**International Journal of Applied Research on Textile**
URL: http://atctex.org/ijartex/current-issue.html
SPECIAL ISSUE CIRAT-8, pp 23-30, January 2019

# Dyeing of polyester woven fabric using a fluorescent organic dye with conventional and irradiation microwave technique

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**Abstract**

We present an investigation and analysis results of a fluorescent disperse dye used for dyeing polyester fabrics to high-visibility colour. In this study, 100% polyester woven fabric was dyed with irradiation microwave technique. The effect of dyeing parameters such as Temperature, duration, dye concentration and dispersing agent were investigated. A comparative study was realized with the conventional high temperature dyeing technique to highlight the advantages of the non conventional dyeing technique. The quality of the obtained dyed samples was evaluated thanks to spectral reflectance measurements and washing and light fastness tests.

**Keywords**

Fluorescent dye; microwave technique; polyester fabric; reflectance; washing and light fastness tests.

## 1. INTRODUCTION

The applications of fluorescent textiles are associated with their ability to attract attention, because of the remarkable vivid brilliance of the colors which results from the extra glow of emitted fluorescent light (Farzana, 2015). Fluorescent dyes are considered to be those dyes which absorb and emit radiation in the visible spectral range light and causes fluorescence. The absorption and emission spectra of a fluorescent dye often approximate to mirror images of one another (Christie, 2011). One of the major application fields where fluorescent dyes have long been used for the dyeing of textiles. The use of fluorescent dyes causes a significant increase in colour brightness, saturation and visibility, which makes the dyed textiles more easily perceptible. This intensified perceptibility of textiles dyed with fluorescent dyes is an advantage in manufacturing sports clothes and apparel for fire fighters and policemen (Liu et al., 2013). In addition, the continuous development of automobile traffic and safety regulations connected to it has resulted in an increasing demand for high-visibility textiles (Stolarski, 2009*)*. Polyester is usually dyed with disperse dyes at high temperatures and high pressures. In order to improve the dyeing properties, many researchers have tried different methods to solve these problems including microwave irradiation (Xu et al., 2002). Microwave irradiation is a well-known heating and drying materials and is used in many private households and industrial applications. It offers a number of advantages over conventional dyeing technique, such as heating (circumventing the decomposition of molecules close to the walls of the reaction vessel), instantaneous and rapid heating (resulting in a uniform heating of the reaction liquor), and highly specific heating (with the material selectivity emerging from the wavelength of microwave irradiation that intrinsically excites dipolar oscillation and induces ionic conduction (Haggag et al., 2015).The textile industry has extensively investigated uses of microwave energy for heating, drying, dye fixing, and finishing ( Bhat et al., 2012). Therefore, this study aimed to investigate the effect of certain parameters of the microwave irradiation dyeing process on the quality of dyeing and to compare the

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results with those obtained in the case of a conventional HT dyeing, in terms of colour yield and colour fastness. The paper must be written in English. It shall contain and be structured in the following way: abstract, introduction, material and methods, results and discussions, conclusion and references.

## 2. MATERIAL AND METHODS

### 2.1. Materials

The size of the fabric samples for the dyeing process using a microwave system had to be adapted to the volume of the vessel used in the microwave. The used vessels have a maximum capacity of 80 mL of which, however, only a 50 mL volume can be processed by the microwave. Therefore, the weight of each fabric sample should be around 4 g. As the vessel has a height of 7 cm, the fabric samples should have a defined width of 6 cm. In this work, two dispersing agent was used; the first one is Opticid PB liquid which is miscible in water with a pH in the dye bath around 4 to 4.5.This product maintains a constant pH of the dye bath in a weakly acid region with its buffering action and additionally avoids agglomeration of the dye particles as it also works as a dispersing agent. The second dispersing agent is CHT-Dispergator XHT-S which is soluble in water and has a pH value 5-6 in dye bath solution.

