Chapter 8

# Impacts of Textile Dyes on Health and the Environment and It's Remediation

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## A. Impact of the Textile Industry

Over the last few long time, the worldwide textile industry has become one of the foremost vital industries. There is no denying that the textile industry contributes to the financial development of the worldwide economy (Reyhan, 2014). The textile industry produces around 1 trillion dollars, contributes 7% of worldwide exports, and utilizes around 35 million laborers worldwide (Desore & Narula, 2018).

Despite its evident significance, this industrial sector is one of the most significant worldwide polluters and expends tall sums of power and chemicals (Bhatia, 2017). The extraordinary accentuation is set on the colossal utilization of drinking water in different operations

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of its generation chain, such as washing, fading, and dyeing, among others (Hossain, et al. 2018).

The textile industry can have a broad list of natural impacts (Muthu, 2017). The discussed contamination created includes, for illustration, the discharge of particulate matter and tidy, oxides of nitrogen and sulfur, and unstable natural compounds. The scraps of textile textures, yarns, and disposed packaging constitute the strong squander. On the other hand, the textile slime uncovers overflow volumes and undesirable composition issues, frequently displaying tall loads of natural matter, micronutrients, overwhelming metal cations, and pathogenic microorganisms (Bhatia, 2017).

The most harm caused by the textile industry to the environment, in any case, are those coming about from the release of untreated effluents into the water bodies (Bhatia, 2017), which generally constitute 80% of the overall emanations delivered by this industry (Wang, 2016). Within the composition of most of the remaining waters of the material industry, there are generally elevated levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) (Setiadi, et al. 2006). The more prominent accentuation should be credited to the expansive sum of non-biodegradable organic compounds, particularly textile dyes (Orts, et al. 2018).

A dye could be a colored compound, ordinarily utilized in arrangement, which is competent of being settled to a texture. The dye must be 'fast' or chemically steady. Thus the color will not wash with cleanser and water or blur on exposure to daylight. Dyeing is regularly exhausted in an unusual arrangement containing dyes and specific chemical fabric. After dyeing, dye particles have an uncut chemical bond with fiber atoms. Temperature and time control are two critical components in dyeing (Mawla, 2021). One of its properties is the capacity to give color to a given substrate (Shamey & Zhao, 2014) because of the nearness of chromophoric bunches in its atomic structures. In any case, the property of settling the color to the fabric is related to the auxotrophic bunches, which are polar and can tie to polar bunches of textile strands (Wardman, 2017).

The color related to textile dyes not only causes harm to the water bodies but also avoids the entrance of light through water, which lessens the rate of photosynthesis and dissolved oxygen levels. It influences the whole oceanic biota (Setiadi et al., 2006; Imran et al., 2015; Hassan & Carr, 2018). The textile dyes act as harmful, mutagenic, and carcinogenic specialists (Aquino et al., 2014; Khatri, et al. 2018). They endure as natural poisons and cross whole nourishment chains giving biomagnification (Sandhya, 2010). Such creatures at higher trophic levels appear to have higher levels of defilement than their prey (Newman, 2015).

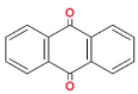
This chapter discusses the impact of textile dyes on health and the environment and its remediation. There are more than 10,000 colors utilized in textile fabricating alone, about 70% being azo dyes complex in structure and manufactured in nature (Hassaan, 2016; Ananthashankar, 2012). A significant source of color discharge into the environment is related to the fragmented fatigue of dyes onto textile fiber from a watery coloring prepare, and the got to diminish the sum of leftover color in material gushing has gotten to be a significant concern in later a long time (Hassaan & Nemr, 2017).

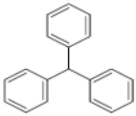
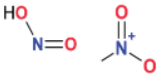
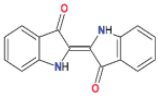
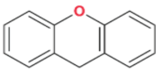
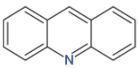
## B. Dyes and Classification

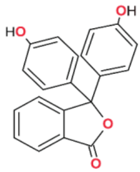
Dyes are common or fake substances that give color to diverse filaments utilized within the material, pharmaceutical, nourishment, corrective, plastic, photographic and paper, and other businesses (Chequer, et al. 2013). Colorants can be pigments or dyes. Pigments are insoluble for all intents and purposes, and the particles that make them up extend from 1–2 μm. Colors are effectively broken up in the water and have a molecule measure extending from 0.025–1.0 μm (Braun, 1983 & Esteves et al., 2016). The mechanical preferences for the utilization of fake dyes are based on (i) being chemically steady over time, (ii) being dormant to physical, chemical, and biological degradation, and (iii) being able to deliver color to the fiber to be dyed through reproducible forms, keeping up the color concentrated (Zucca, 2018) and (iv) are more fetched (Paz, 2017).

