Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.16, 2015
www.iiste.org

Industrial Waste-water Characterisation and Image-Based Assessment of its Color Load

David N Githinji* Mirembe Jacquirine
Department of Manufacturing, Industrial & Textile Engineering
Moi University, P.O Box 3900-30100, Eldoret, Kenya

Abstract
The characteristics of waste-water discharged from a reactive dyeing machine are examined and a simple method of quantifying its color load proposed. The discharged waste-water is typified by a pH value of 10.2, a turbidity value of 230 NTU, a color load of 290 mg/L and total suspended solids of about 970 mg/L. Application of digital image correlation to assess the color load in waste-water is explored through the use of Image Correlator plugin installed in the ImageJ software. The pixel scatter plot from the image correlation exhibit a characteristic spread with increasing concentration of dye solution thus demonstrating its applicability for waste-water color load assessment. The correlation coefficient derived from the image measurement, correlates almost linearly with the dye concentration in water and can thus be used for assessing the efficacy of color removal from the waste-water. With proper calibration, the resultant correlation curve can be applied in the quantification of the colour load in waste-water.
Keywords: Digital Image Correlation, Waste-water, ImageJ, Color Load, Image Correlator, pixel scatter plot

Introduction

Textile wet processes are among the most environmentally unfriendly industrial processes, because they produce colored waste-water that are heavily polluted with dyes, textile auxiliaries and chemicals. These processes utilize large amounts of water with processing of 1 kilogram of textile requiring about 200 liters of water (Ghaly et al. 2014). Consequently, large quantities of waste-water are generated which contains large amount of suspended solids, dissolved organic matters, dyes and heavy metal traces, which are capable of harming the environment upon discharge into sewer or municipal water (Riera-Torres 2010).

Dyeing process is a leading pollutant as it consumes large amounts of water and chemicals. Currently, over 10,000 different types of dyes and pigments are produced annually weighing about 7×10^5 tons (Jin et al. 2007; Riera-Torres 2010; Vaidya 1982) of which more than 280,000 tons are estimated to be discharged into waste-water (Vaidya 1982). Presently, the high demand for cellulosic fabric have led to an increase in the consumption of reactive dyes owing to their bright colors and excellent bonding to cellulose fiber (El Haddad 2014). The world use of reactive dyes increased from 60,000 tons in 1988 to 178,000 tons in 2004 (Phillips 1996). However, during dyeing, reactive dyes are hydrolyzed in water in presence of alkali and as such only 50-80% of these dyes are fixed on the fabric and rest is discharged into waste-water (Cooper 1995; Steankenrichter 1992). Reactive dyes are known to form aromatic amines which are highly carcinogenic and can cause dysfunctioning of some human organs like Kidney (Arslan 1999; Kadirvelu 2003).

Treatment of textile effluents using physico-chemical, chemical, biological processes, and advanced treatment techniques have been studied previously (Ghaly et al. 2014; Verma 2012). These advanced techniques are highly effective on color and most pollutants removal, but are expensive. Coagulation-flocculation with ferrous sulfate, ferric chloride, ferric chloro-sulfate, magnesium chloride, and polyaluminium is widely used because it can remove colour, reduce the total loads of suspensions, economical, easy to operate (Khouni et al. 2011) and above all, de-colorization takes place by removal of dye molecule from the textile waste-water, and not by the partial decomposition of dyes (Golob 2005).

The current study is concerned with the characterisation of waste-water from a reactive dye section of a textile mill. The effluent parameters such as pH, total suspended solids, turbidity and color are characterized and compared with the published values. The use of image correlation technique to quantitatively characterize colored waste-water has not been explored extensively in the literature. The current work aims at contributing in this area through the use of Image Correlator (IC) plugin installed in the ImageJ software (Abramoff et al. 2004). The plugin correlate two images and generate a scatter plot based on their corresponding pixel values. From this plot, statistics such as correlation coefficient and regression line gradient are determined. A typical IC setup consists of a digital camera, light source and image analysis software. For accurate IC assessment, the camera settings and lighting conditions are maintained constant during the measurement. In the current study, the application of IC to assess the efficacy of color removal from waste-water is demonstrated through the use of correlation coefficient between images of waste-water containing varied concentration of dyes.