### 2.2. Methods

#### 2.2.1. Conventional method

Samples of PET fabrics were dyed using fluorescent disperse dye 1.5%, two differents dispersing agents 2g/L and 4 g/L, with bath report 1:10. The total process duration of the conventional HT-dyeing process using a Polycolor Beaker Dyer (laboratory dyeing machine) from Mathis AG is 1 hour and 50 minutes. After the dyeing process, the fabric samples are hand washed with soft water and air-dried. Finally a washing process is performed.

#### 2.2.2. Microwave irradiation technique

Samples of PET fabrics were dyed using a fluorescent disperse dye 0.5%, 1.5%, 2 g/L for two dispersing agents, with a liquor-to-goods ratio of 10:1, using a Focused Microwave Synthesis System, Model Discover from manufacturer CEM Corporation, with set process parameters (table 1). After dyeing a washing process is performed.

Table 1: Set process parameters for the microwave dyeing application

| | |
|---|---|
| Microwave power | 250 watts |
| Temperature control point | 80 °C, 100 °C, 130 °C |
| Run time | 10 minutes |
| Hold time | 5 minutes, 15 minutes |

After starting the microwave dyeing process, first the machine heats up to the set temperature within a run time of maximum 10 minutes. When the set process temperature is reached the system automatically switches to hold time, during which the fabric gets dyed for a defined duration of either 5 or 15 minutes, operating at a maximum power of 250 watts and at oscillating pressure. During hold time the set process parameters are being kept constant. The stirrer is rotating at a low speed.

Afterwards, the cooling is set for maximum 10 minutes. The process pressure is being varied automatically by the system, depending on the actual process temperature.

The following graph shows an example of the relation of process temperature and pressure as function of process duration for a set temperature of 140 °C and 15 minutes hold time.

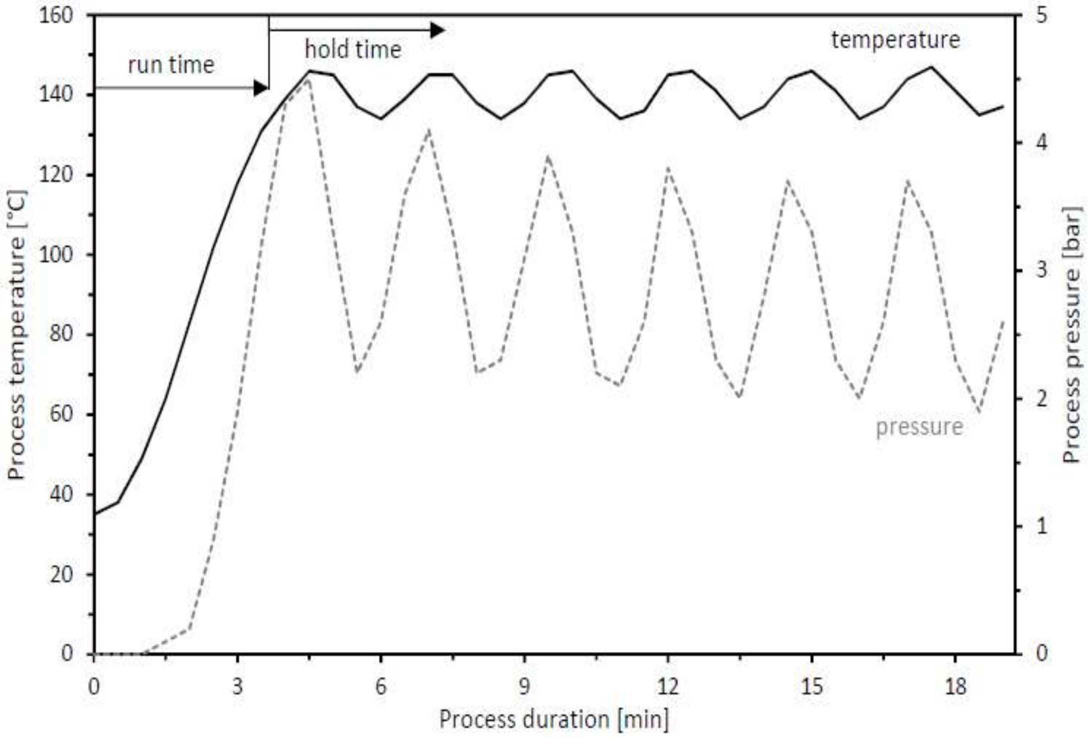



Figure 1 : Relation of process temperature and process pressure as function of process duration for a set temperature of 140 °C and a hold time of 15 minutes.

