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Studies on decolouration, toxicity and the possibility for recycling of acid dye effluents using ozone treatment

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Abstract

Investigations carried out to study the feasibility of application of ozone technology for decolouration, toxicity and towards recycling of acid dye effluents for dyeing of silk fabric are reported in this paper. The dyes Acid Red 88, Acid Red 18, Acid Orange 7, Acid Orange 10 and Acid Red 73 were used in this study. The used dye baths were treated with ozone till complete colour removal and reused. For all the dyes two successive recycling processes were carried out. Characteristics of effluents and ozone treated effluents were assessed in terms of total dissolved solids (TDS) and chemical oxygen demand (COD). *Gambusia affinis* was used for the bioassay tests to find the LC_{50} value of the treated effluents. The effect of recycling on quality of dyeing was determined using colour difference (ΔE^*) and relative unlevelness index (RUI). This study reveals that treatment of acid dye effluents with ozone does not have an effect on TDS reduction. But it reduces the COD of effluents including the effluents obtained in recycling processes. The toxicity of the ozone treated effluents increases with increasing time. A dye having a greater number of sulphonic acid groups in its structure reveals higher toxicity. Resulting effluents from the application of Acid Red 88 and Acid Red 73 on silk fabric can be recycled twice and those from Acid Red 18 and Acid Orange 10 can be recycled once with acceptable ΔE^* values. Acid Orange 7 effluent is found to be unsuitable for recycling because of its higher colour difference values. The levelness of the shade determined on the basis of RUI, produced on the silk fabric in the recycling processes, is either excellent or good in all the cases, which include those producing higher colour difference.

Keywords: Ozonation; Colour removal; Acid dyes; Recycling; Toxicity; Colour difference; Relative unlevelness index

1. Introduction

Reuse of water in textile processes has been the subject of research and development work in recent years [1–11]. The incentives for reuse of water are great, since there is a potential for reduction of both water requirements and wastewater treatment costs. One of the approaches to reuse the dye bath is to reconstitute the dye bath by adding the required amount of dyes and chemicals after analysing the dye liquor. This method is applicable only if the dyeing process does not change the character of the residual dye in the bath. Another approach is to remove the residual colouring matter prior to reuse. This method is applicable to any class of dye provided sufficient colour is removed.

Vandevivere et al. and Skelly [7,9] reviewed the efficiency of the recycling process in textile wet processing industries and they found that reuse of the treated dye baths saves chemicals and water. Perkins et al. [2,4] reported that the dye bath water was suitable for repeated dyeing if it is treated by chlorination. Also, they assessed the performance of the reuse by colour difference (ΔE^*) values of the dyed samples obtained from the treated effluent and found that 4 out of 10 samples were of less than the acceptable level. Perkins and Reed [3] reported that reusing ozone treated water for dyeing with vinyl sulphone dyes shows excellent colour reproducibility.

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The effluents from textile dyeing industries contain a variety of chemicals and dyes, which are carcinogenic and mutagenic [12,13]. The nature and extent of pollution depend on the biochemical oxygen demand (BOD) and dissolved oxygen (DO) in the aquatic bodies [14]. The chemicals present in the dye effluents deplete DO and increase the BOD, which can cause heavy fish mortality by interfering with respiratory physiology [15–17].

Hence, an investigation was carried out to study the feasibility of application of ozone technology towards recycling of acid dye effluents for dyeing of silk fabric and the toxicity of the ozone treated effluents. The dyes Acid Red 88, Acid Red 18, Acid Orange 7, Acid Orange 10 and Acid Red 73 were selected for this study. The used dye baths were treated with ozone until entire colour was removed. The resulting liquor was used for further dyeing studies. For all the dyes, two successive recycling processes were carried out. The results, namely, total dissolved solids (TDS) and chemical oxygen demand (COD) of the effluents before and after treatment, colour difference (ΔE^*), relative unlevelness index (RUI) of the dyed fabrics and LC_{50} of the ozone treated effluents, are reported along with suitable discussions.

2. Experimental

2.1. Apparatus

The experimental set-up consisted of an oxygen concentrator (Sim O_2 plus, Italy), ozone generator (Ozonetek Ltd., India), ozonation chamber and ozone destructor (Ozonetek Ltd., India). A controlled flow rate of 2 l/min of oxygen was used to produce 2 g/h of ozone. The concentration of ozone was analysed using an ozone analyzer (BMT 201, Berlin). The ozonation chamber consists of a 1850 mm glass column with 50 mm inner diameter having a capacity to hold 1000 ml of effluent. It was provided with a sample port at various points, an ozone gas inlet at the bottom with a ceramic diffuser over the inlet port to diffuse the oxygen/ozone gas mixture through the column and a closed top with a collection port to collect the unreacted ozone gas for analysis and to the thermal vent ozone destructor before venting it out. A PTFE tube was used for connecting the ozone outlet port from the ozone generator to the ozone reaction chamber.

Multivoltine plain-woven raw silk fabric used for dyeing studies was obtained from Central Silk Technical Research Institute, Central Silk Board, India. The chemicals and dyes used were of analytical and commercial grades, respectively. Ground water having a hardness of 82 mg/l was used in the dyeing processes.

2.2. Procedure

2.2.1. Recycling of actual effluent

Known weight of degummed silk fabric was dyed to 2% shade on weight of material (OWM) with the dyes selected using a liquor ratio of 20:1. The dye bath was prepared by adding the necessary quantity of dye (dyes, namely, Acid Red 88, Acid Red 18, Acid Orange 7, Acid Orange 10 and Acid Red 73) and 20% OWM of sodium sulphate salt in fresh water. Pre-wetted fabric was introduced in the dye bath having a temperature of 40 °C and worked for 10 min. Then 3% OWM formic acid was added and the temperature was raised to 85 °C and the dyeing was continued for further 45 min. Finally, the material was removed from the dye bath and squeezed in such a way that the liquor falls back in the bath itself. The liquor so obtained was the actual effluent of the respective dye.

The effluents obtained from the above process were subjected to 100% decolouration using the apparatus described, in order to use them in first recycling. The complete decolouration of the effluents was ascertained using a UV–visible spectrophotometer (Hitachi, U-3210, Japan). The treated effluents were used for first and second recycling following the same dyeing procedure as given above but without the addition of sodium sulphate salt in the bath. Dyed samples produced using the treated liquors were assessed for the quality of dyeing.

2.2.2. Characterisation of effluents and dyed materials

Characteristics of effluents generated in each process and the corresponding ozone treated effluents were assessed in terms of pH, TDS and COD using standard methods for analysis of wastewater [18]. The effect of recycling of ozone treated dye effluents on colour reproduction and lightness on silk fabric was analysed using ΔE^* and ΔL^* values, respectively, calculated with the help of 1976 CIE L^*, a^* and b^* (CIELAB) equations [19]. A relative unlevelness index (RUI) value of dyed samples was also calculated by using the equation proposed by Chong et al. [20].

Bioassay studies were carried out following the APHA [18] recommended procedure to determine LC_{50} values of the ozone treated effluents. The fish *Gambusia affinis* was used for the experiment. Preliminary bioassay test was carried out using a wide range of toxicant concentration; the fish mortality was taken for 48 h for concentrations ranging from 10 to 100% by volume of toxicant preceding the final narrow range of toxicant concentration. In these tests, fish mortality was taken for 24 h, 48 h, 72 h and 96 h. The test medium was replaced daily with a freshly prepared one in order to maintain the effect produced by the various contents in the toxicants. During the removal, 80% of the test medium was siphoned