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# Reuse of Beverage Industry Wastewater in Textile Dyeing after its Treatment with Ozone

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**Abstract:** This investigation evaluated a novel idea of reusing wastewater generated during the washing and rinsing stages of soft drink bottling at a beverage factory located in Raiwind, Pakistan. Once the wastewater was collected from the beverage factory, it first underwent ozone ($O_3$) treatment using a bench scale laboratory set-up and then reused in cotton dyeing process. Experimental results showed that 70, 78, 82 and 98% colour removal efficiencies were achieved in a composite wastewater sample at 5, 10, 15 and 20 minutes of $O_3$ treatment, respectively. Turbidity (NTU), COD (mg/L) and pH values were found to be decreasing with increasing ozone exposure time. At the end of ozone treatment, the treated wastewater was used in cotton dyeing process which is also a water-intensive process similar to beverage industry. Finally, the fabrics dyed in $O_3$ treated wastewater were subjected to quality testing in terms of washing, rubbing and colour difference properties. This study concluded that ozonation was an efficient method for the treatment of wastewater from beverage industry and treated water could be successfully reused in cotton dyeing without deteriorating the coloration quality. This method proved to be an eco-friendly process because it did not consume any fresh water and used only discarded wastewater, hence reducing pollution load significantly.

**Key words:** Ozone, wastewater, beverage industry, soft drinks, reactive dyeing

## INTRODUCTION

Industries use high quality fresh water in wide range of applications and sometimes this quality exceeds drinking water standards. The magnitude of water consumption by such industries is a serious matter of concern from a water intake and an effluent discharge point of view. These water-intensive industries are facing increasingly stringent environmental regulations on quality and quantity of wastewater effluents. These regulations have increased the need and attention of researchers to strive for better water management and wastewater minimization alternatives to achieve both economical and ecological benefits (Wu *et al*., 2008).

Soft drink industry forms a major part of the food and beverage industry of Pakistan. Thus it is important to study the nature and amount of wastewater generated by the soft drink plants. It is estimated that per capita soft drinks consumption in Pakistan is around 20 L/year (Hajira *et al*., 2013). Soft drink manufacturing is considered highly water intensive process because for every single liter of soft drink produced, 2.5 to 3.5 L of fresh water is used. Moreover, 50% effluent produced in the making of soft drinks is generated during bottle washing, machine washing of bottle machine, filler back washing, floors and pipe work during change of flavours. The major contaminants in soft drink wastewater are colour, detergents and sodium hydroxide (Camperos *et al*., 2004). Similar to soft drink industry, textile industry is also responsible for high consumption of fresh water and the discharge of huge quantities of wastewater into natural waterways. A typical cotton dyeing process using reactive dyes consumes around 120-280 L of water for 1.0 kg of cotton (Schoeberl *et al*., 2005).

In the past, numerous studies have been carried out to remove organic pollutants and colour from food and beverages waste waters (Satyawali and Balakrishnan, 2008; Huseyin, 2005). Because of high oxidation power of ozone (2.07 V), it can degrade most organic compounds including synthetic colorants (Strickland and Perkins, 1995) with no production of sludge or toxic by-products (Gahr *et al*., 1994). The reactions of Ozone decomposition in aqueous solutions had been studied by Hewes and Davison (1971) and they reported the following mechanism:

$$O_3 + H_2O \rightarrow HO_3^+ + OH^-$$
$$HO_3^+ + OH^- \rightarrow 2HO_2$$
$$O_3 + HO_2 \rightarrow HO^\bullet + 2O_2$$
$$HO^\bullet + HO_2 \rightarrow H_2O^\bullet + O_2$$

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In this study, segregated bottle washing wastewater from local beverage production was collected and given a laboratory-scale ozone oxidation in order to remove colour and chemical oxygen demand (COD). Afterwards, the treated liquor was used in the dyeing of cotton fabrics. The quality parameters of fabrics were determined in terms of washing fastness, rubbing fastness, change of shade and colour difference properties and results were compared with those dyed in fresh water. The reuse of bottle washing wastewater after its treatment with ozone showed satisfactory results and it proved to be an alternative approach that can offer savings of fresh water.

## MATERIALS AND METHODS

Knitted fabric having 100% cotton composition and made with 20/s yarn was used in this study. Three commercially used reactive dyes i.e. Drimarene Yellow CL-2R, Sumifix Supra Brilliant Red 2BF and Procion Blue HEXL were used in this study.

