Evaluation of the Dyes used in Conservation and Restoration of Archaeological Textiles

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Abstract: *Dyes and dyeing processes are very important subjects for textile conservators. The textile conservation field has been traditionally divided into those who use synthetic dyes and those who use natural dyes. This study aims to give the outline of this conflict and giving recommendations for textile conservators on which type of dyes can be used safely in textile conservation. In this study silk textile samples were dyed with selected natural and synthetic dyes. The dyed silk textile samples were artificially aged by light for various periods. The changes in the colour of dyed silk textile samples after ageing by light were observed visually and using an Optimacth 3100 colour Spectrophotometer. This study confirms that both natural and synthetic dyes are important in textile conservation field. This study concludes that if it is possible to achieve the required colour shade using natural dyes, it is recommended to use natural dyes. But if it is not possible to achieve the required colour shade using natural dyes, then synthetic dyes are recommended.*

1. Introduction

Dyes are coloured compounds which can bond to fibres and colour them (Tímár-Balázsy and Eastop, 1998). Dyes and dyeing processes are very important tasks for textile conservation purposes. Dyes are commonly used for dyeing fabrics that can be used in various processes of textile conservation (Abdel-Kareem, 2002, Kajitani, 1987). These dyed fabrics can be used in lining and supporting weakened textile, rugs, tapestries and carpets (Kajitani, 1987, Marko, 1987, Zidan, 1987, Flury-Lemberg, 1988, Ennes, 1991, Hutchison, 1991, Landi, 1998, Abdel-Kareem, 2004). Dyed fabrics can be used in compensation and for completing lost areas in tapestries and carpets (Green and Swetzoff, 1991, Mailand, 1991, Merritt, 1991, Perkins, et al, 1991). The aesthetic conservation processes of textiles depend on the success in selecting the suitable colour for the lining fabric, to give a desirable appearance during the display of the textile object (Flury-Lemberg, 1988). Also dyes are used for dyeing the threads used for fixing any damage in textile objects or fixing the object with lining fabrics (Flury-Lemberg, 1988, Landi, 1998, Nola, et al, 2002, Abdel-Kareem, 2002). Dyed threads can be used in compensation and completion of any lost areas in tapestry textiles and carpets (Green and Swetzoff, 1991, Mailand, 1991, Merritt, 1991, Perkins, et al, 1991, Abdel-Kareem, 2004). Dyes are used in the preparation of textile samples simulating an ancient one to be used as experimental samples and can be used in the evaluation of any new materials or methods suggested to be used in the conservation of textile objects (Abdel-Kareem and Morsy, 2004, Abdel-Kareem, 2006, Abdel-Kareem, and Al-Saad, 2007).

For preparing dyed textile samples to simulate historical ones it is not difficult to decide which dyes can be used because the selected dyes should be the same as the dye used on the original objects, which has been determined by analysis. But it is too difficult to decide which type of dyes should be used for dyeing the materials that will be used for conservation purposes (Abdel-Kareem, 2002). The success of conservation of a textile object

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depends on the success in the selection of dyes and dyeing processes that can give the right shade of colour for any materials which will be used in the conservation of a textile object. The aesthetic success is in achieving the suitable shade of colour for those materials which will give a desirable appearance for a textile object during its display. Also this dye should not be harmful to textile objects and their component materials at the time of application and in the long term effect. The textile conservation field has been traditionally divided into those who use synthetic dyes for textile conservation purposes and those who use natural dyes. For over a century these two groups have argued about their beliefs. Many conservators seem to have aligned themselves behind one of the two groups. One textile conservation group has suggested using natural dyes believing that natural dyes are more compatible with dyes present on museum textile objects because dyes in museum textile objects are often natural dyes (Zidan,, 1987). This group believes that natural dyes are safe and have no hazardous effect on conserved textile objects. They think that synthetic dyes are not compatible with conserved museum textile objects and can cause damage to these textile objects in the long term. Another textile conservation group has suggested using synthetic dyes believing that natural dyes do not have all the requirements that should characterise any dye suggested for textile conservation purposes (Flury-Lemberg, 1988, Landi, 1998, Farnsworth, 1997). They reported that a dye that was suggested for textile conservation purposes should have a high light fastness to remain undetected over a long period of time. A high degree of reproducibility is required. They think that natural dyes fade quickly because they do not have good fastness properties in light. They reported that it is impossible to obtain all the required colours and various shades of these colours by using natural dyes. This is because dyeing processes using natural dyes are very complicated. There are different recipes for dyeing with each one of the natural dyes, and these recipes vary from author to author (Robertson, 1974, Weigle, 1974, Zidan,, 1987, Dalby, 1989, Golikov, and Vishnevskaya, 1990, Wickens, 1990, Abdel-Kareem, and Al-Saad, 2007, Cardon, 2007). Also the concentration of the colouring component in each one of the natural dyes depends on the dye source and the age of the biological source (Zidan,, 1987).

The fading of dyestuffs by light radiation is one of the most important factors which influences the selection of materials used for textile conservation. Light fastness has been investigated widely and intensively in developing new dyestuffs. Most of the fading experiments were made under accelerated conditions with artificial light sources such as carbon arc lamp, xenon arc lamp and so on (Yoshizumi and Crews, 2003). However all testing was done to investigate light fastness characteristics of the dyed textiles in the sun. This study is designed to investigate the fading of dyes under museum condition (without UV radiation). This paper is the first one of a series of studies devoted to the investigation of natural and synthetic dyes which have been suggested for use in textile conservation. The current study will focus on the long term effect of light ageing on the colour values of dyed silk textile fabrics. Also this study aims to reconstruct simple, easy standard recipes for dyeing silk textile fabrics with dyes to be used for textile conservation purposes. These recipes will be a guide for conservators to reproduce the same colours on silk textile fabrics. From the results obtained in this study it will be possible to decide which of the selected dyes can be used safely for textile conservation purposes.

2. Experimental

2.1 Fabrics: Habutai Silk, light silk was used in this study.

2.2 Dyes: Both natural and synthetic dyes were used in this study. Natural dyes used in this study are Cochineal, Cutch, Henna, Indian Safflower, Indigo, Lac, Madder, Safflower, Saffron, Sumac and Turmeric. The selected natural dyes were commonly used in historical periods in Mediterranean countries (Robertson, 1974, Weigle, 1974, Goffer, 1980, Zidan, 1987, Dalby, 1989, Golikov, and Vishnevskaya, 1990, Wickens, 1990, Abdel-Kareem, and Al-Saad, 2007, Cardon, 2007). Synthetic dyes used in this study are acid dyes. Three primary colours of acid dyes, red, yellow and blue were used, which can be mixed in varying proportions to make every other colour. Also each two of these three acid dyes were mixed 1:1 to produce green, orange and violet colours. The mixed dyes were produced to investigate the effect of light ageing on the colours which contain two dyes too.

