or dead) and bioremediation systems as a better alternative as the available physic-chemical methods are generally faced with the limitations of practicability, production of large volumes of sludge etc.

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