### 2.2.3. Spectral Measurement Procedure

Reflectance values and curves of the dyed fabrics were determined in the visible portion of the spectrum (400-700 nm) using a reflectance Spectrophotometer UV-2600 from Shimadzu.

### 2.2.4. Evaluation of colour fastness

Different colour fastness properties of the dyed samples were assessed according to the following methods: Colour fastness to wash (ISO 105 C06) and Colour fastness to light (ISO B02-014).

## 3. RESULTS AND DISCUSSION

### 3.1. Colour Yield Evaluation

The effect of some parameters on the colour yield of an irradiation microwave dyeing was studied.

### 3.1.1. Effect of temperature and time irradiation

The effect of temperature and time irradiation on the reflectance of the dyed polyester fabrics is presented in figure 2. Opticid PB liquid was used as dispersing agent with a concentration of 2 g/L at pH=4.5.

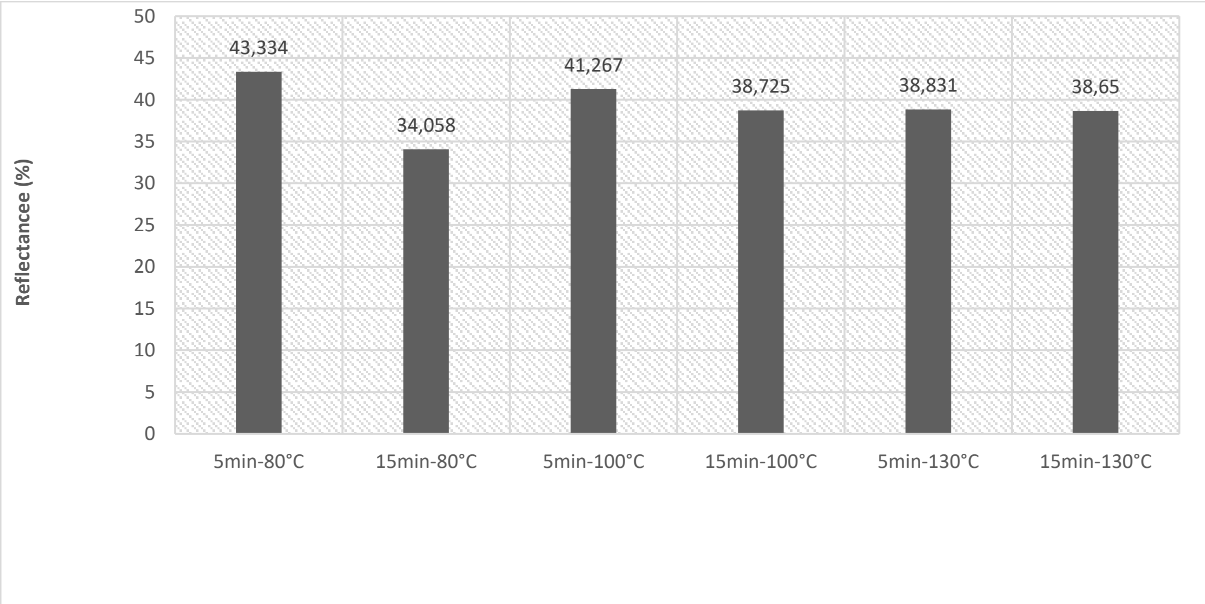



Figure 2: Effect of temperature and time irradiation on sample reflectance

It can be seen that at a temperature of 130°C the irradiation time has no effect on the reflectance of the dyed samples.

