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Purification of textile dye-contained wastewater by three alternative promising techniques: Adsorption, Biodegradation and Advanced Oxidation Processes (AOPs) - A review

Abstract

Wastewater is a major environmental weakness throughout the world. Mainly, the increment of textile industries causes the increment of wastewater in the environment which is the most serious threat to living organisms. The textile industries use different types of synthetic and natural dyes for their functions and discharge large amounts of highly colored wastewater. This highly colored textile wastewater harshly affects human or living creature health as well as photosynthetic function in the plant. It also has an impact on aquatic life due to low light penetration and oxygen consumption. So, this wastewater must be treated before its discharge. Among many treatment techniques, three promising methods such as adsorption, biodegradation and advanced oxidation processes (AOPs) have been discussed in this paper. In comparison, highly recommended methods are the biological method and AOPs, especially Fenton chemistry.

Keywords: textile effluent, wastewater, adsorption, biodegradation, advanced oxidation processes (AOPS)

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Introduction

Water is an essential part of all organisms while the different organic and inorganic pollutants pollute it throughout the world. Textile industries consume large volumes of water and chemicals for wet processing and are highly responsible for discharging wastewater that harmfully affects the water quality as well as our environment.[1] It becomes difficult to remove dyes when once enter the water.[2] Dyes can be acidic, basic, reactive and direct which is a dangerous class of organic pollutants that are mainly used in dyeing, desizing, finishing, scouring, mercerizing, printing, bleaching, and neutralizing.[3] These dyes in water affect COD, BOD, color, pH, salinity, and visibility and obstruct the entry of light into water.[3] The high concentration of dyes may cause an allergic effect on skin & eyes and have mutagenic, toxic and carcinogenic effects for humans and animals.[4] These all are synthetic dyes that are widely used in the textile dyeing processes.[5]

In consequence, the removal of dyes from wastewater has gotten great attention over the past decades to decrease their impact on the environment. Numerous chemical, biological, and physical methods have been applied to remove the high coloration and the toxic or carcinogenic reactive dyes from textile effluents.[6] Adsorption process had been widely used and considered to be efficient in the removal of organic matter like dyes.[7] The preliminarily industrial adsorbents are activated carbon, silica gel and zeolite which are widely and effectively used, even being more expensive.[8] A natural biological process named biodegradation influences the wastewater with micro-organisms in the presence of sunlight and dissolved oxygen (DO) to degrade the organic pollutant into CO_2 and water. Moreover, advanced oxidation processes (AOPs) are also popularly used to remove pollutants from wastewater which is a combination of ozone (O_3), hydrogen peroxide (H_2O_2) and UV irradiation. So, the advanced oxidation processes (AOPS) have been improved to form hydroxyl (OH) free radicals by different techniques.[9]

This review discusses three promising methods, which are adsorption, biodegradation and advanced oxidation processes, to treat the dye-containing wastewater from textile industries, and to find out the effective and efficient method. Giving emphasizing on the identification of the sources of water pollution followed by green chemistry in textile wet processing has also been discussed.

Textile wastewater

Textile wastewater is water that contains various contaminants mixed with dyes at various ranges. It has been reported that the volume of wastewater released by factories is within the capacity of the ETPs used by the textile industry. Reactive dyes containing wastewater are considered problematic because they can be removed less efficiently than other classes of dye.[10] Instances, disperse dyes are the most common for polyester whereas a mixture of reactive dyes and acid dyes is normally used for blended fabrics such as polywool, spandex and cotton fabric, etc. The quality of the textile discharged wastewater parameter is mentioned in Table 1.

Table 1 Composition and quantity of textile wastewater[11]

Wastewater parameters	Quantity of the chemical (mg/L)	Wastewater parameters	Quantity of the chemical (mg/L)
Dye concentration	700	NO_3	2
Chloride	15,867	PO_4	17
Sulfate	1400	Ca	43
Total Nitrogen	23	Mg	4
COD	1781	Na	2900
BOD	363	Fe	1.2
NH_4	17	pH	–10

Textiles - A serious threat to the sustainable environment

Among all basic demands, the textile industry fulfills the second basic requirement of human and it's a major source of revenue generation in Bangladesh. It deals with different processes such as sizing, desizing, dyeing, yarn processing and etc. But the sad fact is that the textile industry is one of the most pollutant-releasing industries and has caused a serious threat to our environment. The textile industry uses millions of gallons of water and then releases wastewater every day. Contamination of the air, water, and land by textile industries and their raw material manufacturing units has become a serious threat to the environment. It has endangered the life of human beings and various other species on Earth. Afterward, the unfixed dyes and other chemicals are discharged as effluents which consequently pollute the environment and pose serious threats to human health. Somewhat a few textile processing units do apply effluent treatment techniques to minimize the discharge of hazardous substances into the environment. Currently, multiple strategies are being adopted in textile processing units to minimize environmental pollution. As an alternative green approach, the acceptability of using green fibers, green reagents, green solvents, and green finishing agents is on the rise, especially in technically advanced countries.[12]

