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Chemicals Utilised in Industries of Food and Textile Dyes, Their Effects and Treatment

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Abstract: *Artificial food dyes are responsible for the bright colors of candy, sports drinks and baked goods.They're even used in certain brands of pickles, smoked salmon and salad dressing, as well as medications.In fact, artificial food dye consumption has increased by 500% in the last 50 years, and children are the biggest consumers .Claims have been made that artificial dyes cause serious side effects, such as hyperactivity in children, as well as cancer and allergies.The topic is highly controversial and there are many conflicting opinions about the safety of artificial food dyes. This article separates the fact from fiction. Food dyes are chemical substances that were developed to enhance the appearance of food by giving it artificial color.People have added colorings to food for centuries, but the first artificial food colorings were created in 1856 from coal tar.Nowadays, food dyes are made from petroleum.Over the years, hundreds of artificial food dyes have been developed, but a majority of them have since been found to be toxic. There are only a handful of artificial dyes that are still used in food.Food manufacturers often prefer artificial food dyes over natural food colorings, such as beta carotene and beet extract, because they produce a more vibrant color.However, there is quite a bit of controversy regarding the safety of artificial food dyes. All of the artificial dyes that are currently used in food have gone through testing for toxicity in animal studies.Regulatory agencies, like the US Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA), have concluded that the dyes do not pose significant health risks.Not everyone agrees with that conclusion. Interestingly, some food dyes are deemed safe in one country, but banned from human consumption in another, making it extremely confusing to assess their safety.Textile dyes are substances used to color fabrics. The dyes soak into the fabric and change it chemically, resulting in color that stays permanently through repeated use. Today, more than 10,000 substances are classified as textile dyes, and different kinds of dyes work better on specific kinds of fabric. Most of our clothing and home furnishings are colored with synthetic, or man-made, dyes.*

Keywords: *textile, food, dyes, human, impact, effect, environment, toxicity, carcinogenic.*

Introduction

Food coloring, or color additive, is any dye, pigment, or substance that imparts color when it is added to food or drink. They come in many forms consisting of liquids, powders, gels, and pastes. Food coloring is used in both commercial food production and domestic cooking. Food colorants are also used in a variety of non-food applications, [1,2] including cosmetics, pharmaceuticals, home craft projects, and medical devices. People associate certain colors with certain flavors, and the color of food can influence the perceived flavor in anything from candy to wine. Sometimes the aim is to simulate a color that is perceived by the consumer as natural, such as adding red coloring to glacé cherries (which would otherwise be beige), but sometimes it is for effect, like the green ketchup that Heinz launched in 2000. Color additives are used in foods for many reasons including:

- To make food more attractive, appealing, appetizing, and informative
- Offset color loss due to exposure to light, air, temperature extremes, moisture and storage conditions
- Correct natural variations in color
- Enhance colors that occur naturally
- Provide color to colorless and "fun" foods
- Allow consumers to identify products on sight, like candy flavors or medicine dosages

While naturally derived colors are not required to be certified by a number of regulatory bodies throughout the world (including the U.S. FDA), they still need to be approved for use in that country. Food colorings are tested for safety by various bodies around the world and sometimes different bodies have different views on food color safety.[3,4]

The U.S. FDA's permitted colors are classified as subject to certification or exempt from certification in Code of Federal Regulations – Title 21 Part 73 & 74 Archived October 23, 2008, at the Wayback Machine, both of which are subject to rigorous safety standards prior to their approval and listing for use in foods.