2.3 Mordant: Three mordant salts, commonly used in mordanting silk textile fabrics, were used in this study. The mordant salts used in this study are Potassium aluminium sulphate (Alum), Ferrous sulphate (Iron) and Copper sulphate (Copper).

2.4 Preparation for Dyeing: Some silks contain a considerable amount of sericin, a naturally occurring gum. Commercially, the sericin may be removed using Marseille soap or enzymes to give a soft feel to the silk. In this study each 100 g of a silk fabric was washed in a solution of 10-15 g of soap dissolved in distilled water at 95 ºC for 30 minutes (Cardon, 2007). Then the silk was washed in distilled water. The final rinse was done in de-ionised water.

2.5 Mordanting: Silk textile fabrics were mordant by each one of metal salts as described by Cardon, 2007. The mordant salt was added to bath of soft water. The bath water was heated to approximately 30 ºC. The clean wetted textile fabric was entered into the bath. The mordant bath was heated with the fabric gradually to boiling point. When the boiling point was reached, the heat was lowered and the bath simmered for about 1 hour at 95 ºC. The bath was allowed to cool for 1 hr, then the fabric was rinsed and hung up to dry for at least 24 hrs (Wickens, 1990).

2.6 Dyeing Process:

2.6.1 Natural dyes: The amount of liquor needed for the dye bath was calculated on the basis of the weight of the dry textile fabric, expressed as a ratio between the two, e.g. 50:1, meaning that 50ml of water is required for every gram of textile fabric. The necessary quantities of the dyes were weighed according to Abdel-Kareem, 2006. All dyes except indigo were used as follows. The exact weight of each one of the dyes used was added to the dye bath. The dye bath was left overnight. The dye bath was gently heated, and the clean wetted textile fabric was entered into the dye bath. The dye bath was heated with the fabric gradually to boiling point except for madder which was heated to 60 ºC. When the required point has been reached, the bath was simmered for about 1 hour. The bath was allowed to cool for 1 hr. After that the dyed fabric was washed in soapy water. After that the fabric was rinsed in distilled water and hung up to dry for at least 24 hrs.

2.6.2 Dyeing of samples with Indigo (Blue Colour): The natural indigo powder was ground with 10 ml water until a creamy, even consistency was obtained. 50 ml of warm water was added to a bottle and 1g of sodium hydroxide was slowly added with continual stirring until dissolved. 50 ml of warm water was also added to another bottle and gently slowly mixed with 1g of sodium dithionite. All were added, apart from small amounts of the sodium hydroxide solution and the sodium dithionite solution which were reserved. After

1 hour, it was tested by dipping in a glass rod according to Dalby (1989). After preparing the vat dye according to Abdel-Kareem (2006) the clean wetted fabric was entered into the vat dye. It was kept there and moved gently for 1 to 5 minutes. The fabric was taken out of the vat and had a faint yellow colour, which later turned blue in the air within a few minutes. After the dyed fabric had dried, it was washed in soapy water, rinsed very thoroughly, and dried.

2.6.3 Dyeing of samples with synthetic dyes: 1% of each dye was added to dye bath. Acetic acid was added to dye bath. The clean wetted silk textile samples were entered into the dye bath. Then the dye bath was heated with the fabric gradually to 80 ºC. When the required point has been reached, the bath was simmered for about 30 minutes. The bath was allowed to cool for 1 hr. After that the dyed fabric was washed in distilled water. Then the fabric was hung up to dry for at least 24 hrs.

2.7 Light Ageing: To produce stable colours the dyed silk textile fabrics should be aged by exposure to light. As Landi (1998) confirms that the most change in the colour occurs during the first exposure to light. Also to assess the lightfastness of selected tested dyes it is very important to expose them to artificial light ageing. For ageing by exposure to light, tests were carried according to international standard tests for colour fastness (ISO 105-B02:1994). Dyed silk samples were mounted on standard specimen holders and were exposed to light irradiation for 10, 20, 40, 80 and 160 hours using a turned system. This is equal to 5, 10, 20, 40 and 80 hours without turning of samples holders. Irradiation of the samples was carried out using the Atlas Light Fastness Tester. The type of Atlas Fade-Ometer used in this study is XENOTEST®150S+). A light filter was used to simulate light in museums. Exposure conditions were 50ºC and 55% of RH.

2.8 Evaluation of Colour Changes: Changes in colour of tested samples were evaluated visually and using Optimacth 3100 colour Spectrophotometer using the CIELab colour system. CIELab colour coordinates for L (lightness), a (red/green axis), and b (yellow / blue axis) values were recorded. Five colour readings were made and averaged for each sample. Colour changes are the differences between unaged and aged dyed silk textile sample after aging for each control one, are expressed as ΔL, Δa , Δa. Calculation of the total colour change (ΔE) is achieved by the use of the following equations: ΔE = [(ΔL)2 + Δa)2 + (Δb)2]0.5. The positive and negative nature of ΔL, Δa and Δb values also gives information about other changes which have occurred to the samples as a result of the treatment. A positive ΔL value indicates that the sample is lighter than the control sample, and a negative value indicates that it is darker. If Δa is positive then the sample has a greater degree of redness, and if negative then it has a greater degree of greenness or a decrease in redness. Lastly, a positive Δb value signifies an increase in yellowness, and a negative value signifies an increase in blueness or a decrease in yellowness (Hutchison, 1991).