**Ozone oxidative treatment to bottling wastewater:** Bottle washing wastewater collected from local beverage company was subjected to ozone oxidation using a laboratory-scaled setup (Fig. 1). It was consisted of an oxone concentrator (M5C5 Nidek, USA), $O_3$ generator (L10 G Farady, India), bubble column reactor and a stone diffuser. Ozone generator was capable to produce up to 1000 mg/h ozone. Ozone output and flow rate was maintained at 500 mg/h and 2 LPM, respectively, to maintain ozone concentration at 4.2 mg/L. The reactor was made of 40 cm long Pyrex column having 6.0 cm internal diameter, attached with a stone diffuser at the bottom of column in order to get homogeneous distribution of ozone gas into the liquor. Ozone-resistant tubing (Teflon) was used for connections.

**Coloration method:** Bleached cotton fabric samples, weighing 5 g each, were dyed in sealed steel dyeing pots (300 mL capacity) and were housed in a laboratory-scale dyeing machine (AHIBA NUANCE, USA) employing a liquor ratio (L:R) of 10:1. The dyeing method used is shown in Fig. 2. At the completion of dyeing step, dyed samples were taken out of the machine, rinsed twice in warm and hot water and finally dried in the dryer using hot air. Afterwards, the quality of dyed samples was evaluated in terms of washing (ISO 105 C06) and wet and dry rubbings (ISO 105-X12).

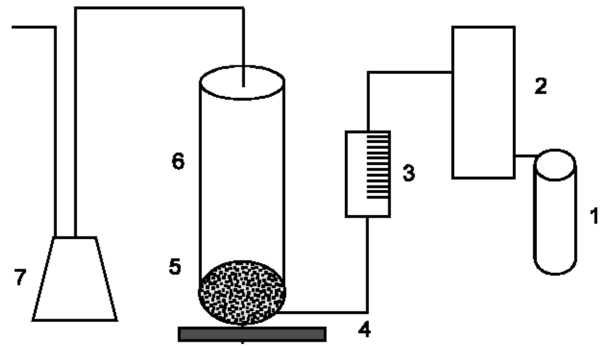


Fig. 1: Laboratory set-up for $O_3$ application. 1: Oxygen Concentrator, 2: Ozone Generator, 3: Flow meter, 4: Stirrer, 5: Stone diffuser, 6: Reactor and 7: Trap solution (KI)

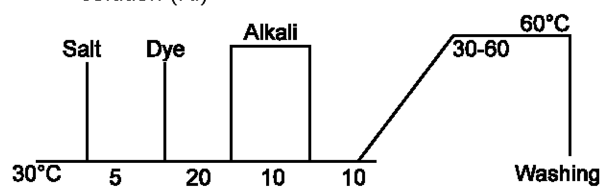


Fig. 2: Dyeing method used in the study

Table 1: Characteristics of bottling wastewater

| Constituents | Concentration | NEQS |
|---|---|---|
| BOD | 250 ppm | 80 ppm |
| COD | 376 ppm | 150 ppm |
| TSS | 245 ppm | 200 ppm |
| Dissolved oxygen | 3ppm | - |
| Turbidity | 20 NTU | - |
| pH | 10.2 | 6.0-9.0 |
| Conductivity | 845 µS/cm | - |
| Colour | light brown | - |
| Temperature | 32°C | 40°C |

BOD: Biological oxygen demand, COD: Chemical oxygen demand, TSS: Total suspended solids

## RESULTS AND DISCUSSION

**Bottling wastewater analysis:** Wastewater generated during the course of bottle washing and rinsing at a beverage factory located in Raiwind, Pakistan was collected and subjected to the laboratory analysis. The physical and chemical properties of wastewater sample along with National Environmental Quality Standards (NEQS) were displayed in Table 1. The results showed that BOD values (250 ppm) found in bottling wastewater were about 3 times higher than those allowed (80 ppm) by NEQS. COD values (376 ppm) of wastewater also exceeded the allowable limits (150 ppm) set by NEQS. The pH was also found on alkaline side (10.2) due the fact that caustic soda (NaOH) is used during the final washing of beverage bottling (Camperos *et al*., 2004).

**Decolorization and reduction of COD:** Table 2 shows the colour removal efficiency of ozone for composite wastewater sample comprised of bottling washing and rinsing drains. The results indicated that ozone oxidation was extremely effective for decolorization of bottling wastewater. In the first 5 min of ozonation, 71% colour removal efficiency was achieved. When ozone treatment was continued to 10, 15 and 20 min it yielded 78, 82 and 98% reduction of colour, respectively. The results also

Table 2: Process conditions and efficiency of $O_3$ application

| Ozonation period (min.) | Ozone production (g/h) | Ozone flow (LPM) | Ozone dose (mg/min) | Ozone con. (mg/L) | COD (ppm) | Conductivity (µS/cm) | Turbidity (NTU) | pH | Colour removal (%) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.50 | 2.0 | 8.33 | 4.2 | 376 | 845 | 20 | 10.2 | - |
| 5 | 0.50 | 2.0 | 8.33 | 4.2 | 301 | 740 | 18 | 10.0 | 71 |
| 10 | 0.50 | 2.0 | 8.33 | 4.2 | 280 | 599 | 12 | 9.7 | 78 |
| 15 | 0.50 | 2.0 | 8.33 | 4.2 | 147 | 412 | 11 | 9.2 | 82 |
| 20 | 0.50 | 2.0 | 8.33 | 4.2 | 64 | 210 | 9 | 8.9 | 98 |