With regard to colour intensity a process temperature of 100 °C and a duration of 15 min is enough to reach a similar result in terms of colour intensity to the one obtained with a process temperature of 130 °C and a duration of 5 min. This shows that there is a need of a certain temperature level, lying above the glass transition temperature of polyester, in order to ensure an adequate mobility of the polymer chains, allowing the dye to diffuse into the fibre, and thus, achieving a good dyeing result with regard to colour intensity.

### 3.1.2. Effect of dye concentration

The effect of dye concentration on the reflectance of dyed polyester fabrics is shown in figure 3. Dyeing is realized at 80, 100 and 130 °C and during 5 minutes

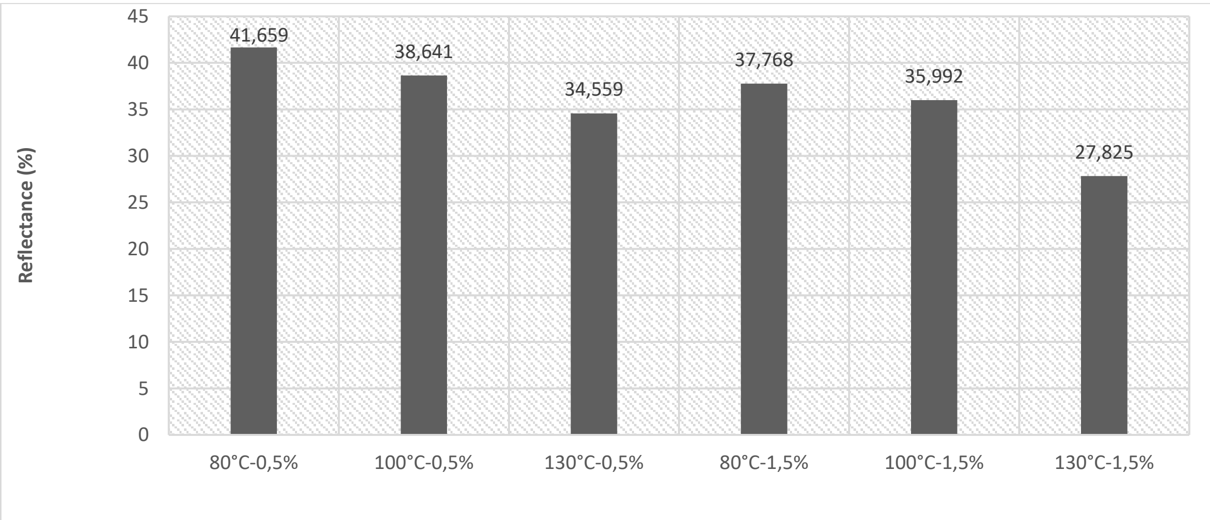



Figure 3: Effect of dye concentration on samples reflectance

Overall, the reflectance spectra show that in the case of non-conventional dyeing process, an increase in the intensity of the color was observed with the increase of the temperature of the process and the concentration of the fluorescent dye. Indeed, an increase of the temperature and an increase of the holding time (treatment time) increase the intensity of the color, because a higher temperature leads to an easier and faster penetration of the dye particles in the fiber up to achieve a dye balance.

#### 3.1.3. Comparaison between conventional dyeing and irradiation microwave technique

##### 3.1.3.1. Morphological characterization

Polyester surface morphology was examined by scanning electron microscopy (SEM) in order to check the presence of the fluorescent product.

