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Impact of textile dyeing effluent on environment; a study based on Bangladesh

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ABSTRACT:In textile processing, about 200,000 tons of these dyes are lost to effluents every year during the dyeing and finishing operations, due to the inefficiency of the dyeing process. Unfortunately, most of these dyes discharge conventional wastewater treatment methods and persevere in the atmosphere as a result of their high stability to light, temperature, water, detergents, chemicals, soap and other parameters such as bleach. In addition, anti-microbial agents' resistant to biological degradation are frequently used in the manufacture of textiles, particularly for natural fibers such as cotton. The synthetic origin and complex aromatic structure of these agents make them unrulier to biodegradation. The textile industry consumes a substantial amount of water in its manufacturing processes used mainly in the dyeing and finishing operations of the plants. The wastewater from textile plants is classified as the most polluting of all the industrial sectors, considering the volume generated as well as the effluent composition. In addition, the increased demand for textile products and the proportional increase in their production, and the use of synthetic dyes have together contributed to dye wastewater becoming one of the substantial sources of unadorned pollution problems in present periods.

KEYWORDS: Textile Dyeing, Effluent water, Pollution, Environment, Contamination

I. INTRODUCTION

Dyes is a constituent with substantial coloring capacity are broadly engaged in the textile, food, cosmetics, plastics, photographic and paper industries. The dyes can observe to compatible surfaces by solution, by forming covalent bond or developments with salts or metals, by physical adsorption or mechanical retention [1,2]. 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 color. These chromophore containing centers are based on varied functional groups, such as azo, anthraquinone, nitro, carbonyl etc. It is projected that over 10,000 different dyes and pigments are used industrially and over 7 x 10^5 tons of synthetic dyes are annually produced worldwide [3,4]. Textile materials can be dyed using batch, continuous or semi-continuous processes. The kind of process used depends on many characteristics including type of material as such fiber, yarn, fabric, fabric construction and garment, as also the generic type of fiber, size of dye lots and quality requirements in the dyed fabric.

Textile waste waters are characterized by extreme fluctuations in many parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), pH, colour and salinity. The composition of the waste water will depend on the different organic based compounds, chemicals and dyes used in the dry and wet-processing steps. Unruly organic, coloured, toxicant, surfactant, chlorinated compounds and salts are the main pollutants in textile effluents [10].

In addition, the effects caused by other pollutants in textile waste water, 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 [11].

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

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downstream beneficial uses such as recreation, drinking water and irrigation [14]

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 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 [15]. They have a wide range of applications in the textile, pharmaceutical and cosmetic industries, and are also used in food, paper, leather and paints [16]. However, some azo dyes can show toxic effects, especially carcinogenic and mutagenic events [17]. One of the most difficult tasks confronted by the wastewater treatment plants of textile industries is the removal of the colour 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 hydrolysed dye Reactive Blue 19 is about 46 years at pH 7 and 25°C.

II. DIFFERENT STAGES OF DYEING PROCESS

Dyeing is one of the key aspects in the successful trading of textile products like yarn, fabric or any apparel. In addition, the consumer usually looks for some basic product characteristics, such as good fixation with respect to rubbing, light, perspiration, saliva and washing. To confirm these properties, the materials that give colour to the fibre must show high affinity, uniform colour, resistance to fading, can be economically feasible. Dyeing methods have not changed much with time. Basically water is used to clean, dye and apply auxiliary chemicals to the fabrics, and also to rinse the treated fibres or fabrics [18]. The dyeing process involves three steps: preparation, dyeing and finishing, as follows:

Preparation is the step in which undesirable impurities are removed from the fabrics before dyeing. This can be carried out by cleaning with aqueous alkaline substances and detergents or by applying enzymes. Many fabrics are bleached with hydrogen peroxide or chlorine-containing compounds in order to remove their natural colour, and if the fabric is to be sold white and not dyed, optical brightening agents are added.

Dyeing is the aqueous application of colour to the textile substrates, mainly using synthetic organic dyes and frequently at elevated temperatures and pressures in some of the steps. It is significant to point out that there is no dye which dyes all existing fibres and no fibre which can be dyed by all known dyes. During this step, the dyes and chemical aids such as surfactants, acids, alkali/bases, electrolytes, carriers, levelling agents, promoting agents, chelating agents, emulsifying oils, softening agents etc are applied to the textile to get a uniform depth of colour with the colour fastness properties suitable for the end use of the fabric. This process includes diffusion of the dye into the liquid phase followed by adsorption onto the outer surface of the fibres, and finally diffusion and adsorption on the inner surface of the fibres. Depending on the expected end use of the fabrics, different fastness properties may be required. For instance, swimsuits must not bleed in water and automotive fabrics should not fade after prolonged exposure to sunlight. Different types of dye and chemical additives are used to obtain these properties, which is carried out during the finishing step. Dyeing can also be accomplished by applying pigments (pigments differ from dyes by not showing chemical or physical affinity for the fibers) together with binders (polymers which fix the pigment to the fibres).