3. Results

The results of visual observation (figure 1) and instrumental measurements (table 1) of silk samples dyed with cochineal after the light ageing for various periods show that there are moderate changes in the colour of all samples except those mordanted with alum which exhibit a greater total colour change reaching 29 units. These results are in agreement with the results obtained by Abdel-Kareem and Al-Saad (2007) on wool which confirmed that wool dyed with cochineal and alum is the most sensitive to light among all tested samples dyed with cochineal. The results of visual observation (figure 2) and instrumental measurements (table 2) of silk samples dyed with cutch after the light ageing for various periods show moderate change

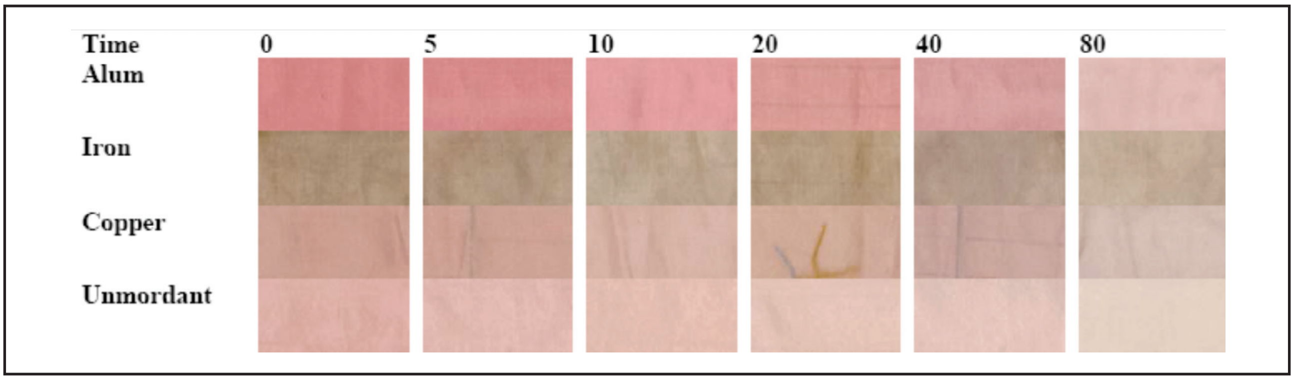

Fig. 1: Visual observation of the effect of light ageing on samples dyed with cochineal

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Alum	56.53	37.31	7.57		2.87	-3.54	1.12	4.69
Iron	54.86	6.20	12.32		-0.59	-0.17	1.04	1.21
Copper	61.56	17.01	9.75		2.96	0.03	1.59	3.36
Not mordanted	69.42	16.49	8.34		3.2	-2.97	0.91	4.46
Mordant	10 hours				20 hours			
	ΔL	Δa	Δb	ΔE	ΔL	Δa	Δb	ΔE
Alum	6.93	-7.02	-1.42	9.97	7.01	-8.51	2.57	11.32
Iron	9.94	-2.22	0.05	10.19	4.53	-0.3	2.25	5.07
Copper	7.2	-3.3	-0.79	7.96	6.67	-3.31	3.07	8.05
Not mordanted	4.58	-3.05	1.7	5.76	6.33	-6.1	1.91	9.00
Mordant	40 hours				80 hours			
Alum	2.21	-7.77	2.51	8.46	18.19	-23.03	1.43	29.38
Iron	8.8	0.24	5.04	10.14	16.78	-1.14	10.24	19.69
Copper	6.1	-5.1	3.49	8.68	14.2	-11.09	2.42	18.18
Not mordanted	9.63	-7.04	3.82	12.53	13.48	-11.61	4.75	18.41

Table 1: Colour change of samples dyed with cochineal after light aging for various times

in the colour of all tested samples. However, the results point to the fact that the change in samples mordant to iron show little more change than all other tested samples dyed with cutch. The results of visual observation (figure 3) and instrumental measurements (table 3) of silk samples dyed with henna after the light ageing for various periods show that there is moderate change in the colour of all other tested samples. However, the results show that the change in samples mordanted with iron is the least than all other tested sampled dyed with cutch. The results of visual observation (figure 4) and instrumental measurements (table 4) of silk samples dyed with indigo after the light ageing for various periods show high changes in the colour; here the total colour change reached 32 units. These results are in agreement with the results obtained by Abdel-Kareem (2006); he confirmed that silk dyed with indigo is the most

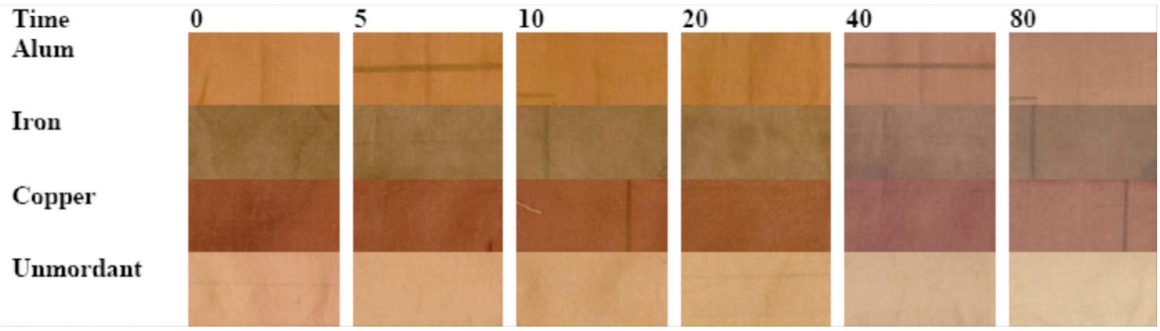

Figure 2 Visual observation of the effect of light ageing on samples dyed with cutch

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Alum	52.13	22.75	36.39		-4.92	-4.16	-4.16	7.67
Iron	44.79	12.35	17.06		-19.56	-5.75	-10.77	23.06
Copper	34.78	24.43	18.19		-6.88	-11.5	-5.25	14.39
Not mordanted	65.54	17.57	27.75		-19.49	-6.67	3.94	20.97
Mordant	10 hours				20 hours			
	ΔL	Δa	Δb	ΔE	ΔL	Δa	Δb	ΔE
Alum	-5.64	-4.71	-4.65	8.70	-4.82	-5.86	-5.13	9.16
Iron	-18.46	-5.84	-10.79	22.17	-19.56	-6.26	-9.88	22.79
Copper	-6.69	-11.56	-4.98	14.25	-5.77	-12.06	-4.02	13.96
Not mordanted	-13.28	-4.51	-4.91	14.86	-14.74	-5	-3.12	15.87
Mordant	40 hours				80 hours			
Alum	-5.43	-7.77	-6.19	11.32	-1.55	-11.38	-6.95	13.42
Iron	-17.83	-6.97	-8.98	21.15	-15.2	-7.78	-5.51	17.94
Copper	-6.22	-13.4	-4.04	15.32	-4.43	-13.82	-1.69	14.61
Not mordanted	-12.48	-7.05	-2.13	14.49	-10.6	-8.87	-0.33	13.83

Table 2 Colour change of samples dyed with cutch after light aging for various times