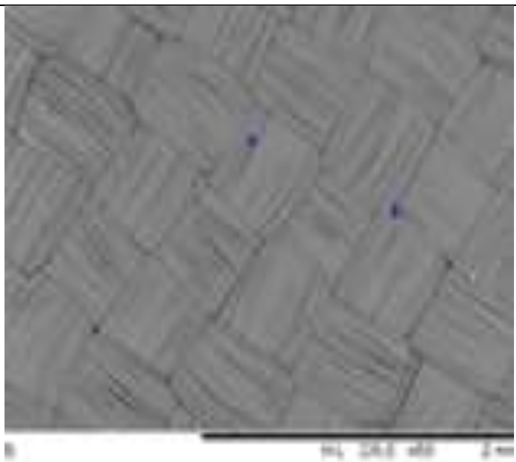
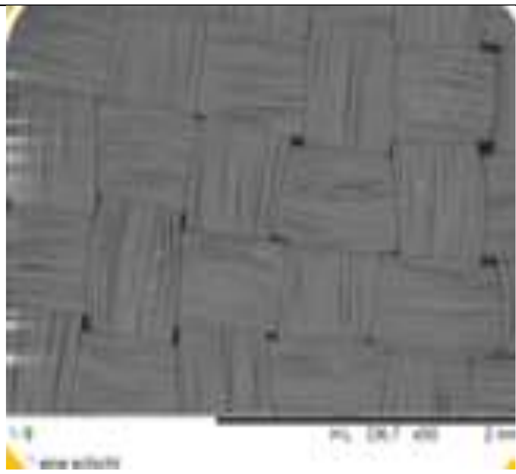
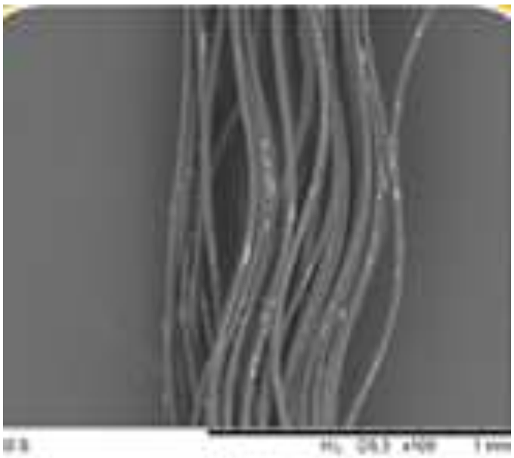
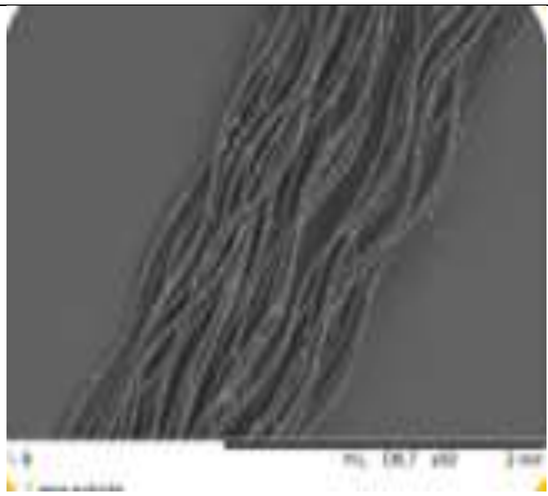
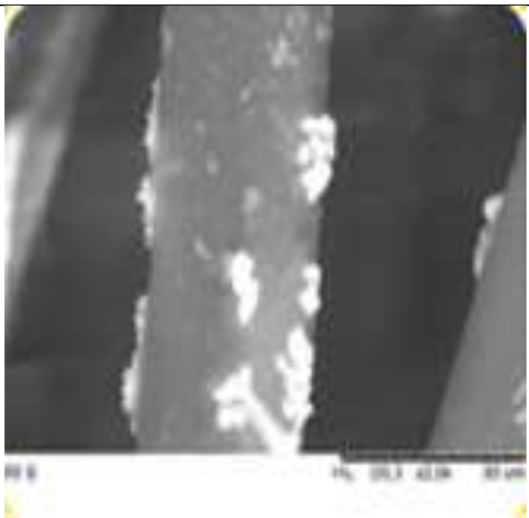
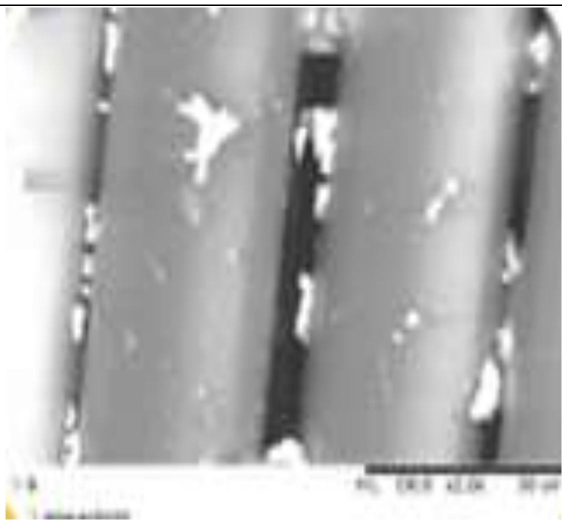
| | Microwave dyeing technique | Conventional dyeing technique |
|---|---|---|
| PET fabric x50 |  |  |
| PET yarn x100 |  |  |
| PET yarn X2000 |  |  |