- Certified colors are synthetically produced and are used widely because they impart an intense, uniform color, are less expensive, and blend more easily to create a variety of hues. There are nine certified color additives approved for use in the United States. Certified food colors generally do not add undesirable flavors to foods.
- Colors that are exempt from certification include pigments derived from natural sources such as vegetables, minerals, or animals. Nature derived color additives are typically more expensive than certified colors and may add unintended flavors to foods. Examples of exempt colors include annatto, beet extract, caramel, beta-carotene, turmeric and grape skin extract. This list contains substances which may have synthetic origins, such as nature identical beta-carotene.[5,6]

In the United States, FD&C numbers (which indicate that the FDA has approved the colorant for use in foods, drugs and cosmetics) are given to approved synthetic food dyes that do not exist in nature, while in the European Union, E numbers are used for all additives, both synthetic and natural, that are approved in food applications. The food colors are known by E numbers that begin with a 1, such as E100 (turmeric) or E161b (lutein). The safety of food colors and other food additives in the EU is evaluated by the European Food Safety Authority. Color Directive 94/36/EC, enacted by the European Commission in 1994, outlines permitted natural and artificial colors with their approved applications and limits in different foodstuffs.This is binding to all member countries of the EU. Any changes have to be implemented into their national laws within a given time frame. In non-EU member states, food additives are regulated by their national authorities, which usually, but not in all cases, try to harmonize with the laws adopted by the EU. Most other countries have their own regulations and list of food colors which can be used in various applications, including maximum daily intake limits.

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As per the Food Safety and Standard Act, 2006 In India, the following eight artificial colourings are generally permitted in food.

SL No.	Colour	Common name	INS No.	Chemical class
1	**Red**	**Ponceu 4R**	**124**	**Azo**
		Carmoisine	**122**	**Azo**
		Erythrosine	**127**	**Xanthene**
2	**Yellow**	**Tartrazine**	**102**	**Pyrazolone**
		Sunset yellow FCF	**110**	**Azo**
3	**Blue**	**Indigo carmine**	**132**	**Indigoid**
		Brilliant blue FCF	**133**	**Triarylmethane**
4	**Green**	**Fast green FCF**	**143**	**Triarylmethane**

Widespread public belief that artificial food coloring causes ADHD-like hyperactivity in children originated from Benjamin Feingold, a pediatric allergist from California, who proposed in 1973 that salicylates, artificial colors, and artificial flavors cause hyperactivity in children; however, there is no evidence to support broad claims that food coloring causes food intolerance and ADHD-like behavior in children. It is possible that certain food colorings may act as a trigger in those who are genetically predisposed, but the evidence is weak.

Despite concerns expressed that food colorings may cause ADHD-like behavior in children,; the collective evidence does not support this assertion.The US FDA and other food safety authorities regularly review the scientific literature, and led the UK Food Standards Agency (FSA) to commission a study by researchers at Southampton University of the effect of a mixture of six food dyes (tartrazine, allura red, ponceau 4R, quinoline yellow, sunset yellow and carmoisine (dubbed the "Southampton 6")) on children in the general population. These colorants are found in beverages.; The study found "a possible link between the consumption of these artificial colours and a sodium benzoate preservative and increased hyperactivity" in the children;; the advisory committee to the FSA that evaluated the study also determined that because of study limitations, the results could not be extrapolated to the general population, and further testing was recommended; The U.S. FDA did not make changes following the publication of the Southampton study. Following a citizen petition filed by the Center for Science in the Public Interest in 2008, requesting the FDA ban several food additives, the FDA reviewed the available evidence, and still made no changes;[7,8]

The European regulatory community, with an emphasis on the precautionary principle, required labelling and temporarily reduced the acceptable daily intake (ADI) for the food colorings; the UK FSA called for voluntary withdrawal of the colorings by food manufacturers.; However, in 2009 the EFSA re-evaluated the data at hand and determined that "the available scientific evidence does not substantiate a link between the color additives and behavioral effects" for any of the dyes.

We know that people such as the early Egyptians used dye to color textiles. The oldest dyes came from natural sources like plants, berries, and roots, or animals like mollusks and insects. Blue came from a plant called indigo, and several shades of red came from smashing insects (yes, bugs) such as kermis and cochineal. A very prized and rare natural purple dye came from crushed snails in the Mediterranean region. Some natural dyes produced vivid colors, but many tended to fade over time.