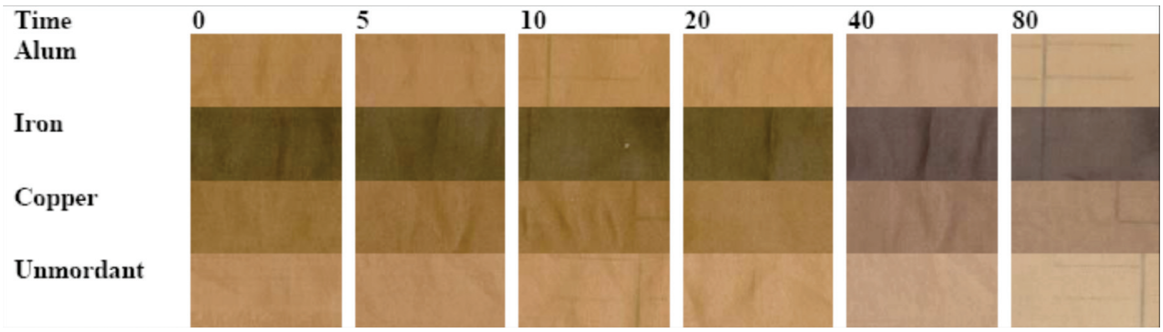

Figure 3 Visual observation of the effect of light ageing on samples dyed with henna

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Alum	50.82	12.47	29.54		0.94	1.09	0.89	1.69
Iron	32.06	5.03	10.51		-0.83	-0.21	0.06	0.86
Copper	44.62	10.44	23.88		1.83	0.97	1.64	2.64
Not mordanted	55.69	12.68	27.79		0.09	0.58	0.35	0.68
Mordant	10 hours				20 hours			
	ΔL	Δa	Δb	ΔE	ΔL	Δa	Δb	ΔE
Alum	3.68	0.58	2.21	4.33	3.22	0.25	2.55	4.12
Iron	2.76	-0.13	1.12	2.98	0.49	-0.57	0.99	1.24
Copper	0.84	0.37	1.52	1.78	6.92	0.54	4.29	8.16
Not mordanted	1.24	0.3	1.22	1.77	5.365	-1.01	2.49	6.00
Mordant	40 hours				80 hours			
Alum	11.13	-0.51	6	12.65	17.24	-3.84	6.93	18.97
Iron	1.16	-0.82	1.83	2.32	7.91	-0.67	4.57	9.16
Copper	6.97	0.39	5.58	8.94	10.95	-0.53	8.29	13.74
Not mordanted	9.5	-2.13	4.35	9.74	17.07	-6.12	4.44	18.67

Table 3 Colour change of samples dyed with Henna after light aging for various times

sensitive to light among all the tested natural textile samples dyed with indigo. The results of visual observation (figure 5) and instrumental measurements (table 5) of silk samples dyed with lac after the light ageing for various periods show that there are obvious changes in the colour of all tested samples especially in samples mordanted with alum which exhibit a greater level of total colour change reaching 18 units. The results of visual observation (figure 6) and instrumental measurements (table 6) of silk samples dyed with madder after the light ageing for various periods show that there are obvious changes in the colour of all tested samples but less than all other tested dyes. The results of visual observation (see figure 7) and instrumental measurements (table 7) of silk samples dyed with safflower after the light ageing for various periods show that there are moderate changes in the colour of samples mordanted with iron and copper. There are great changes in the colour of samples mordanted with alum and the non-mordanted ones as the total colour change reached up to about 29 units. These results are in agreement with the results obtained on wool by Abdel-Kareem and Al-Saad, (2007) who confirm that wool dyed with safflower and alum or non-mordanted is the most sensitive to light among all the tested samples dyed with safflower. The results of visual observation (figure 8) and instrumental measurements (table 8) of silk samples dyed with saffron after the light ageing for various periods show that there are little changes in the colour of all tested samples except for samples mordanted with iron which show a moderate change. The results of visual observation (figure 9) and instrumental measurements (table 9) of silk samples dyed with sumac after the light ageing for various periods show that there are little changes in the colour of all tested samples except for samples mordanted with alum and non-mordanted ones which show moderate change. The results of visual observation (figure

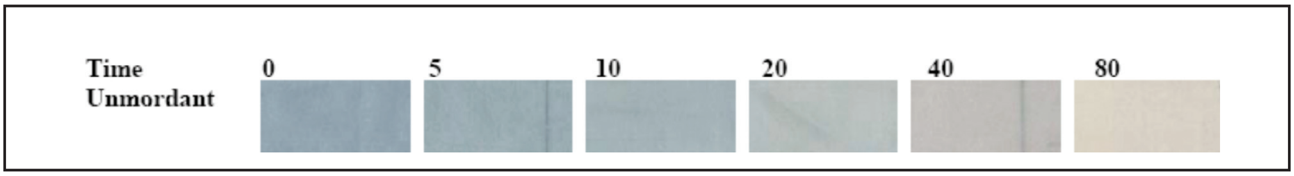

Figure 4 Visual observation of the effect of light ageing on samples dyed with indigo

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Not mordanted	61.07	-6.23	-11.64		2.46	0.52	2.88	3.82
Mordant	10 hours				20 hours			
	ΔL	Δa	Δb	ΔE	ΔL	Δa	Δb	ΔE
Not mordanted	3.91	1.09	4.57	6.11	11.41	2.24	9.51	15.02
Mordant	40 hours				80 hours			
Not mordanted	17.94	3.85	15.97	24.33	22.34	6.38	21.86	31.90

Table 4 Colour change of samples dyed with Indigo after light aging for various times

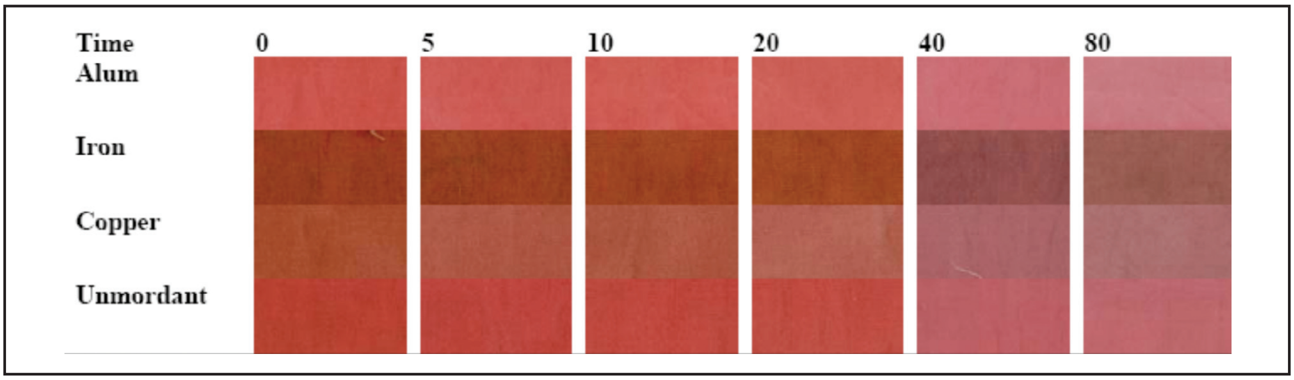

Figure 5 Visual observation of the effect of light ageing on samples dyed with Lac