Figure 4: SEM images of PET samples dyed with microwave and conventional technique

#### 3.1.3.2. Reflectance value

The dyeing is performed with a microwave-assisted system at different process temperatures (80 °C, 100 °C and 130 °C) for a process time of 5 minutes with concentration of fluorescent dye 1.5%. The reflectance curves obtained are compared with the one obtained for a sample dyed in a conventional way with the same dye.

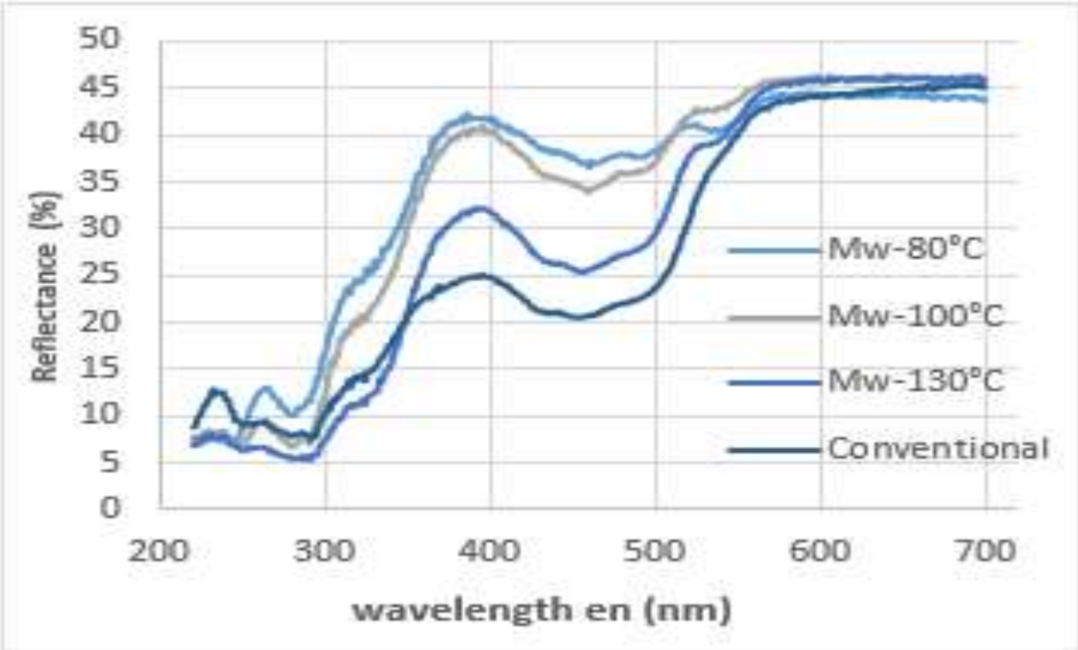



Figure 5: Reflectance curves of treated samples with conventional and microwave technique

The reflectance curves show that the sample treated by the microwave has a colour intensity lower than that treated by the conventional technique. Using the microwave and at a temperature of 130 ° C during 5 minutes, we can approach the dye reflectance obtained with a conventional dyeing process, from point of view, colour intensity and dyeing uniformity.

#### 3.1.3.3. Fluorescence effect

Despite the difference in reflectance of the treated samples by both dyeing methods and regarding the samples dyed with the fluorescent dye using a microwave-assisted process, it is to be concluded that high temperatures lead to a much better fluorescent effect, compared to that achieved with the conventional dyeing process.