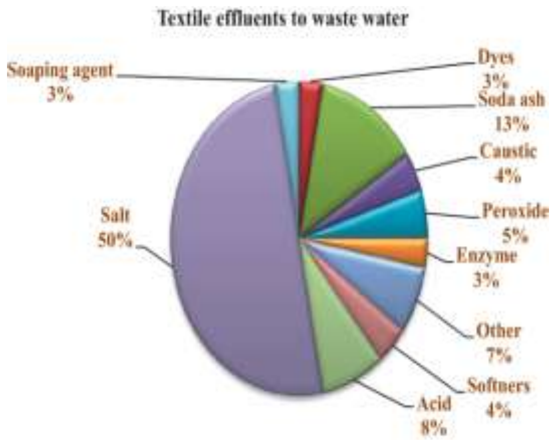

Figure 1: Textile effluent from used chemicals

Finishing involves treatments with chemical compounds aimed at improving the quality of the fabric. Permanent press treatments, water proofing, softening, antistatic protection, soil resistance, stain release and microbial/fungal protection are all examples of fabric treatments applied in the finishing process.

III. WASTE WATER

The pollution of natural water has become one of the major problems in current civilization, and the economical use of this natural resource in production processes has gained special attention, since in forecasts for the coming years, the amount of water required per capita is of concern. This environmental disruptive is related not only to its

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waste through misappropriation, but also to the release of industrial and domestic effluents [20]. The industries with high polluting power, the textile dyeing industry, responsible for dyeing various types of fiber, stands out. Independent of the characteristics of the dyes chosen, the final operation of all dyeing process involves washing in baths to remove excesses of the original or hydrolysed dyes not fixed to the fibre in the previous steps. In these baths, it is estimated that approximately 10-50% of the dyes used in the dyeing process are lost, and end up in the effluent [13], polluting the environment with about one million tons of these compounds. The dyes end up in the water bodies due mainly to the use of the activated sludge treatment in the effluent treatment plants, which has been shown to be ineffective in removing the poisonousness and colouring of some types of dye. Moreover, the reduction of azo dyes by sodium hydrosulphite and the following chlorination steps with hypochlorous acid, can form 2-benzotriazoles fenilbenzotriazol (PBTA) derivatives and highly mutagenic aromatic amines, often more mutagenic than the original dye [22].

In an aquatic environment, this dye reduction can occur in two phases: 1) The application of reducing agents to the newly-dyed fibers to remove the excess unbound dye, which could lead to "bleeding" of the fabrics during washing, and 2) The use of reducing agents in the bleaching process, in order to make the effluent colourless and conform with the legislation. This reduced colourless waste containing dyes is sent to the municipal sewage treatment plant, where they chlorinate the effluents before releasing them into water bodies where they may generate PBTAs. Several different PBTAs are already described in the literature, and their chemical structures vary depending on the dyes that originated them.

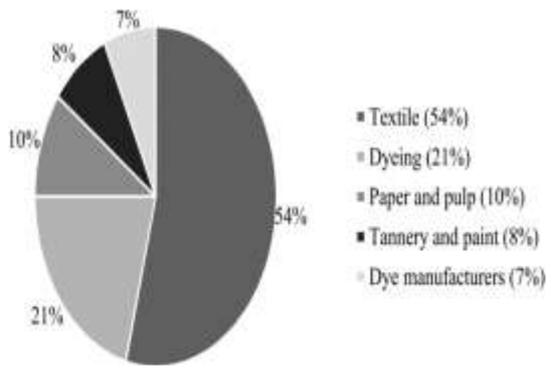

Figure 2: Sources of waste in water

In addition to the problem caused by the loss of dye during the dyeing process, within the context of environmental pollution, the textile industry is also focused due to the large volumes of water used by its industrial park, subsequently generating large volumes of effluent. It has been calculated that approximately 200 litters of water are needed for each kilogram of cotton dyeing produced. These effluents are complex mixtures of many contaminants, ranging from original colours lost during the dyeing process, to associated pesticides and heavy metals, and when not properly treated, can cause serious contamination of the water sources. So the materials that end up in the water bodies are effluents containing a high organic load and biochemical oxygen demand (BOD), low dissolved oxygen concentrations, strong color and low biodegradability. In addition to visual pollution, the pollution of water bodies with these compounds causes changes in the biological cycles of the aquatic biota, predominantly affecting the photosynthesis and oxygenation processes of the water body, for instance by hindering the passage of sunlight through the water.