Physical process – Significance of adsorption in textile wastewater treatment

All physical methods include adsorption, ion exchange, coagulation, irradiation, membrane filtration etc.[13] Among them, adsorption is one of the most effective due to its greater decolonization efficiency, simplicity of operation and potential application in wastewater treatment. This process has a percentage of dye removal ranging from 86.8 to 99 %.[14] Adsorption is a surface phenomenon in which atoms and molecules are transferred and adhered to the surface of the adsorbent (solid) creating a thin film.[15] Adsorption process usually occurs in three consecutive steps. In the first step, the adsorbate ions from the bulk of the solution diffuse to the external surface of the adsorbent (film diffusion). Second step, the adsorbate from the external surface migrates from the relatively small area within the pores of each adsorbent particle. Although, a small amount of absorption occurs at the external surface of the absorbent (particle diffusion). In the final step, the adsorbate ions are adsorbed on the interior surface of the pore. The performance of the adsorption process may influence by many factors such as solution pH, initial dye concentration, contact time, temperature and adsorbent dosage.[16]

Significance of bio-degradation process on textile industry wastewater

It has been found that biological wastewater treatment possesses a high degree of efficiency with minimum running cost. On the basis of oxygen condition, biological processes can be classified into anaerobic digestion, aerobic and anoxic. Anaerobic digestion methods use microbes to treat high-strength wastewater and degrade the unwanted compounds into CO_2 and CH_4 by using different bacteria in absence of oxygen.[17] While, aerobic methods use microbes for the removal of organic materials in presence of oxygen. Aerobic treatment is commonly used for final decontamination and removal of nutrients after using physicochemical or anaerobic techniques.[18] The combination of the anaerobic and aerobic methods are typically applied to treat textile wastewater of chemical oxygen demand (COD).[19] Different organisms have been introduced in the following Table 2.

Table 2 Introduction of different organisms which are highly used in the bio-degradation process

Organism	Introduction
Fungi	Fungi are aerobic, multi-cellular, nonphotosynthetic eukaryotes.
Algae	Algae are single-celled and multi-cellular photosynthetic eukaryotes.
Bacteria	Bacteria are single-cell, prokaryotic organisms that use soluble food.
Protozoa	Protozoa are single-celled microbes without cell walls and are eukaryotes.

Advanced Oxidation Processes (AOPs) for wastewater treatment

Chemistry in AOPs could be essentially divided into three parts: (i) Generation of $^{\bullet}OH$, (ii) Primary attacks on target microorganisms (through $^{\bullet}OH$ radicals) and then their disruption to fragments and (iii) Subsequent attacks by $^{\bullet}OH$ until final mineralization.[20] The hydroxyl radicals are powerful oxidizing agents which react with most dyes with a high rate of reaction constants.[21] Thus, AOP methods are widely used in almost every industry, especially the Fenton chemistry method is highly recommended. Several AOPs are listed in Table 3.

Table 3 Typical AOPs systems

Photochemical processes	
O3+UV	This is very effective when O_3+UV is used for wastewater treatment.
Fenton Chemistry	The reaction between Fe_3+ ions and H_2O_2 stimulates the oxidation of complex organic pollutants which generates iron sludge due to the combined flocculation of reagent & dye.
Photocatalytic Oxidation (PO)	The PO involved both direct and indirect reactions of ozone which is based on the formation of hole-electron pairs. The mechanism is that organics would be oxidized to H_2O, CO_2, or any harmless substances with the help of TiO_2 and UV light.[24]
Non-photochemical processes	
Ozonation at elevated pH (>8.5)	Ozone decomposition is faster under the alkaline condition of pH > 8.5. So, continuous monitoring of the textile effluent pH is required.[25]
Ozone + Hydrogen peroxide (O_3/H_2O_2)	AOP processes use oxidizing agents like O_3 and H_2O_2. Ozone and H_2O_2 form strong non-selective hydroxyl radicals at high pH values due to less production of hydroxyl radicals
Catalytic Ozonation (Ozone + catalyst)	The catalyst provides a surface for the reaction of O_3 with pollutants in wastewater where O_3 interacts with the reactive functional groups on the catalyst's surface and generates very reactive species with much higher oxidation potential than O_3.[26]

Cost efficiency and Comparison of these three promising methods

In comparison to all the processes, Fenton chemistry and biological-based treatment have lower costs as compared to others.[22] To minimize the costs, first, the most expensive treatment parts should be identified and then those parts should be minimized or substituted with cheaper or more effective solutions. In the future, there should emphasis on the cost analysis of more treatments like physical, AOP

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and Biological processes. After that, the combination having low cost and low toxicity should be applied for the treatment of textile wastewater. Whatever, the benefits of biological methods are: (a) eco-friendly, (b) cost-competitive, (c) less sludge production, (d) giving non-hazardous metabolites and (e) less consumption of water compared to physical/AOPs methods.[23]

Green chemistry in wet textile processing

Scouring involves alkalies, bleaching needs hypochlorites, cross-linking agents involve auxiliaries derived from formaldehyde, and dyeing in textile processing is carried out by using nonbiodegradable synthetic dyes containing azo groups or heavy metals containing antimony and bromine. These hazardous chemicals pose serious health threats to laborers of processing units. Over the last few years, the use of biodegradable and less toxic chemicals is on the rise in textile wet processing as alternative green chemicals. These have been adapted for better biodegradability and to reduce the toxicity of effluents discharged from processing units.[27]

Conclusion

The textile industry is one of the most important industrial concerns throughout the world. It is responsible for environmental water pollution because the water is not properly treated before its discharge. Unfortunately, no particular treatment methodology is appropriate or universally adaptable for all kinds of textile effluents. Every method has several drawbacks. Therefore, the treatment of textile wastewater is done by a combination of several methods, which maybe contain physical, AOP and biological methods. In recent periods, the reuse of textile effluents has increased attention towards reducing the scarcity of water resources.

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Conflicts of interest

Author declares that there is no conflict of interest.

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