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Anju Kushwaha
Research Scholar,
Department of Family and Community Sciences,
University of Allahabad,
Prayagraj, Uttar Pradesh, India

Rashi Kushwaha
Research Scholar,
Department of Family and Community Sciences,
University of Allahabad,
Prayagraj, Uttar Pradesh, India

Pinki Singh
Research Scholar,
Department of Family and Community Sciences,
University of Allahabad,
Prayagraj, Uttar Pradesh, India

Shreya Mishra
Research Scholar,
Department of Family and Community Sciences,
University of Allahabad,
Prayagraj, Uttar Pradesh, India

Corresponding Author:
Anju Kushwaha
Research Scholar,
Department of Family and Community Sciences,
University of Allahabad,
Prayagraj, Uttar Pradesh, India

Impact of chemical dyes on human health and environment

Anju Kushwaha, Rashi Kushwaha, Pinki Singh and Shreya Mishra

Abstract
Dyes may be defined as substances that, when applied to a substrate provides colour. Dyes are classified according to their application and chemical structure, and are composed of a group of atoms known as chromophores. The most common auxochromes are amine, carboxyl, sulfonate and hydroxyl. Interestingly, the widespread use of synthetic colorants and the modern dye industry dates only to 1856 with the synthesis of mauveine by W.H. Perkin. The existence of sulphur, naphthol, dyes from vats, nitrates, acetic acid, soaps, enzymes, compounds containing chromium, and copper, arsenic, lead, cadmium, mercury, nickel, and cobalt are examples of heavy metals. The textile effluent is extremely harmful due to a number of auxiliary chemicals used jointly. These organic substances combine with various disinfectants, particularly chlorine and form undesired by products (DBPs), which are frequently carcinogenic. If this effluent is allowed to flow through the fields, it plugs the soil pores and reduces soil production. An overview of impact of dyes on human health and the environment is provided in this paper.

Keywords: AZO dyes, chemical dyes, environment, health, human, pollution

Introduction
Dyes may be defined as substances that, when applied to a substrate provides colour by a process that alters, at least temporarily, any crystal structure of the coloured substances (Bafana, A. *et al*., 2011) [3]. Such substances with considerable colouring capacity are widely employed in the textile, pharmaceutical, food, cosmetics, plastics, photographic and paper industries (Zollinger, H 1987; Carneiro P. A., *et al*. 2007) [33, 34]. The dyes can adhere to compatible surfaces by solution, by forming covalent bond or complexes with salts or metals, by physical adsorption or by mechanical retention (Kirk-Othmer, Encyclopedia of Chemical Technology 2004; Bafana, A., *et al*. 2011) [21, 3]. Dyes are classified according to their application and chemical structure, and are composed of a group of atoms known as chromophores, responsible for the dye colour. These chromophore-containing centers are based on diverse functional groups, such as AZO, anthraquinone, methine, nitro, arilmethane, carbonyl and others. In addition, electrons withdrawing or donating substituents so as to generate or intensify the color of the chromophores are denominated as auxochromes. The most common auxochromes are amine, carboxyl, sulfonate and hydroxyl (Christie R. 2001, Dos Santos A. B., *et al*. 2007) [11, 35]. The manufacture and use of dyes and pigments is a multibillion-dollar industry (Bumpus, J. A. 2004) [4]. The use of these substances is an integral part of almost all manufacturing processes. Interestingly, the widespread use of synthetic colorants and the modern dye industry dates only to 1856 with the synthesis of mauveine by W.H. Perkin (Kirk-Othmer Encyclopedia of Chemical Technology 1992) [20].
Approximately 40,000 different synthetic dyes and pigments are used industrially, and about 4, 50,000 tons of dyestuffs are produced worldwide. AZO dyes are the largest and more versatile class of dyes, accounting for up to 50% of the annual production (Zollinger, H. 1987) [33]. They are extensively used in many fields of up-to-date technology, in e.g., various branches of the textile industry, the leather tanning industry, paper production, food, colour photography, pharmaceuticals and medicine, cosmetic, hair colourings, wood staining, agricultural, biological and chemical research, light-harvesting arrays, and photo electrochemical cells (Kuhad *et al*. 2004; Couto 2009) [22, 10].

Moreover, synthetic dyes have been employed for the efficacious control of sewage and wastewater treatment, for the determination of specific surface area of activated sludge for ground water tracing, etc.

The largest consumer of these dyes is the textile industry, accounting for 2/3rds of its market. Different classes of dyes are used according to the fibres to which they can be applied. Reactive dyes are most commonly used as they can be applied to both in natural (wool, cotton, silk) and synthetic (modified actylics) fibres (O'Neill *et al*. 1999) [27]. Reactive dyes differ from other class of dyes in that their molecules contain one or more reactive groups capable of forming a covalent bond with a compatible fibre group. They have become very popular due to their high wet-fastness, brilliance and range of hues (Hao *et al*. 2000) [13]. Their use has increased as synthetic fibres became more abundant. Acid and basic dyes are used for dyeing all natural fibres (wool, cotton, silk) and some synthetics (polyesters, acetylic and rayon). Direct dyes are classified this way because they are applied directly to cellulose fibres. Furthermore, they are used for colouring rayon, paper, and leather and to small extent nylon. The application of mordant dyes is limited to the colouring of wool, leather, furs and anodised aluminium. Solvent dyes are used for colouring inks, plastics, and wax, fat and mineral oil products. One of the significant industries that produce a lot of industrial effluents is the textile sector. Any fabric's main draw is its colour. Because of this, the production and use of synthetic dyes for fabric dyeing has grown significantly. Many different colourfast, vibrant hues are now available thanks to synthetic dyes. However, Environmentalists are quite concerned about their toxicity. Using synthetic colours has a negative impact on all life forms.