Material and Methods

Material

Waste-water was collected from a textile mill at a point of discharge from a dyeing machine applying reactive blue dyes. The collected samples were kept in 100 ml containers and their characterisation conducted within 5 hour of collection. Stock solution containing 1%, 2% and 3% reactive black dyes were prepared by dissolving the dyes in distilled water.

Methods

The turbidity characterization of the collected waste-water was carried out in accordance with ASTM D7315-12 standard (ASTM 2012) while alkalinity was measured using a digital pH meter. The total suspended solids in the waste-water were determined using the dry weight method as specified in (APHA 2005) while the waste-water color was measured using a photometer.

The assessment of efficacy of dye removal from waste-water was evaluated by analyzing digital images of colored water using ImageJ software. A digital camera (Nikon D3100 14.2 MP with 18-55mm VR Lens) was used to capture images of colored water with varying concentrations (0%, 1%, 2% and 3%) of reactive black dyes. The experimental set-up was as shown in Fig. 1 and consisted of a clear glass box for holding water, a light source placed beneath the glass box and a digital camera. A white paper with black circular patterns was placed between the light source and the glass box to enhance contrast in the captured RGB images. The IC plugin installed in ImageJ software was used to correlate an image of water with 0% dye concentration (source-image) with an image captured at higher dye concentrations. The dye concentration in the water was quantified using the correlation coefficient parameter with values ranging from 0 (no correlation) to 1 (perfect correlation). To facilitate comparative assessment, the camera settings and lighting conditions were kept constant during the image capturing.

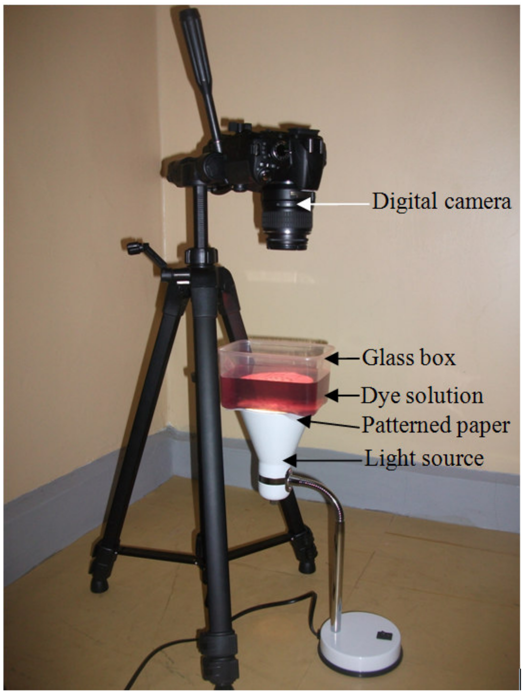

Fig. 1. Digital image capturing system consisting of: a camera, a lighting system, a glass box and a dye solution.

Results and Discussion

Characterization of Waste-water

Table 1 gives the average values of the waste-water total suspend solids, color load, pH and turbidity. The pH value of the collected waste-water was highly alkaline implying that large amount of alkali remained unused during the dyeing process. Similar results have been reported previously (Hussain 2004)] during characterization of effluents from six different industries. However, the result is beyond the set standard (pH 9) by the Environmental Protection Agency (EPA 1997). According to (EPA 1997), strongly acidic or alkaline waste-water may seriously affect the collection system as well as the treatment process. To improve on the process efficiency, neutralization prior to entry to the collection system may be required through the use of common acids such as sulphuric and hydrochloric acid. According to studies by (Fatehah 2013), there exists a relationship between turbidity and pH. The studies reveal that at high values of pH, there is a significant reduction in the level of turbidity removed from the waste water. But at low pH values, reduction is insignificant. From this, it can be concluded that during waste-water treatment, there is need to adjust the pH to the required value for effective results.

Table 1: Characteristics of waste-water collected from a dyeing machine applying reactive dyes

Property	Average value	Unit
pH	10.2	-
Turbidity	230	NTU
Total suspended solids	970	Mg/L
Color	290	Mg/L

The total suspended solids in the waste-water were about 970 mg/L, which is, consistent with the results of (Eswaramoorthi 2008). However, the result is beyond the recommended value of 87.5 mg/L set by the EPA. Suspended solids play an important role in characterizing the treatability and hence the degree of contaminant removal of a waste-water. In addition, the size of suspended solids has considerable impact on separation processes such as sedimentation, flocculation and filtration (Alon 1994) and thus should be removed efficiently.