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Alum	46.67	51.62	24.45		1.73	-0.08	-1.67	2.41
Iron	36.40	33.92	20.88		0.62	-0.47	0.02	0.78
Copper	41.10	37.41	22.17		4.16	-1.15	-3.2	5.37
Not mordanted	40.78	47.86	25.42		2.07	1.57	0.06	2.60
Mordant	10 hours				20 hours			
	ΔL	Δa	Δb	ΔE	ΔL	Δa	Δb	ΔE
Alum	2.3	-0.89	-1.68	2.98	3.53	-0.5	-1.83	4.01
Iron	2.6	1.96	1.75	3.70	2.55	-0.07	1.52	2.97
Copper	2.36	-1.23	-1.94	3.29	6.55	-1.74	-4.37	8.06
Not mordanted	4.02	3.47	0.79	5.37	4.66	3.32	0.38	5.73
Mordant	40 hours				80 hours			

Alum	4.78	-2.5	-2.93	6.14	10.87	-12.77	-7.73	18.47
Iron	3.06	-2.28	0.62	3.87	6.66	-5.61	2.97	9.20
Copper	6.54	-1.6	-4.3	7.99	10.12	-6.98	-5.57	13.50
Not mordanted	3.92	-0.91	-1.99	4.49	9.84	-3.59	-4.4	11.36

Table 5 Colour change of samples dyed Lac with after light aging for various times

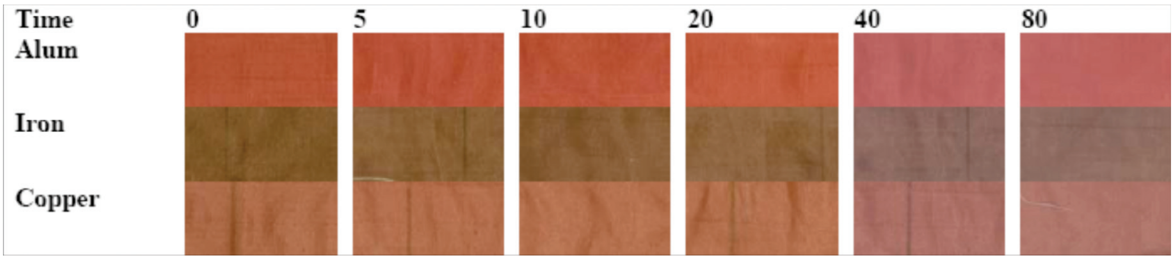

Figure 6 Visual observation of the effect of light ageing on samples dyed with madder

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Alum	42.20	38.93	28.24		-9.24	-0.66	-3.83	10.02
Iron	37.86	11.01	15.21		-14.59	-0.46	-9.81	17.59
Copper	44.38	24.77	22.46		-13.6	-6.55	-6.36	16.38
Mordant	10 hours				20 hours			
Alum	-6.55	0.54	-1.42	6.72	-8.11	1.16	-3.1	8.76
Iron	-15.82	-2.04	-10.78	19.26	-13.22	-0.33	-9.64	16.36
Copper	-11.2	-6.82	-5.63	14.27	-11.24	-6.63	-6.23	14.46
Mordant	40 hours				80 hours			
Alum	-7.3	1.59	-2.4	7.85	-1.74	2.02	-0.87	2.80
Iron	-11.62	-0.04	-9.69	15.13	-12.39	-1.29	-10.15	16.07
Copper	-11.27	-7.71	-6.84	15.27	-9.28	-8.9	-5.5	13.98

Table 6 Colour change of samples dyed with madder after light aging for various times

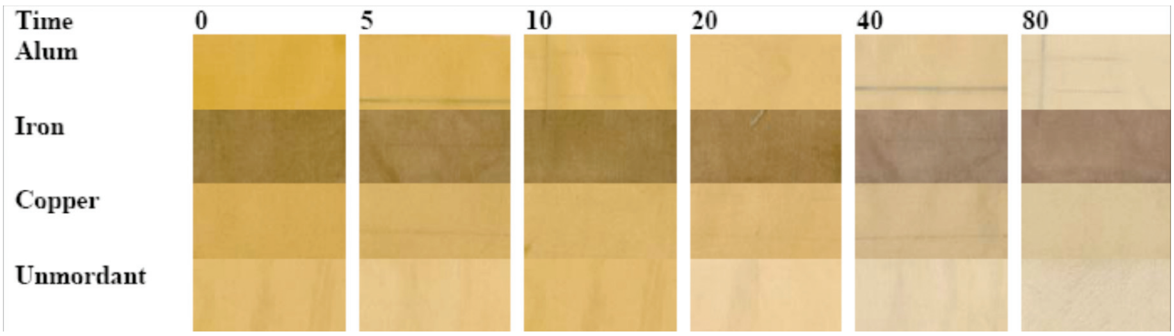

Figure 7 Visual observation of the effect of light ageing on samples dyed with safflower

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Alum	68.90	4.89	54.61		3.62	0.14	-3.48	5.02
Iron	50.86	5.10	28.69		1.7	1.28	-0.91	2.31
Copper	68.53	3.49	46.86		3.52	0.72	-1.8	4.02
Not mordanted	73.55	2.72	46.02		3.55	-1.03	-7.6	8.45
Mordant	10 hours				20 hours			
Alum	2.4	-1.75	-9.69	10.14	7.22	-1.16	-12.28	14.29
Iron	-1.57	0.85	-3.03	3.52	0.5	2.77	-2.53	3.78
Copper	3.44	0.92	-3.24	4.81	5.29	0.34	-5.43	7.59
Not mordanted	6.51	-0.64	-10.42	12.30	6.7	-0.68	-15.04	16.48
Mordant	40 hours				80 hours			
Alum	11.74	-1.73	-16.16	20.05	13.06	-3.23	-26.54	29.76
Iron	8.67	3.58	1.02	9.44	8.37	3.98	-0.75	9.30
Copper	9.65	-0.07	-6.54	11.66	9.21	-1.7	-13.63	16.54
Not mordanted	9.09	-0.52	-19.54	21.56	12.39	-0.89	-24.99	27.91

Table 7 Colour change of samples dyed with Safflower after light aging for various times