Dyes assimilate light within the unmistakable range (400–700 nm) and have expanded conjugation and one or more chromophores (Kuenemann, 2017). Chromophores contain heteroatoms such as N, O, and S and incorporate bonds such as -N=N- (azo), =C=O (carbonyl), NO or N-OH (nitrous), -NO2 or NO-OH (nitro), and C=S (sulfur) (Pereira & Alvez, 2011). Chromophore bunches are unsaturated and comprise biotas or bunches of particles. The course of action of progressive single and twofold bonds reverberates, permitting the retention of light beams (Berradi et al., 2019). Synthetic dyes display considerable fundamental differences and thus have exceptionally diverse chemical and physical properties (Pereira & Alvez, 2011). Table 8 presents the most chromophores that impact the classification of dyes. In expansion to chromophores, most colors contain autochrome bunches, which are not capable of color but are for escalated (tone) and affinity for the the fibre. A few of them are -NH3 (amine), -COOH (carboxyl), HSO3 (sulphonate), and -OH (hydroxyl) (Pereira & Alvez, 2011; International Agency for Research on Cancer, 2010).

**Table 8.1** Classification and Characteristics of Dyes

| Dye Chemical Classes | Chromophore Structure | Examples of Dyes | Characteristics |
|---|---|---|---|
| Azo |  | -Methyl Orange A<br>-Congo Red<br>-Orange G<br>-Amaranth | Azo dyes are frequently used (60%). These dyes have a functional group (-N=N-) linking two alkyl or aryl radicals, symmetrical and or asymmetrical, identical or non-azoic. |
| Anthraquinone |  | - Remazol Brilliant Blue R<br>- Reactive Bright Blue X-BR<br>- Reactive Blue 4<br>- Alizarin Red S | Anthraquinone dyes are the second most widely used dyes due to their low price, accessibility, and performance in the dyeing process. They have anthraquinone chromophore groups comprising two carbonyl groups on either side of a benzene ring. |

| Dye Chemical Classes | Chromophore Structure | Examples of Dyes | Characteristics |
|---|---|---|---|
| Triphenylmethane |  | -Malachite Green<br>- Crystal Violet<br>- Bromophenol Blue<br>- Light Green SF | These molecules have a central sp3 hybridized carbon atom, bonded to three aryl groups, and belong to the textile industry's most commonly used synthetic dyes. |
| Nitro and Nitroso |   | - Naphthol Yellow S<br>- Disperse Yellow 26<br>- Disperse Yellow 14 | In nitro dyes, a nitro group conjugates to an electron donor group via an aromatic system. Nitro dyes always contain a hydroxyl group as a donor. |
| Indigoid |   | - Indigo Carmine<br>- Ciba Blue 2B | Synthetic indigo is the most widely used dye in the textile industry worldwide. It is highly resistant to light and high temperatures. |
| Xanthene |   | - Rhodamine 6G<br>- Rhodamine 123<br>- Fluorescein | Xanthenes are dyes used in the food, cosmetics, paper, and ink manufacturing industries because of their superior dyeing and coloring properties. Still, they are poorly biodegradable, and some of them are very toxic. |
| Acridine |   | - Acridine orange<br>- Basic Yellow 9 | Acridine dyes are heat-resistant, although they have low lightfastness. They are currently not very important commercially. |

| Dye Chemical Classes | Chromophore Structure | Examples of Dyes | Characteristics |
|---|---|---|---|
| Phthalein |  | - o-cresolphthalein<br>- Thymolphthalein<br>- Dixylenolphthalein<br>- Phenolphthalein | Phthalein dyes are employed to titrate weak acids. Phthalein dyes are insoluble in water but soluble in alcohol. There are frequently in the construction, coatings, electronics, and electrical industries. |

Source: Ardila-Leal et al., (2021)[1]

## C. Impacts of Textile Dyes on Health and the Environment

Besides contain many mechanical poisons, the textile dyes are profoundly harmful and possibly carcinogenic (Sharma, et al. 2018), so they are related to natural corruption and different maladies in creatures and people (Khan & Malik, 2018).