The waste-water color was about 290 mg/L. This value is in the range with results obtained by (Eswaramoorthi 2008) in the study on waste-water treatment using advanced techniques. To the contrary, higher values have been reported elsewhere (Reife and Freeman 1996) and this may be attributed to the differences in characterization methods and the nature of waste-water analyzed. Color even in its lowest level posses threats to the environment (Malik et al. 2014) and thus need to be removed from the waste-water. Addition of coagulating chemicals: ferrous chloride, ferrous sulphate, magnesium chloride, lime and polyaluminium chloride can improve on the primary treatment of color removal. Coagulation process neutralizes the charge present on the particles surface with help of coagulants while flocculation makes them come together to form flocs by slow agitation that are later removed. Optimum doses of coagulants at suitable pH give maximum color removal with less sludge and settling of flocs (Amokrane 1997). Quantification of the color load in waste-water may be an effective method of assessing color removal efficiency for disposal purposes.

Image-based Analysis of colored water

Fig. 2 shows sequential macro-images of water solutions with 0%, 1%, 2% and 3% dye concentration. It is clear that the image contrast reduces with the increasing dye concentration. This may be attributed to the progressive reduction in water transparency owing to increasing concentration of dye molecules.

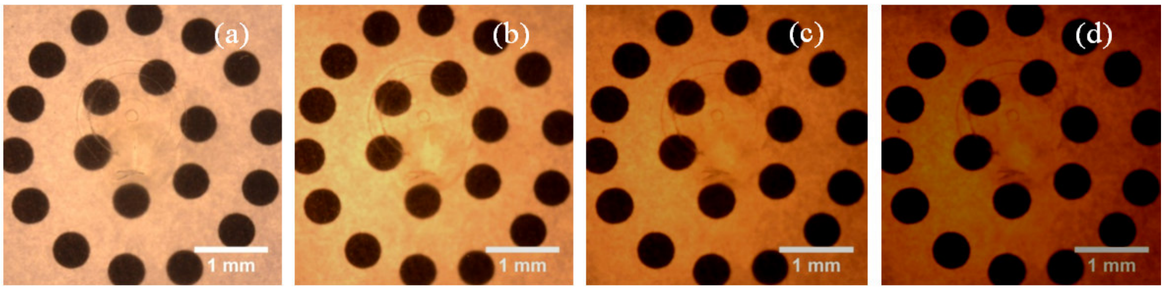

Fig. 2. Macrographs of water solutions with: (a) 0%, (b) 1%, (c) 2% and (d) 3% dye concentrations.

Fig. 3 shows the pixel scatter plots obtained by correlating an image of a solution with 0% dye concentration to an image of a solution with 0%, 1%, 2% and 3% dye concentration. Apparently, as the dye concentration increases the corresponding pixels in the two images correlated become distinct as evidence by the spread in the scatter plot. This phenomenon thus demonstrates the sensitivity of pixel's gray value to dye concentration thus the applicability of image correlation method for waste-water color load assessment.