Synthetic dyes came along in the 19th century when William Perkin, a young British chemist, was trying to create synthetic quinine for medicinal use, since quinine was known as a great preventative for diseases like malaria. He was experimenting with a substance called coal tar, a type of oozy liquid that's a byproduct of processing coal.

In 1856, Perkin stumbled onto a synthetic mauve, a type of purple, and realized its potential as a dye. Other scientists followed his lead, and in 1869, an artificial red dye was successfully created. Many other dyes also came from coal tar, which means they're connected to fossil fuels.

This rise in the development of synthetic dyes came around the same time as the growth of industrial fabric production. Effective synthetic dyes were eagerly accepted in the expanding industry. Germany became a leader in dye production. By World War I, the Germans manufactured most of the synthetic dyes used in the textile industry. From then on, most mass-produced fabrics were colored with synthetic chemical dyes. Natural dyes were largely forgotten, except in places where the synthetic dyes were unavailable or where people kept traditional ways of coloring textiles alive[9,10]

Discussion

In addition, the effects caused by other pollutants in textile wastewater, and the presence of very small amounts of dyes (<1 mg/L for some dyes) in the water, which are nevertheless highly visible, seriously affects the aesthetic quality and transparency of water bodies such as lakes, rivers and others, leading to damage to the aquatic environment .

During the dyeing process it has been estimated that the losses of colorants to the environment can reach 10–50% . It is noteworthy that some dyes are highly toxic and mutagenic, and also decrease light penetration and photosynthetic activity, causing oxygen deficiency and limiting downstream beneficial uses such as recreation, drinking water and irrigation .[11,12]

With respect to the number and production volumes, azo dyes are the largest group of colorants, constituting 60-70% of all organic dyes produced in the world .The success of azo dyes is due to the their ease and cost effectiveness for synthesis as compared to natural dyes, and also their great structural diversity, high molar extinction coefficient, and medium-to-high fastness properties in relation to light as well as to wetness . They have a wide range of applications in the textile, pharmaceutical and cosmetic industries, and are also used in food, paper, leather and paints . However, some azo dyes can show toxic effects, especially carcinogenic and mutagenic events .

The toxic effects of the azo dyes may result from the direct action of the agent itself or of the aryl amine derivatives generated during reductive biotransformation of the azo bond .The azo dyes entering the body by ingestion can be metabolized to aromatic amines by the azoreductases of intestinal microorganisms. If the dyes are nitro, they can be metabolized by the nitroredutases produced by the same microorganisms . Mammalian liver enzymes and other organizations may also catalyze the reductive cleavage of the azo bond and the nitroreduction of the nitro group. In both cases, if N-hydroxylamines are formed, these compounds are capable of causing DNA damage .

Many types of dyes:

Acid dye:
Acid dyes are water-soluble anionic dyes, containing one or more sulfonic acid substituents or other acidic groups. An example of the class is Acid Yellow 36.

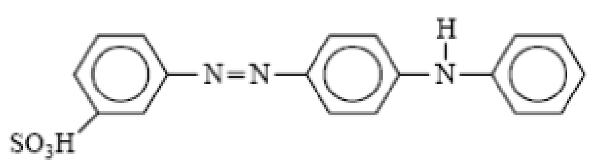


Fig: Acid yello36

Acid dyes are water-soluble anionic dyes that are applied to fibers such as silk, wool, nylon and modified acrylic fibers using neutral to acid dye baths. Acid dyes are not substantive to cellulosic fibers. Most synthetic food colors fall in this category. The dyeing process is reversible and may be described as follows:

$$\text{Dye}^- + \text{H}^+ + \text{Fiber} \rightleftharpoons \text{Dye}^- \, \text{H}^+ - \text{Fiber}$$

Basic or Cationic Dye:

This group was the first of the synthetic dyes to be taken out of coal-tar derivatives. As textile dyes, they have been largely replaced by later developments. They are still used in discharge printing, and for preparing leather, paper, wood, and straw. More recently they have been successfully used with some readymade fibers, especially the acrylics. Basic dyes were originally used to color wool, silk, linen, hemp, etc., without the use of a mordant, or using agent. With a mordant like tannic acid they were used on cotton and rayon. Basic dyes give brilliant colors with exceptional fastness to acrylic fibers. They can be used on basic dyeable variants of nylon and polyester.[13,14]

Basic Brown 1 is an example of a cationic dye that is readily protonated under the pH 2 to 5 conditions of dyeing.

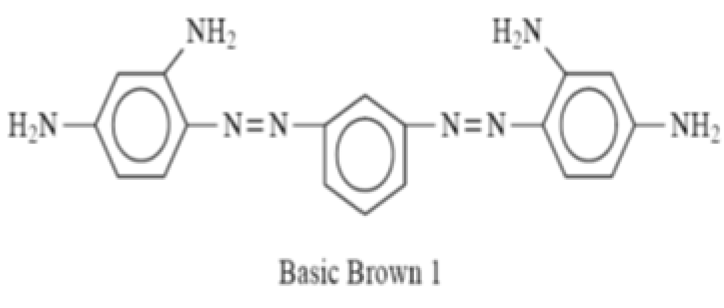


Fig: Basic Brown 1

Direct Dye:

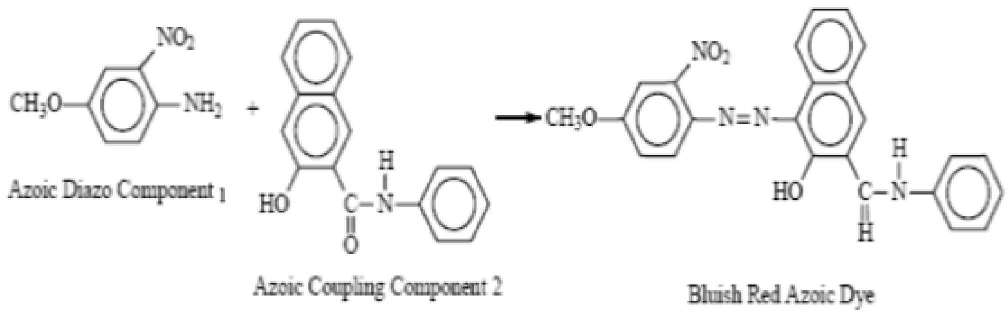
These are the dyes which can be applied directly to the fabrics from an aqueous solution. These are most useful for fabrics which can form hydrogen bonds with the Dyeing of Fabrics. The direct dyes mainly the basic dyes and were widely hailed because they made it unnecessary to use a mordant or binder in dyeing cotton. The colors are not as brilliant as those in the basic dyes but they have better fastness to light and washing, and such fastness can be measurably improved by after treatments (diazotized and developed.) Direct dyes can be used on cotton, linen, rayon, wool, silk and nylon. These dyes usually have azo linkage –N=N- and high molecular weight. They are water soluble because of sulfonic acid groups.

Direct orange 26 is a typical direct dye.

Azoic Dye:

Azo dyes contain at least one azo group (-N=N-) attached to one or often two aromatic rings. These dyes are used primarily for bright red shades in dyeing and printing since most other classes of fast dyes are lacking in good red dyes. Azoic dyes, called Naphthols in the industry, are actually manufactured in the fabric by applying one half of the dye. The other half is then put on and they combine to form the finished color. Unless they are carefully applied and well washed, they have poor fastness to rubbing or crocking.

The production of bluish red azoic dye from the following two components is an example.