Impact of Chemical Dyes on Human Health

Most of the dyestuffs at present used in textile dyeing and finishing are risky to human health at the levels of exposure that workers generally face in the factories. However, with long term or accidental over exposure, there can be likely health hazards and all dyes and chemicals must consequently be treated with care. The most common hazard of reactive dyes is respiratory problems due to the inhalation of dye particles. Sometimes they can affect a person's immune system and in extreme cases this can mean that when the person next inhales the dye their body can react dramatically. This is called respiratory sensitization and symptoms include itching, watery eyes, sneezing and symptoms of asthma such as coughing and wheezing (Hassaan, M. A. 2016) [14]. Despite its undeniable importance, this industrial sector is one of the biggest global polluters and it consumes high amount of fuel and chemicals (Hao O. J. 2000) [13]. The special emphasis is placed on the enormous use of drinking water in various operations of its production chain, such as washing, bleaching, dyeing among others (Hossain, M.S., *et al*. 2018) [36].

The acute toxicity to textile dyes is caused by oral ingestion and inhalation, especially by the exposure to dust (Clark, M. (ed.). 2011) [8], triggering irritation to the skin and eyes (Christle, R. M. 2007) [6]. The workers, who produce or handle reactive dyes, may have contact dermatitis, allergic conjunctivitis, rhinitis, occupational asthma or other allergic reaction (Hunger, K. 2003) [17]. The latter are the result of the formation of a conjugate between human serum albumin and the reactive dye, which acts as an antigen (Christle, R. M. 2007) [6] producing immunoglobulin E antibodies, which combine with histamine (Hunger, K. 2003) [17].

Some AZO dye components such as benzidine have been linked to cancers of human bladder. Also, there is a higher incidence of bladder cancer in dye workers exposed to AZO dyes (5). Therefore, AZO dyes pose lethal effects, genotoxicity, mutagenicity, and carcinogenicity to humans as well as animals (Puvaneswari, N., *et al*., 2006; Correia, V. M., *et al*. 1994; Chung, K. T. 2016) [28, 9, 7]

Impact of Chemical Dyes on Environment

Textile industries produce large amounts of liquid wastes. These textile effluents contain organic and inorganic compounds (Elliott, A. *et al*. 1954) [12]. During the dyeing processes, not all dyes that are applied to the fabrics are fixed on them and there is always a portion of these dyes that remains unfixed to the fabrics and gets washed out. These unfixed dyes are found to be in high concentrations in textile effluents (Hassaan, M. A. & El Nemr, A. 2017) [15]. The amount of water consumed and released also varies depending on the type of fabrics produced (Ananthashankar, R. 2012) [1]. The usage of cotton has been increasing constantly throughout the past century (UNCTAD 2003) [32]. Cotton fibres are mainly dyed using AZO dyes which are one of the largest groups of synthetic colorants used in the industry (Mohan, V., *et al*. 2002) [25]. AZO dyes are difficult to degrade by the current conventional treatment processes. They are characterized by the presence of the nitrogen-nitrogen bond (-N=N-) in the centre and hence they are highly electron deficient (Robert, L., *et al*. 2008) [29].

These AZO dyes are found to be complex in nature and have been found to show carcinogenic evidences on reductive cleavage. These dyes are capable of altering the physical and chemical properties of soil, deteriorating water bodies and causing harm to the flora and fauna in the environment (UNCTAD 2003) [32]. It was observed that the toxic nature of dyes causes death to the soil micro-organisms which in turn affect the agricultural productivity (Savin, I. and Butnaru, R. 2008) [31]. AZO dyes are stable in light and resistant to microbial degradation or fading away due to washing. Therefore, AZO dyes are not readily removed from waste water by conventional waste water treatment methods. It has been estimated that about 10% of the dyestuff in the dyeing process of textiles do not bind to fibers and are, therefore, released to the environment (Puvaneswari, N., *et al*., 2006; Hildenbrand, S. F., *et al*., 1999) [28, 16].

In textile dyeing, various salts are used providing significant difficulties for biodegradable microbial communities. The reason is that high saline concentrations can cause plasmolysis (Meng, X., *et al*. 2012) [24], that is, lead the cytoplasm to lose water and contract, such that the plasma membrane gradually separates from the cell wall (King, T., *et al*. 2001) [19]. The discharge of this effluent into the aquatic reservoir affects its biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and pH. The release of the effluents without any remedial treatment will generate a gigantic peril to the aquatic ecosystem (Islam, T., *et al*. 2023) [18].

Future Perspectives

In order to effectively address the growing production and use of synthetic dyes while also considering how they affect the environment, coloured effluents must first undergo effective and practical treatment procedures before being released into the environment as waste. Synthetic dyes are biodegraded by using various bacteria in rivers and separated enzymes are a promising strategy both individually and in combination with

conventional treatments.

Conclusion

Despite the prohibited agreements (Christle, R. M. 2007) [6], of the 400 dyes that have been investigated for their toxicity, more than 100 of them with potential for the formation of carcinogenic amines are still available on the market (Asthana, V., & Shukla, A. C. 2014) [2]. In several regions of the globe, such as in India, export demands associated with cheap labour determine the existence of small scale textile factories that clandestinely release toxic dyes into water bodies (Lacasse, K., & Baumann, W. 2012) [23].

It was reported that the synthetic textile dyes exhibited a great group of organic compounds that could have many impacts on the environment, as well as, some of them can cause hazards to humans. The growing complication and struggles in treating textile wastes has led to a continuous examination for new approaches that are applicable and economically feasible. However, till now, there is no very highly effective technique capable of complete removal of both the colour and the toxic properties of the dyes released into the environment.

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