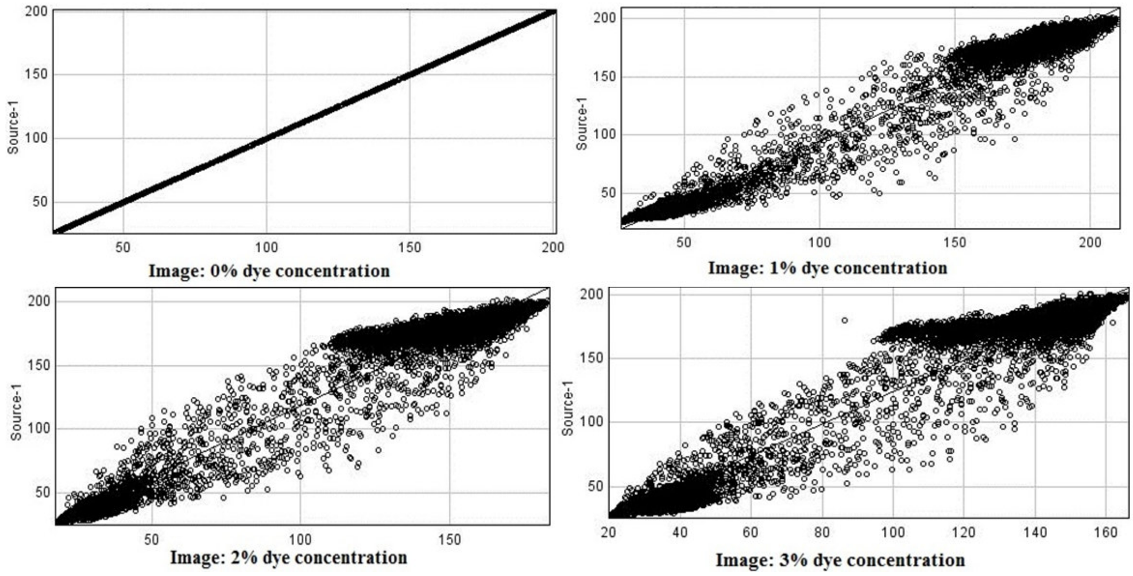

Fig. 3. Pixel scatter plots obtained by correlating a reference image of a solution with 0% dye concentration to images of solutions with (a) 0%, (b) 1%, (c) 2%, and (d) 3% dye solution.

Fig. 4 shows variation of correlation coefficient with the dye solution concentration. The reduction in correlation coefficient with increasing dye solution concentration may be attributed to reduction in image clarity owing to increased concentration of dye molecules which leads to a reduction in water transparency. Consequently, similar pixels of the correlated images end up having different gray values as the amount of light reaching them is different. Since other factors, e.g. variation of lighting conditions, may affect the gray values associated with each pixel, it is important to maintain imaging capturing and processing constant during this assessment. Apparently, the correlation coefficient parameter can be used to assess the concentration of dye molecules in waste-water if proper calibration is carried out for the specific dyes in the waste-water.

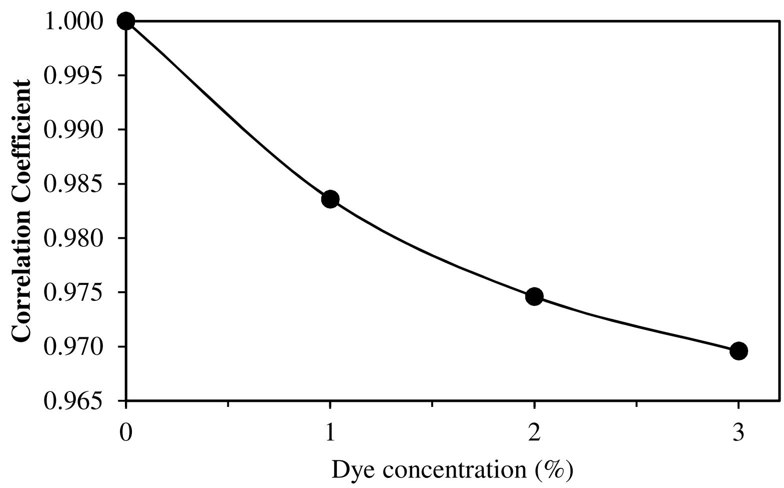

Fig. 4. Correlation coefficient versus dye concentration curve: digital images were captured under similar conditions.

Conclusion

In the current study, the waste-water from a textile mill dyeing section was characterized and a novel image-based method for quantifying color load in waste-water proposed. From the study, the following conclusions are drawn:

- The waste-water discharged from a dyeing machine applying reactive dyes is characterized by a pH value of about 10.2, a turbidity value of about 230 NTU, a color load of about 290 mg/L and total suspended solids of about 970 mg/L. The waste-water traits thus necessitate proper treatment prior to discharge into sewers to avoid negative environmental effects.
- Digital image correlation method is applicable for assessing color load in stock solution containing reactive black dyes. The pixel scatter plot from the image correlation exhibit a characteristic spread with increasing concentration of dye solution thus demonstrating its applicability for waste-water color load assessment.

- Digital image correlation using correlation coefficient parameter gives a quantitative assessment of color load in water. The correlation coefficient derived from the image measurement, correlates almost linearly with the reactive black dye concentration in water and can thus be used for assessing the efficacy of color removal from the waste-water.

Acknowledgement
The authors would like to thank MU_VLIR-OUS for partially funding this research.

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