Nitro Dye:

Nitro dyes are polynitro derivatives of phenols containing at least one nitro group ortho or para to the hydroxyl group. It is used to dye wool. It Consist of two or more aromatic rings (benzene, naphthalene).[15,16]

Example:

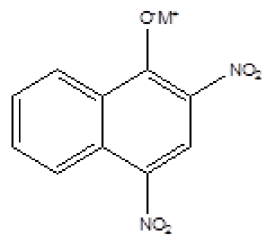


Fig: Maritus yellow

Disperse Dye:

Disperse dyes were originally developed for dyeing secondary cellulose acetate fibers. These dyes are relatively insoluble in water and are prepared for dyeing by being ground into relatively fine powder in the presence of dispersing agents. In the dye bath, a suspension of the dye particle dispersion produces a very dilute solution of the dyes, which are then absorbed by the fibers. This dye class is used to dye polyester, nylon, acetate and triacetate fibers.

Disperse yellow 3, Disperse Red 4, and Disperse Blue 27 are good examples of disperse dyes.

Example:

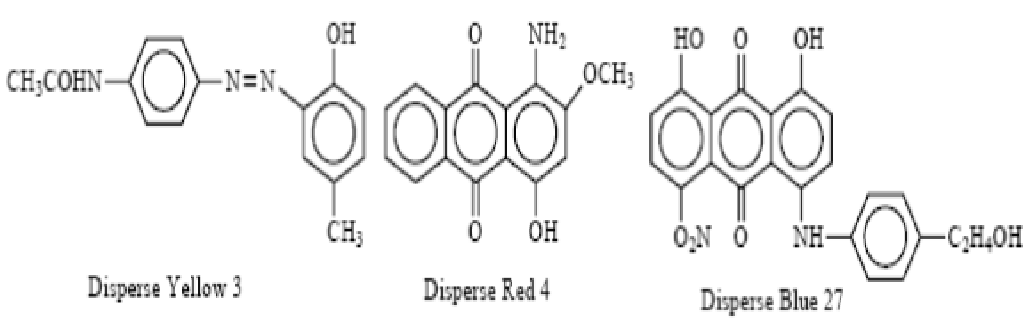


Fig: Disperse Dye

Vat Dye:

The vat dyes are insoluble complex polycyclic molecules based on the quinone structure (ketoforms). The term vat comes from the old indigo method dyeing in a vat: indigo had to be reduced to light form. Vat dyes are made from indigo, anthraquinone and carbazole. They are successfully used on cotton, linen, rayon, wool, silk, and sometimes nylon. Vat dyes are also used in the continuous piece of dyeing process sometimes called the pigment application process. The dyeings produced in this way have high wash and light fastness.

An example of a vat dye is Vat Blue 4 (Indanthrene).

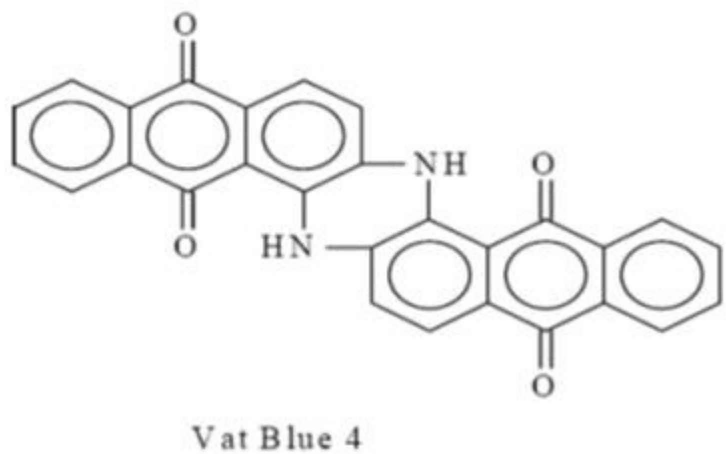


Fig: Vat Blue 4

Mordant Dye:

These Dyeing of Fabrics do not dye the fabric directly but require a binding agent known as mordant. The mordant acts as a binding agent between the fibre and the dye. Some dyes combine with metal salts (mordanting) to form insoluble colored complexes (lakes). These materials are usually used for the dyeing of cotton, wool or other protein fiber. The metallic precipitate is formed in the fiber producing very fast colors highly resistant to both light and washing.