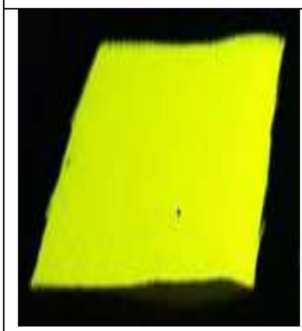
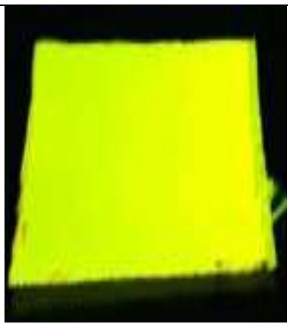
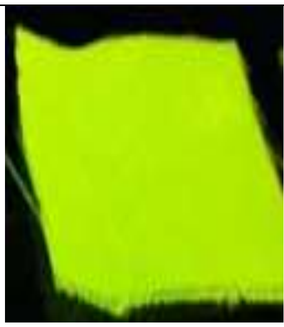
| Conventional dyeing | Microwave 130°C | Microwave 100°C | Microwave 80°C |
|---|---|---|---|
|  |  |  |  |
| *Exposure under UV lamp* | | | |

Figure 6: Dyeing results of polyester dyed with the fluorescence dye showing the fluorescent effect.

Using microwave dyeing technique, it is possible to obtain a good fluorescence results even at a lower temperature than that used for the conventional technique.

### 3.2. Colour fasteness evaluation

#### 3.2.1. Washing Fastness

Colour fastness was tested according to standard methods; the obtained results are given in Table 2.

Table 2 : Washing fastness evaluation

| Technique | Color change | Staining | | | | | |
|---|---|---|---|---|---|---|---|
| | | Wool | Acrylic | Polyester | Polyamide 6 | Cotton | Acetate |
| Conventional | 5 | 4 | 4/5 | 5 | 5 | 2/3 | 5 |
| Mw-80°C | 3/4 | 4 | 4/5 | 5 | 5 | 3/4 | 4/5 |
| Mw-100°C | 3/4 | 3/4 | 4/5 | 5 | 4/5 | 3 | 5 |
| Mw-130°C | 4 | 3 | 4/5 | 5 | 5 | 3 | 3/4 |

As shown in Table 2, the results indicate good to excellent fastness properties of the dyed samples when using conventional heating and fair to good when using microwave technique.

At a temperature of 130°C using microwave assisted dyeing it is possible to obtain a washing fastness similar to that obtained with the conventional technique.

#### 3.2.2. Light Fastness

Table 3: Light fastness evaluation

| Light fastness | Colour change | Fluorescence Duration |
|---|---|---|
| Conventional | 4 | more than 24 hours |
| Microwave 80°C | 3 | more than 24 hours |
| Microwave 100°C | 3 | more than 24 hours |
| Microwave 130°C | 4 | more than 24 hours |

We can see from the table above that microwave dyeing can give us encouraging results similar to those obtained with conventional polyester dyeing.

With regard to the fluorescence duration, all samples treated with the fluorescent dye have a good light fastness exceeding 24 hours.

## 4. CONCLUSION

100% polyester fabric was dyed using fluorescent organic dye by conventional and microwave dyeing techniques. The conventional HT dyed fabric samples have uniform dye penetration into the polyester fibre. However, samples dyed by recommended recipe using microwave technique have few undyed fibres in the center of the yarn of the fabric. Moreover, conventional HT dyeing gives very good washing fastness results than microwave dyeing technique. Overall, the experiments show that dyeing with a microwave-assisted finishing process can be realised in less than 20 % or even 10 % of the time of a conventional process would need. Additionally, microwave technology enables textile functionalisation at lower process temperatures. Moreover, with a microwave assisted finishing process, it is possible to achieve much higher colour intensities similar to those obtained by the conventional dyeing technique while increasing the fluorescent dye concentration in the dye bath or the time of irradiation (hold time).

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