The biggest generator of colored wastewater is evaluated to be the textile industry (Senthivelan, et al. 2016; Hadibarata, 2012). Around 20% of the dye used for dyeing textile strands is not settled and disposed of within the wastewater, resulting in an elevated level of contamination (Kant, 2012). In any case, the natural harm does not depend interestingly on the sum of color released; moreover, it depends on the colors blended with the other substances, all with harmful properties that make up the emanating from the industries (Tkaczyk, 2020; Clarke, 1980).

The colored wastewater, sometimes contains dyes, evident to the bare eye (<1 ppm) (Golka, et al. 2004; Mojsov, et al. 2016), released into surface or groundwater bodies, diminish the concentration of broken up oxygen within the water (Ali, 2010). It increments the values of physicochemical and biological parameters such as the

[1] The chemical structures were elaborated in the software ACD/ChemSketch, version 2020.1.2, Advanced Chemistry Development, Inc., Toronto, ON, Canada, www.acdlabs.com, 2020.

chemical oxygen demand (COD) (Zhou et al.,2017), biochemical oxygen demand (BOD), total dissolved solids (TDS), total nitrogen (TN), total phosphorus (TFP), and non-biodegradable organic compounds. On the other hand, wastewater has a fluctuating pH and overwhelming metals such as chromium (Cr), arsenic (Ar), and zinc (Zn) (Berradi et al., 2019).

In common, synthetic dyes are not biodegradable due to their chemical properties and structure, creating an antagonistic impact on the environment (Husain, 2006). Most synthetic dyes are obstinate, carcinogenic, and harmful to biological systems (Aghaie-Khouzani et al., 2012). On the other hand, the negative effect of dyes can be biomagnified, creating high damage rates at elevated trophic levels (Lellis et al., 2019). In any case, the harmfulness of each dye must be surveyed separately, as the harm they cause depends on the structure and introduction concentration (Ferraz, 2011), which implies that dyes can endure for a long time (~50 a long time or more) within the environment (Pereira & Alves, 2011). The dyes' determination is closely related to their chemical reactivity, so unsaturated compounds are less determined than immersed ones. The perseverance of fragrant compounds increments as the number of chemical and halogen substitutions increments; the same happens for the perseverance of colors (Berradi et al., 2019). It illustrates the pertinence of assessing the debasement of dyestuffs separately and in combination. The foremost agent dyes in utilizing a place in the azo, anthraquinone, or triarylmethane classes (Berradi et al., 2019; Liu et al., 2021).

The azo course dyes have broadly considered their utilization and negative impacts. Between 60% to 70% of the azo dyes are poisonous, carcinogenic, and safe for routine Physico-chemical treatments (Berradi et al., 2019). The harmfulness of azo dyes takes after their chemical lessening and the consequent arrangement of fragrant amines, such as benzidine, dimethoxy-benzidine, and dimethyl-benzidine. The aromatic amines' poisonous quality is due to their metabolic oxidation since the oxidation produces electrophilic reductive mediators (diazonium salts) that empower covalently tied to DNA. These compounds are mutagenic and cause illnesses such as cancer. A variety of this instrument is the chemical decrease of a few of the azo bonds (found in certain dyes) to compare poisonous fragrant mono-azo amine (Sarayu & Sandhya, 2012; Varjani et al., 2020; Sarkar et al., 2017).

When azo ionic dyes are disposed of in surface or wastewater, they can tie to suspended natural matter by electrostatic intuitive follow to dregs or wastewater slime, expanding the perseverance (Soriano et al., 2014). Also, colored water or sullied slime contact oceanic creatures exchanges the poisonous compounds through the nourishment chain to people, causing wellbeing disarranges such as hypertension, issues, queasiness, dying, ulceration of the skin or the layers and mucous films. Depending on the introduction dosages of colors, significant harms may happen to the kidney, regenerative framework, liver, brain, and central anxious framework (CNS) (Sarayu & Sandhya, 2012; Sarkar et al., 2017). Parrot et al. (2016) assessed the impacts of azo dyes on the big-headed angle (Pimephales promelas) within the embryonic (larval) organize by comparing the dye impacts at diverse concentrations. Creators found that the utilization of 25.4 mg L−1 and 16.7 mg L−1 of the azo dyes Scatter Yellow 7 and Sudan Red G, separately, diminished the survival of the hatchlings, biting the dust between four and ten days after hatch.