Example:

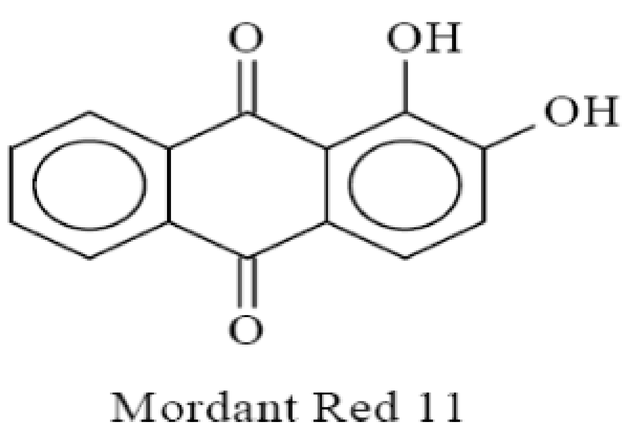


Fig: Mordant Dye

Reactive Dye:

These dyes react with the cellulosic fiber to form a covalent bond. This produces dyed fiber with extremely high wash fastness properties. These are the dyeing of fabrics which contain a reactive group which combines directly with the hydroxyl or the amino group of the fibre. Because of the chemical reaction the colour is fast and has a very long life. Cotton, wool or silk can be dyed with this type of dyeing of Fabrics. There are various types of reactive dyes used in dyeing industry.[17]

Results

Over the past 100 years, food dyes have been found to be more risky to our health than any other category of food additives. Despite being commonly used in processed foods, the majority of artificial food colorings have been found to raise significant health concerns:

1. Increases inflammation and disrupts functioning of the immune system.

Consumption of foods containing artificial dyes can cause an inflammatory response in the body, which leads to the activation of the immune system (increases the amount of white blood cells entering the bloodstream).

artificial dyes contain small molecules, which are able to attach to proteins in our body. This can cause disruptions in the immune system since the immune system finds it difficult to defend the body against them.

2. Contain cancer-causing, toxic contaminants.

Some of the most commonly used food dyes (red 40, yellow 5, and yellow 6) are contaminated with known carcinogens or cancer-causing substances, such as 4-aminobiphenyl, 4-aminoazobenzene, and benzidine. According to the fda, these contaminants are present in food dyes at “safe” levels.

Red 3 was found to be an animal carcinogen way back in 1990, but for some reason is still allowed in our food.

3. May cause cancerous tumor development. Some of the most commonly used food dyes are linked to many different forms of cancer:

Citrus red 2 caused bladder and other tumors in mice and bladder tumors in rats.

Red 3 caused thyroid tumors in rats.

Blue 2 may cause brain and bladder tumors in rats.

Red 40 may cause reticuloendothelial (immune system cells that are spread throughout the liver, spleen, and lymphatic system) tumors in mice.

Yellow 6 may cause adrenal and testicular tumors in rats.

4. Causes hypersensitivity, especially in children.

Red 40 has been shown to trigger hypersensitivity in children.

Yellow 5 has linked to hyperactivity, hypersensitivity, and other unfavorable behavioral effects in children.

Studies have shown that the elimination of artificial food dyes from children’s diets may help to reduce symptoms of attention-related disorders and other behavioral problems in children.[18,19]

Artificial food dyes have also been shown to:

Negatively impacts the functioning of the liver and other vital organs

Interfere with the digestive enzymes that our bodies produce to help properly break down the food that we eat

Increases intestinal permeability aka "leaky gut"

Linked to respiratory disorders, such as asthma and bronchitis

Negatively impacts nerve cell development

Most foods containing artificial food dyes are highly processed, contain little if any natural nutrients, and are high in calories and added sugars. Food dyes are likely to be detrimental to our health, which is supported by the cancer-causing, immune disrupting, and hypersensitivity effects that they are linked to.