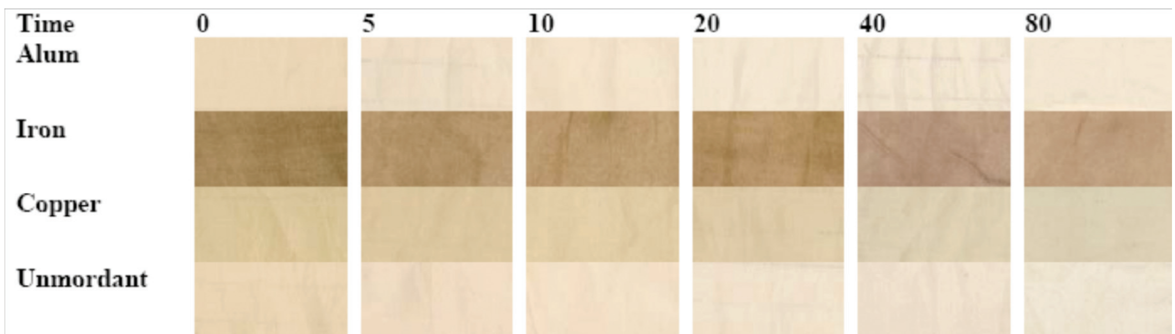

Figure 8 Visual observation of the effect of light ageing on samples dyed with saffron

Mordant	Control before ageing				5 hours			
	L	a	b		ΔL	Δa	Δb	ΔE
Alum	82.16	2.53	17.14		0.78	-0.01	-4.36	4.43
Iron	50.00	6.66	19.85		9.32	0.71	3.14	9.86
Copper	75.66	0.86	25.01		2.05	1.19	-0.89	2.53
Not mordanted	81.69	3.35	20.08		0.58	-0.15	-4.91	4.95
Mordant	10 hours				20 hours			
Alum	4	1.11	-2.35	4.77	3.33	0.44	-5.23	6.22
Iron	9.92	1.01	3.62	10.61	7.75	1.54	3.54	8.66
Copper	4.66	0.97	-2.53	5.39	6.21	0.98	-4.15	7.53
Not mordanted	2.7	0.34	-5.02	5.71	1.98	-0.45	-7.51	7.78

Mordant	40 hours				80 hours			
Alum	3.78	-0.36	-5.25	6.48	4.1	-1.09	-3.55	5.53
Iron	12.07	2.16	5.82	13.57	16.5	2.9	9.65	19.33
Copper	5.88	0.35	-3.27	6.74	7.6	-0.81	-4.09	8.67
Not mordanted	5.44	-0.4	-6.57	8.54	5.62	-1.46	-6.6	8.79

Table 8 Colour change of samples dyed with Saffron after light aging for various times

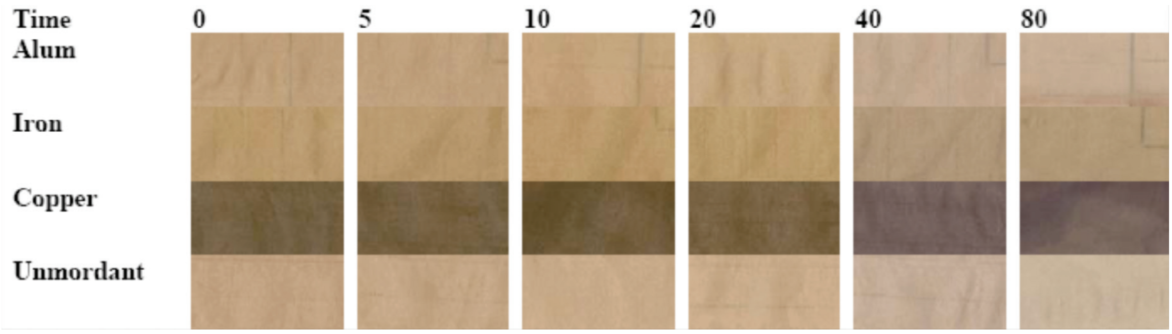

Figure 9 Visual observation of the effect of light ageing on samples dyed with sumac

	Control before ageing				5 hours			
Mordant	L	a	b		ΔL	Δa	Δb	ΔE
Alum	58.69	6.43	20.63		2.79	0.4	1.65	3.27
Iron	59.63	6.12	24.68		0.67	0.08	0.9	1.12
Copper	37.82	5.32	8.43		-0.52	-0.02	0.92	1.06
Not mordanted	63.28	6.81	19.67		1.83	-0.18	0.79	2.00
Mordant	10 hours				20 hours			
Alum	4.6	0.52	3	5.52	4.04	-0.82	1.2	4.29
Iron	0.34	0.02	1.5	1.54	2.53	-0.07	2.81	3.78
Copper	-5.81	-0.19	-1.82	6.09	2.52	-2.86	2.43	4.52
Not mordanted	1.77	-0.5	0.95	2.07	0.69	-1.53	0.3	1.70
Mordant	40 hours				80 hours			
Alum	8.79	-1.3	3.21	9.45	14.11	-2.1	5.07	15.14
Iron	1.84	-0.2	4.24	4.63	3.21	-0.69	6.46	7.25
Copper	3.51	0.24	3.43	4.91	4.29	0.48	4.3	6.09
Not mordanted	7.57	-1.66	1.98	8.00	10.08	-3.13	2.39	10.82

Table 9 Colour change of samples dyed with Sumac after light aging for various times

10) and instrumental measurements (table 10) of silk samples dyed with turmeric after the light ageing for various periods show that there are greater changes in the colour of all tested samples except samples mordanted with iron which show moderate change. The total colour changes in samples dyed with turmeric and mordanted with alum, copper or non-mordanted are 36, 36, 41 respectively. These results confirm that samples dyed mordant with alum and non-

mordanted ones are more sensitive to light, while samples dyed with iron mordant are more stable to light. It may be that the results depend on the colour shade produced using different mordants. These results are in agreement with results obtained by Abdel-Kareem (2006) and Abdel-Kareem and AlSaad (2007), who confirm that dyes with dark colour shades are less sensitive to light than dyes with light colour shades. The results of visual observation (figure 11) and instrumental measurements (table 11) of silk samples dyed with synthetic dyes after the light ageing for various periods show that there are greater changes in the colour of all tested samples except for samples dyed with red and orange dyes which show moderate colour change.