Moreover, studies have shown that some classes of dye, especially azo dyes and their by-products, may be carcinogenic and / or mutagenic, endangering human health, since the wastewater treatment systems and water treatment plants (WTP) are ineffective in removing the colour and the mutagenic properties of some dyes. The difficulty in removing them from the environment can be attributed to the high stability of these compounds, since they are designed to resist biodegradation to meet the demands of the consumer market with respect to durability of the colours in the fibres, consequently implying that they also remain in the environment for a long time. Based on all the difficulties cited above regarding the discharge of effluents into the environment, it is obvious there is a need to find alternative treatments that are effective in eliminating dyes from wastes.

IV. OPTIMIZATION OF THE DYEING PROCESSES TO DIMINISH THE ENVIRONMENTAL IMPACT

The progress of new methods to promote the treatment of effluents from the textile industry with a maximum of efficiency of the process of de-colorization and / or removal of these complexes present in the medium can trigger further damage human health and the environment is fundamental importance. The thoughtful of the composition of waste generated is extremely significant to develop these methods of treatment due to the high complexity by virtue of huge number of compounds which are added at different phases of the dyeing fabrics. Environmental problems with used dye baths are related to the wide variety of different components added to the dye bath, often in relatively high concentrations. In the future, many of textile factories will face the requirement of reusing a significant part of all incoming freshwater because traditionally used methods are insufficient for obtaining the required water quality.

However, due to dwindling supply and increasing demand of water in the textile industries, a better alternative is to attempt to further elevate the water quality of wastewater effluent from a secondary wastewater treatment plant to a higher standard for reuse. Thus far very little attention has been paid to this aspect. Therefore, the investment in the search for methodologies to more effective treatment of these effluents can be much smaller than that spent in tertiary treatment to remove these products in low level of concentrations and in the presence of much other interference. This requires action that the cost / benefits is studied and the development of new techniques for waste water treatment accomplished of effective removal of these dyes is strengthened and made economically feasible. An alternative to minimize the problems related to the treatment of textile effluents would be the development of more effective dye that can be fixed fibre with higher efficiency decreasing losses on tailings waters and reducing the amount of dye required in the dyeing process, reducing certainly improve the cost and quality of the effluent.

V. RESULTS AND DISCUSSION

Environmental effluence can certainly be observed as one of the main problems both for developed and developing countries. This is due, not just to one, but to a number of factors, such as the misuse of natural assets, unproductive legislation and a lack of environmental consciousness. Auspiciously, in recent years there has been a trend for change and a series of scientific studies are being used as an important tool in the development of new treatment technologies and even in the implementation of processes and environmentally friendly actions.

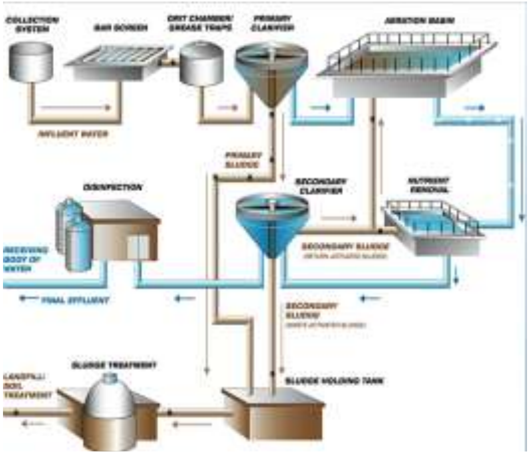

Figure 3: Waste water treatment plant

Each manufacturing process is characterized by the use of inputs (raw materials, water, energy, etc.) that undergo transformation giving rise to products, byproducts and waste. The wastes produced at all stages of the various types of human activity, both in terms of composition and volume, vary according to the consumption practices and production methods. The main concerns are focused on the impact these can have on human health and the environment. Hazardous waste, produced mainly by industry, is particularly worrying, because when incorrectly managed, it becomes a serious threat to the environment and therefore to human health.

Amongst that of several other industries, the textile sector waste has received considerable attention in recent years, since it can generate large volumes of effluents that, if not correctly treated before being disposed into water resources, can be a problem, as previously mentioned. Effluents from the textile industry are extremely complex, since they contain a large variety of dyes, additives and derivatives that change seasonally, increasing the challenge to find effective, feasible treatments. Currently, the processes developed and available for these industries are based on methods that were designed for other waste, and have limitations when applied to textile effluents. As a consequence, these industries produce coloured waste water with a high organic load, which can contribute enormously to the environmental pollution of surface water and treatment plants if not properly treated before disposal into the water resources. The digestion of water polluted with textile dyes can cause serious damage to the health of humans and of other living organisms, due to the toxicity, highlighting mutagenicity of its components. Therefore, treatments that are more efficient and economical than those currently available are required.