Table 3: Colour difference values of standard and samples dyed in ozone treated wastewater

| | Colour difference values | | | | | |
|---|---|---|---|---|---|---|
| Dyes | ΔL* | Δa* | Δb* | Δc* | Δh* | ΔE* |
| Drimarene Yellow CL-2R | -1.2 | 0.25 | -0.10 | -0.27 | 0.80 | 0.97 |
| Sumifix Supra Brilliant Red 2BF | -0.97 | 0.36 | 0.29 | -0.91 | -0.84 | 1.22 |
| Procion Blue HEXL | -1.47 | 0.24 | -0.67 | -1.97 | -0.29 | 1.75 |

Table 4: Wash fastness properties of reference and samples dyed in ozone treated wastewater

| | Rubbing fastness | | Multi-fibre staining | | | |
|---|---|---|---|---|---|---|
| Dyes | Dry | Wet | Cotton | Nylon | Polyester | Shade change |
| Reference | 5 | 5 | 5 | 5 | 5 | - |
| Drimarene yellow CL-2R | 5 | 5 | 4.5 | 5 | 5 | 4.5 |
| Sumifix supra brilliant red 2BF | 5 | 4.5 | 4.5 | 5 | 5 | 4.0 |
| Procion blue HEXL | 5 | 4.5 | 5 | 5 | 5 | 4.0 |

showed that significant reduction of COD was observed when ozone treatment was given to wastewater sample. The initial COD value of 376 ppm was reduced to 64 ppm in 20 min of ozone exposure using flow rate and ozone dose of 2 L/min and 8.33 mg/min, respectively. Conductivity and turbidity values were also found to be decreasing with increasing ozonation time. In all cases, it was also noticed that pH values of wastewater under investigation decreased (10.2 to 8.9) during ozone treatment. Other researchers had reported similar results and attributed this phenomenon to the formation of acidic by-products that cause a decrease in pH (Shu and Huang, 1995; Soares *et al*., 2006). A change in conductivity was also observed, which was due to the degradation of colorants in wastewater (Khare *et al*., 2007).

**Evaluation of colour properties:** Table 3 summarizes colour difference values i.e., ΔL*, Δc*, Δh* and ΔE* between standard fabric (dyed in fresh water) and samples (dyed in ozone treated bottling washing wastewater). Overall results showed that total colour difference (ΔE*) in all three dyeing was found to be nearer to 1.0, which is considered a commercially acceptable tolerance level. The results (ΔE* = 0.97) of Drimarene Yellow CL-2R dyeing showed that final shade of the fabric dyed using treated bottling wastewater was comparable to that of standard sample. In case of Sumifix Supra Brilliant Red 2BF, considerable colour differences in lightness (ΔL* = -0.97), chroma (Δc* = -0.91), hue (Δh* = -0.84) and total difference (ΔE* = 1.22) showed somewhat different shade but closer to commercial acceptance level (ΔE*<1.0). In the dyeing of Procion Blue HEXL dye, comparable trend was observed and lower colour difference values of ΔL*, Δc*, Δh* and ΔE* suggested no apparent colour difference between reference and sample dyed in treated bottling wastewater.

**Evaluation of colour fastness properties:** Table 4 shows a comparison of fastness properties of dyed samples. The overall results revealed that fabric samples dyed in ozone treated bottling wastewater possessed comparable fastness ratings compared to those of standard dyed samples. The colour fastness results with regard to Drimarene Yellow CL-2R dye showed good results in the range of 4.5 to 5.0, which are considered accepted in the industry. For Sumifix Supra Brilliant Red 2BF and Procion Blue HEXL dyes, all fastness results i.e., dry and wet crocking, staining to cotton, nylon and polyester and change of shade were found to be similar to those of standard dyed samples.

**Conclusion:** The present study investigated an alternative method of dyeing cotton wherein ozone treated wastewater from a beverage company was used instead of using fresh water. Besides reducing turbidity, pH, conductivity and chemical oxygen demand (COD), ozone treatment was found to be capable of decolorizing wastewater up to 98% in 20 min of ozone exposure. Several cotton dyeings using ozone treated wastewater were carried out and commercially acceptable results in terms of wash fastness, rubbing fastness and colour difference properties were attained. This study concluded that ozone oxidation is an effective method for the treatment of bottle washing and rinsing wastewater and its reuse in textile coloration process.

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