4. Discussion

The results obtained in table 12 and figures 1-10 show that various colours can be achieved using natural dyes. These colours depend on both the type of dye and type of mordant. The results show that yellow dyes are the most sensitive tested dyes (both natural and synthetic dyes) to light aging. These results agree with the results obtained by Abdel-Kareem and Al-Saad (2007), who confirm that yellow dyes are the most sensitive natural dyes on wool to light in museums. As the fading of yellow dyes was found in both natural and synthetic, it is confirmed that dark colour dyes are more stable against the light than light colour dyes. The results show that the changes in the colours obtained with synthetic dyes are greater than they are in the colours obtained with natural dyes. For example, the total change in the colour of samples dyed with madder after 80 hours is 3 while for those dyed with synthetic dyes is about 20. The results show that the changes in some colours of both natural and synthetic dyes are relatively the same. For example, the changes in red colours obtained from cochineal, lac and synthetic dyes are 29, 19, 20. The results show that the change in the blue colour obtained with the natural dye (indigo) is more than in the colour obtained from the synthetic dye. By comparing all the data it is clear that in a museum the synthetic dyes are more sensitive to light than natural dyes. These results are in disagreement with the opinions of both Flury-Lemberg (1988), and Landi (1998) who confirm that natural dyes are very sensitive to light. However, this could have been so because of the light source that was used in their tests; our tests were designed to simulate the environmental conditions inside the museums. Also it may be due to the type of natural dyes that they have tested. As our results show, turmeric dye, for example, is very sensitive to light too. Also it may be due to the type of fabric that they have tested; the current study was conducted on silk fabric. Based on the previous results natural dyes are recommended for textile conservation as they have good light fastness in museum conditions. They can be safely used for textiles with no hazardous effect on conserved textile objects. Also the fading in the dyed new fabrics used in the conservation of an object will be equal to the fading that will occur in the future for dyes on a conserved object since the nature of the dyes is the same.

Although the results obtained show that various colours can be achieved from natural dyes, the study believes that it may be difficult to achieve the same colours if the source of dyes is changed. We are not sure if the concentration of dye matters in all the dye sources will be the same. As many authors confirm, there are many factors which play a role in the amount of dyestuff matters in each dye such as the agriculture process and the age of the plant (Zidan, 1987). For that the study confirms that if it is not possible to achieve the required colour shade using natural dyes, then synthetic dyes are recommended.

This is due to the fact that success in

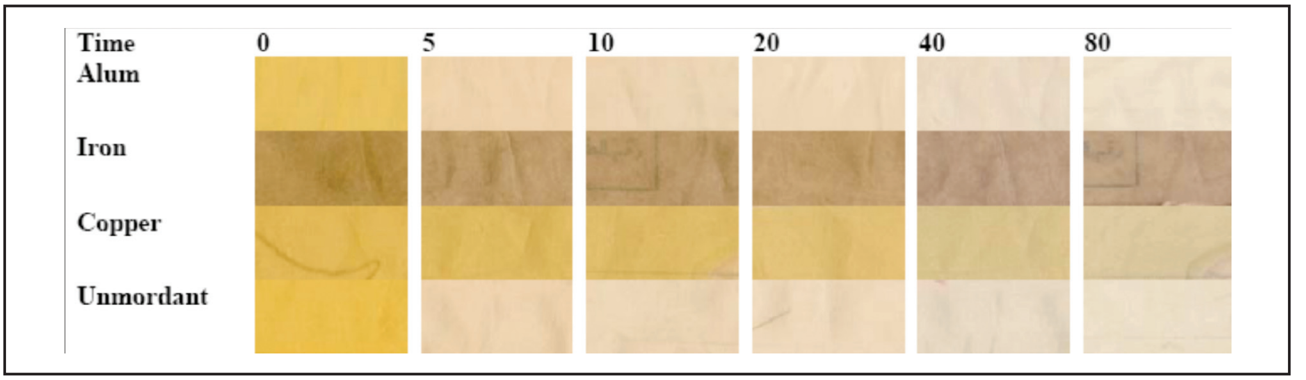

Figure 10 Visual observation of the effect of light ageing on samples dyed with turmeric

	Control before ageing				5 hours			
Mordant	L	a	b		ΔL	Δa	Δb	ΔE
Alum	77.32	-3.60	56.89		-6.11	7.25	-25.71	27.40
Iron	59.22	5.25	36.36		-12.11	0.62	-13.35	18.03
Copper	73.23	1.26	55.98		-19.14	-3.25	-26.25	32.65
Not mordanted	75.04	-0.66	60.32		-0.37	3.11	-33.72	33.87
Mordant	10 hours				20 hours			
Alum	-4.28	6.74	-28.68	29.77	-4.28	6.94	-31.09	32.14
Iron	-12.01	0.79	-13.83	18.33	-11.7	1.03	-13.85	18.16
Copper	-18.31	-3.35	-26.99	32.79	-17.68	-3.87	-26.48	32.07
Not mordanted	0.65	3.33	-36.29	36.45	1.28	2.95	-38.78	38.91
Mordant	40 hours				80 hours			
Alum	-1.34	6.08	-34.5	35.06	2	5.29	-35.69	36.14
Iron	-8.71	1.67	-12.6	15.41	-6.89	2.66	-11.09	13.32
Copper	-15.48	-6.24	-31.05	35.25	-13.45	-7.13	-33.44	36.74
Not mordanted	4.32	2.46	-40.15	40.46	5.64	1.8	-41.04	41.46

Table 10 Colour change of samples dyed with Turmeric after light aging for various times

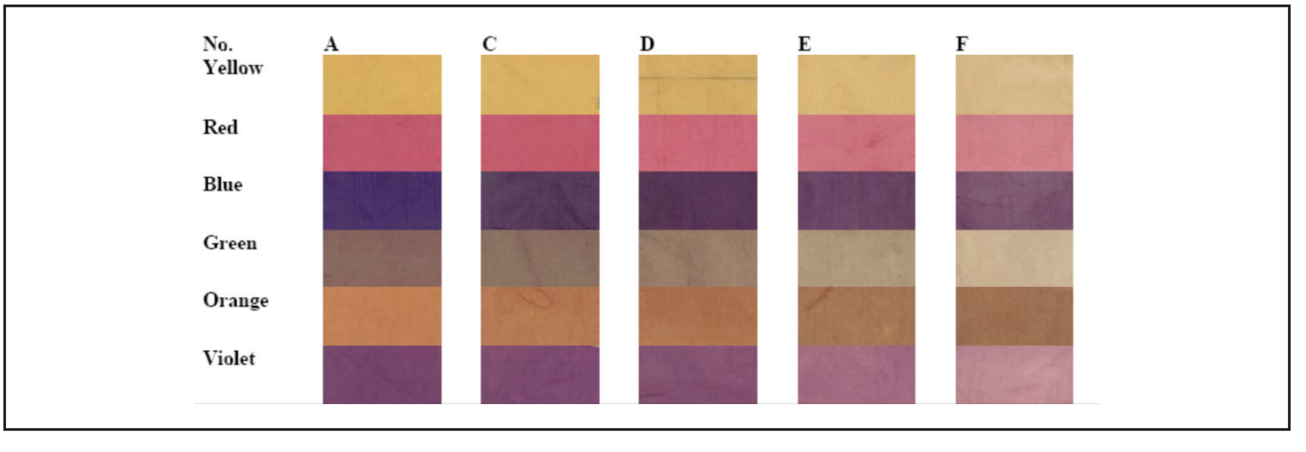

Figure 11 Visual observation of the effect of light ageing on samples dyed with synthetic dyes