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There are several techniques for the treatment of effluents, such as incineration, biological treatment, absorption onto solid matrices, etc. However, these techniques have their drawbacks, such as the formation of dioxins and furans, caused by incomplete burning during incineration; long periods for biological treatment to have an effect, as also the adsorptive process, that is based on the phase transfer of contaminants without actually destroying them. The problem is further aggravated in the textile industry effluents, due to the complexity of their make-up. Thus it can be seen that processes are being used that are not entirely appropriate for the treatment of textile effluents, thereby creating a major challenge for the industry and laundries that need to adapt to current regulations for the control of the colour of effluents with a high organic load.

The use of filtration membranes and/or separation and biological methods, in addition to incineration processes involving adsorption onto solid matrices, has also being adopted by the textile industry and is receiving considerable attention. However, all these processes only involve phase transfer, generating large amounts of sludge deposited at the end of the tanks and low efficiency in colour removal and reduction of the organic load. According to this scenario, many studies have been carried out with the aim of developing new technologies capable of minimizing the volume and toxicity of industrial effluents. Unfortunately, the applicability of these types of system is subject to the development of modified procedures and the establishment of effluent recycling systems, activities that imply evolutionary technologies and which are not yet universally available. Thus the study of new alternatives for the treatment of many industrial effluents currently produced is still one of the main weapons to combat the phenomenon of anthropogenic contamination.

In the studies carried out using a source of hydroxyl radicals with oxidizing agents, the photo Fenton system developed by Fukushima et al., 2000 to promote the degradation of aniline stands out. This method has shown promise for the mineralization of aromatic amines, obtaining a reduction of approximately 85%. However, high performance liquid chromatography (HPLC) identified a number of intermediate species formed during the degradation of the aniline, such as p-aminophenol, p-hydroquinone, maleic and fumaric acids and NH_4^+.

Low et al. (1991) monitored the inorganic products resulting from the degradation of several organic nitrogenated, sulphured and halogenated compounds. Degradation was carried out using TiO_2 as the semiconductor and artificially illuminated UV radiation. Ammonium ions were found to be present in higher concentrations than nitrate ions, which can be explained by the fact that compounds having a nitrogen element in their structure pass through a complex degradation step where the generation of ammonium ions is more favourable than the generation of nitrate ions. In turn, compounds with nitro groups in their structures, showed higher concentrations of nitrate ions. Under ideal conditions, all the elements were converted into their respective inorganic forms. Organic carbon was converted to CO_2, the halogens to their corresponding halide, sulphur compounds to sulphate, the phosphate to phosphorus and nitrogen to ammonium and nitrate [100]. However, all these studies used a photocatalytic titanium suspension, requiring a subsequent step to remove the semiconductor.

Augugliaro et al. (2000), confirmed that heterogeneous photocatalysis using TiO_2 as a semiconductor may be a suitable method for the complete photodegradation of aniline, 4-ethylaniline and 4-chloroaniline in an aqueous medium. The kinetic parameters for the Langmuir-Hinshelwood model were used to describe the importance of the adsorption results, which proved to be independent of the pH of the solution and of the type of substituent on the aromatic ring of the amine.

Chu et al. (2007) observed the effects of pH variation and the addition of hydrogen peroxide on the degradation of 2-chloroaniline using TiO_2 as a semiconductor, with and without the application of UV radiation. The results showed that the addition of low concentrations of H_2O_2 to the UV/TiO_2system provided a significant increase in degradation of the aromatic amine. The addition of an excess of H_2O_2 promoted no increase in degradation, as expected; to the contrary, a reduction in the reaction rate was observed. The variation in pH was evaluated in both systems, and the condition leading to the highest percentages of mineralization was obtained in an alkaline medium using $H_2O_2/UV/TiO_2$.

The results of this process were very promising because of the relatively short treatment time but with great efficiency, both in the removal of color and in the reduction of the organic load. However, the limitations of this technique are related mainly to the choice of the ideal catalyst for promoting the generation of these oxidizing species. Catalysts that promote the generation of radicals absorbing radiation in the visible spectral region are the most desirable for this type of reaction, due to the large percentage emitted in the solar spectrum (approximately 45%).

Thus, the development of an ideal process that promotes colour removal and a reduction in the organic load of wastewater from the textile industry with great efficiency is a major challenge in all fields of science, since the synthesis of the best catalyst to take advantage of solar radiation, thus reducing the operating costs, and at the same time solve the problems involved in the hydrodynamics of the reactors, is of importance in the development of the treatment.

VI. CONCLUSION

It has been concluded that the synthetic textile dyes represent a large group of organic compounds that could have undesirable effects on the environment, and in addition, some of them can stance dangers to humans. The increasing complexity and difficulty in treating textile wastes has led to a constant search for new methods that are effective and economically viable. Though, up to the present moment, no efficient method capable of removing both the color and the toxic properties of the dyes released into the environment has been established.

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