## D. Remediation of Textile Dyes Impact

### 1. Harmonization of Environmental Standards

Harmonization of environmental standards requests as a way to assist substantial natural targets around the world since natural issues frequently transgress national borders and are of concern to the individuals of different countries. Distinctive importers' benchmarks can hoist exporters' fabricating costs, as specific guidelines require distinctive strategies to avoid utilizing natural benchmarks as a frame of protectionism (Houses of Parliament, 2014).

Harmonizing defilement impediments from dyeing production lines seems to assist in moderating the natural issues related to Azo dyes and other dyes. Since the situations in each nation are not standardized, harmonization can lead to wastefulness. As concerns color release from coloring factories: Every environment incorporates a diverse absorptive capacity for water poisons; The taken toll required to expel color contamination varies between nations; Readiness to contribute to a more beneficial environment at individual cost varies from nation to nation, for case, in connection to the degree of nearby destitution (Houses of Parliament, 2014).

## 2. Water Remediation

In numerous nations, it is required for textile dyeing production lines to introduce effluent treatment plants (ETPs) to treat wastewater. Sometime recently it clears out the manufacturing plant premises. Weight for viable profluent treatment is additionally mounting, and numerous worldwide buyers are presently appearing more concerned over whether or not textiles are created with due ecological consideration. This move within the textile trade's worldview implies that in the future, it is likely that the operation of an ETP will be indispensable to support commerce within the competitive world of advertising (Houses of Parliament, 2014).

Because of their chemical steadiness and manufactured nature, responsive Azo dyes are not entirely corrupted and show moderate debasement by ordinary wastewater treatment strategies (Puvaneswari, 2006). They are troublesome to expel since they are outlined to be steady in oxygen-consuming conditions, but biotreatment in anaerobic conditions can result in an era of unsafe fragrant amines (Puvaneswari, 2006). Remediation does not right now capitalize on this reality.

Wastewater is often treated with actuated slime, and the fluid profluent is discharged to adjacent surface waters. Ekici et al. (2001) tried Azo dye solidness in both actuated slime and water, concluding that they were moderately steady within the sea-going environs and cannot be successfully debased in standard wastewater plants. Physicochemical methods can reduce toxic quality levels, but balance is not total, and a more concentrated slime is made, successfully exchanging the contamination issue between stages. The time is taken, and handling time is too inadmissible (Houses of Parliament, 2014).

New, cheap, and proficient remediation strategies must be planned. Cases of rising innovations incorporate, but are not limited to:

1. Advanced oxidation processes (AOPs) (Hassaan & Nemr, 2017);
2. Zero-valent iron degradation processes. (Pereira & Freire, 2006);
3. Better Physico-chemical treatment methods (including precipitation, coagulation, adsorption, flocculation, flotation, electrochemical destruction, mineralization, and decolorization process) (Gogate and Pandit, 2004);
4. Fungal Degradation. (Bumpus, 2004);
5. Bacterial remediation. (Sudha et al.,2014);
6. Waterless dyeing technology;
7. Synthetic biology. (UCL iGEM, 2014);

## E. Conclusion

In conjunction with many mechanical toxins, the textile dyes are profoundly poisonous and possibly carcinogenic, related to environmental degradation and different illnesses in creatures and people. The biggest generator of colored wastewater is assessed to be the textile industry. Approximately 20% of the color utilized for dyeing textile strands is not settled and is arranged within the wastewater, resulting in an elevated level of contamination. Harmonization of environmental standards requests to assist in fathoming important natural goals worldwide. New, cheap, and proficient remediation strategies ought to be deliberated. Cases of rising innovations incorporate, but are not limited to, advanced oxidation processes (AOPs); zero-valent iron degradation processes; better Physico-chemical treatment methods; fungal degradation; bacterial remediation; waterless dyeing technology, and synthetic biology.

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