	Yellow			Red			Blue		
Not mordanted	L	a	b	L	a	b	L	a	b
	71.55	15.47	75.90	45.66	56.39	15.14	21.73	20.14	-28.71
	Green			Orange			Violet		
Not mordanted	36.21	-3.93	19.56	57.00	31.95	61.54	25.17	16.78	-15.01

Table 11 Colour values of silk textile samples after dyed with tested synthetic dyes

Mordant	10 hours				20 hours			
	ΔL	Δa	Δb	ΔE	ΔL	Δa	Δb	ΔE
Yellow	1.12	-0.92	-3.87	4.13	-0.51	-3.01	-13.03	13.38
Red	1.46	-0.51	0.04	1.55	-18.06	-9.52	4.02	20.81
Blue	0.54	-13.65	20.88	24.95	0.64	-12.77	20.75	24.37
Green	6.79	2.19	4.96	8.69	13.36	3.87	6.09	15.18
Orange	-1.7	-2.51	-5.77	6.52	-6.02	-4.37	-12.17	14.26
Violet	4.04	2.16	1.69	4.88	8.5	3.93	4.84	10.54
	40 hours				80 hours			
Yellow	2.38	-6.23	-25.07	25.94	6.37	-8.78	-34.4	36.07
Red	9.21	-9.79	-2.93	13.76	14.1	-15.38	-3.29	21.12
Blue	6.73	-8.87	19.77	22.69	16	-8.51	23.54	29.71
Green	24.09	5.09	7.82	25.83	34.06	6.32	7.82	35.51
Orange	-4.85	-10.71	-18.78	22.16	-6.21	-11.2	-19.92	23.68
Violet	-20.82	7.17	15.02	26.65	34.72	3.84	21.97	41.27

Table 12 Colour change of samples dyed with synthetic dyes after light aging for various times

	Alum	Iron	Copper	Not mordanted
Cochineal	Magenta Rose Crimson	Light brown	Pale pink Light Rose	Light pink Light rose
Cutch	Light reddish brown	Brown	Brick red	Yellowish brown
Henna	Light brown	Bluish brown	Bluish brown	Yellowish brown Light brown
Indigo	Light blue			
Lac	Crimson Pinkish red	Purple	Brick red	Red
Madder	Red	Brick red	Orange	
Safflower	Orange yellow	Light brown	Brownish yellow	yellow
Saffron	Pale yellow	Light yellowish brown	Dull yellow	Yellow
Sumac	Beefy colour	Light brown	Light bluish brown	Light bluish brown
Turmeric	Yellow	Light bluish brown	Bright yellow	Bright yellow

Table 13 The obtained colour of silk samples after dyeing with natural dyes

conservation processes of textiles depends on the success in selecting the required colour shade for the lining fabric, to give a desirable appearance during the display of the textile object, as well as on selecting the required colour shade for the threads used for fixing any damage in a textile object or fixing the object with lining fabric. Finally the study confirms that there is a necessity to carry out other researches to investigate of other synthetic dyes which may be more stable to light ageing than our tested synthetic dyes.

5. Conclusion

This study confirms that both natural and synthetic dyes are important in the textile conservation field. This study concludes that if natural dyes achieve the required colour shade, then their use is recommended, because natural dyes are more stable to light change and are compatible with the historical dyes. Natural dyes are safe and present no hazardous effect on conserved textile objects. But if it is not possible to achieve the required colour shade using natural dyes, then synthetic dyes are recommended. Finally this study needs to be followed by other studies to investigate the characterisation of dyes on other fabrics and threads. Also this study invites chemistry scientists to look into the possibility of extracting natural dyes from their sources to produce these dyes as pure dry materials.

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Notes

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ملخص: تعدّ الأصباغ وطرق الصباغة من الموضوعات المهمة للقائمين على صيانة المنسوجات الأثرية ومرمميها. وينقسم العاملون في مجال صيانة المنسوجات القديمة وترميمها إلى فريقين: أحدهما يفضل استخدام الأصباغ الطبيعية، والآخر يفضل استخدام الأصباغ الصناعية. يهدف هذا البحث إلى شرح التضارب في الرأيين، وعمل دراسة تجريبية على بعض الأصباغ المستخدمة في صيانة تلك المنسوجات وترميمها؛ وذلك للوصول إلى توصيات خاصة بهذا الشأن، والوصول إلى الطريقة الأنسب لأعمال صيانة وترميم المنسوجات القديمة. وقد أجريت الدراسة على الأقمشة الحريرية، نظراً لشيوع استخدامها في عمليات صيانة وترميم المنسوجات الأثرية؛ إذ صُبغت عينات نسيجية حريرية حديثة، غير معالجة بأصباغ طبيعية، وأخرى صناعية. العينات المصبوغة تم تعريضها للضوء الصناعي لفترات زمنية مختلفة وذلك بهدف معرفة التقادم الزمنى على الأصباغ المختبرة. التغيرات اللونية للعينات المصبوغة المتقادمة تم تعيينها بالعين المجردة وباستخدام الاسبكتروفوتوميتر، حيث تم قياس التغيرات اللونية في كل المعاملات اللونية. وقد أوضحت الدراسة أن كلا النوعين من الأصباغ سواء الطبيعية أو الصناعية مهم في صيانة وترميم المنسوجات القديمة. وتوصلت إلى أنه إذا أمكن الوصول إلى اللون المطلوب في عملية الصيانة والترميم بأصباغ طبيعية، فيكون من الأفضل استخدام الأصباغ الطبيعية؛ أما إذا تعذر الوصول إلى الدرجة اللونية المطلوبة من الأصباغ الطبيعية، فإنه يفضل استخدام الأصباغ الصناعية، عوضاً عن استخدام درجات لونية غير مناسبة من الأصباغ الطبيعية.

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