Remember, what we put in our bodies has a huge effect on our cells, which in turn affects our health and wellbeing. Do a big favor for your health and choose to put healthy, naturally-colored foods in your body!

The toxic effects of the azo dyes may result from the direct action of the agent itself or of the aryl amine derivatives generated during reductive biotransformation of the azo bond . The azo dyes entering the body by ingestion can be metabolized to aromatic amines by the azoreductases of intestinal microorganisms. If the dyes are nitro, they can be metabolized by the nitroredutases produced by the same microorganisms . Mammalian liver enzymes and other organizations may also catalyze the reductive cleavage of the azo bond and the nitroreduction of the nitro group. In both cases, if n-hydroxylamines are formed, these compounds are capable of causing dna damage .

One of the most difficult tasks confronted by the wastewater treatment plants of textile industries is the removal of the color of these compounds, mainly because dyes and pigments are designed to resist biodegradation, such that they remain in the environment for a long period of time. For example, the half-life of the hydrolyzed dye reactive blue 19 is about 46 years at ph 7 and 25°c .

Carneiro et al. (2010) designed and optimized an accurate and sensitive analytical method for monitoring the dyes c.i. disperse blue 373 (db373), c.i. disperse orange 37 (do37) and c.i. disperse violet 93 (dv93) in environmental samples. This investigation showed that db373, do37 and dv93 were present in both untreated river water and drinking water, indicating that the effluent treatment (pre-chlorination, flocculation, coagulation and flotation) generally used by drinking water treatment plants, was not entirely effective in removing these dyes. This study was confirmed by the mutagenic activity detected in these wastewaters .

In this context, and considering the importance of colored products in present day societies, it is of relevance to optimize the coloring process with the objective of reducing the environmental impact of the textile industry. For this purpose, liposomes could be used to carry several encapsulated dyes, and hence improve the mechanical properties of textile products, resulting in better wash fastness properties and reducing the process temperature, thus economizing energy . Another way is to use ultrasonic energy, studied with the objectives of improving dye productivity and washing fastness, and reducing both energy costs and water consumption

Considering the fact that the textile dyeing process is recognized as one of the most environmentally unfriendly industrial processes, it is of extreme importance to understand the critical points of the dyeing process so as to find alternative, eco-friendly methods.[20]

Conclusions

Dye wastewater from textile and dye based industries is one of the most complex industrial wastewaters to treat. It is known that 90% of reactive textile dyes entering the activated sludge sewage treatment plants discharge into rivers and cause problems such as (a) reduction in penetration of sunlight in the streams, which is essential for photosynthesis and consequently, the ecosystem of the stream is seriously affected (b) toxicity to fish and mammals life (c) inhibition of the activity and the growth of microorganisms particularly at high concentrations (d) some cationic species (mostly triphenylmethanes) affect the flora and fauna even at lesser concentrations . Dermal and immunological effects have also been reported in workers exposed to benzidine and cancer is the documented toxic effect of benzidine in both human and animals. Direct brown, Direct black, Direct blue, are the dyes generally used in textile industries and the workers exposed to these compounds excrete high level of benzidine into their urine . Metabolic transformation of benzidine results in the formation of reactive intermediates which are thought to produce DNA adducts, which may initiate carcinogenesis by producing mutations that become fixed before DNA can be repaired .Moreover, anthraquinone based dyes, which are the most resistant to degradation when form metal -based complex can also be carcinogenic, in water supplies . Other compounds like formaldehyde, carbon disulphide, some phenolic and sulphur containing compounds are also used in textile industries. Formaldehyde is generally used in textile industries to attain a permanent press finish. It is a well-known cause of ocular and airway irritation and it can cause certain skin reactions including contact dermatitis via either allergic or irritant mechanism [21,22]

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