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Experimental Design of Woolen Fabrics' Accelerated Ageing

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ABSTRACT

This paper presents the accelerated ageing of woollen fabrics that are often found in ethnographic collections stored or exhibited in open display in an uncontrolled environment. It is part of the INVENVORG (Thales Research Funding Program – NRSF) investigating the effects of the environmental factors on organic materials. This paper presents the experimental design of a protocol of accelerated ageing tests concerning the effect of abiotic parameters, two gaseous pollutants (SO_2, NO_2) and two relative humidity values.

Keywords: Experimental design; museum environment; wool; fabric; accelerated ageing

INTRODUCTION

Fabrics when found in museums or storage rooms under uncontrolled environmental conditions are subjected to different types of damage. Abiotic and biotic factors may cause physical, chemical and biological deterioration of them affecting the material durability or their aesthetic appearance. Within the INVENVORG framework biodeterioration mechanisms were not investigated, whereas the abiotic factors were under consideration. The textile fibers, depending on their origin and chemical composition, show different rates of degradation and resistant to environmental parameters. The abiotic factors that affect the condition of fabrics and cause polymer degradation include heat, relative humidity variations, visible light, ultraviolet radiation, gaseous pollution, such as SO_2, NO_x and particulates (Leene *et al*. 1975, Zhang 2008a,b). According to the literature, a lot of experimental procedures have illustrated the detrimental effect of visible and UV radiation, as well as, the thermal degradation of fabrics (Rutherford & Harris 1941, Phillips & Arthur 1964, Gordon 1968, Lennox & King 1968, Harris 1984, Holt & Milligan 1984, Karpovicz 1989, Feller 1994, Davidson 1996, Seli *et al.* 1998, Timár-Balázsy & Eastop 1998, Korenberg 2007, Zhang *et al*. 2008a).

Although there are also many studies conducted regarding the effect of some gaseous pollutants in some types of fibres, it seems that the examination of fibres' morphology, the role of weave and the chemical alteration is not fully investigated (Bogaty *et al.*1952, Zeronian 1970, Upham & Salvin 1975, Walsh *et al.* 1977, Crawshaw 1978, Walters *et al*. 1983, Kobayashi and Yoshizumi 1994, Riganti *et al.* 1995).

EXPERIMENTAL DESIGN

The investigation of the degradation mechanisms of the fabrics constituting the cultural heritage, despite all the conducted studies, needs further thorough research. According to the literature and due to the duration of INVENVORG project and the scientific equipment availability, one type of textile was selected to be investigated. The chosen textile was wool due to its extensive use for production of ethnographic artefacts found very often in ethnographic museums (Schaffer 1981).

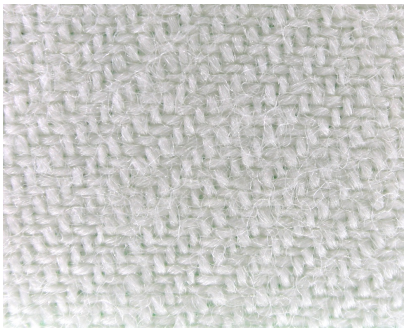

Fig.1: Merino wool worsted twill flannel used for samples

The fabric used for ageing was merino wool, where its fibers have bilateral divided cortex (half and half orthocortex and paracortex. The fabric was worsted twill flannel (fig. 1), natural scoured, of approximate weight: 241 grams/m^2 and approximate width of 152 cm and have product item code 526 from the Testfabrics, Inc©., 415 Delaware Avenue, West Pittston PA 18643 USA, Tel: 1 (570) 603 0432, Fax: 1 (570) 603 0433 and email: info@testfabrics.com

The design of the experimental protocol was in line to the main aim of the INVENVORG project, which was the determination of the critical environmental factors, occurring in open display museum environments, causing deterioration of organic materials, in order to specify the optimum values of each factor that will lead to the better preservation of each organic material.

FACTORS AND LEVELS

The experimental design has taken into account the literature cited above. Main objectives of the project were to become aware of the significant role and to compare the different rate of deterioration occurred by each environmental parameter and to determine the critical environmental factors causing deterioration of wool fabrics. Thus, for the implementation of the accelerated ageing procedure of the woolen samples, the following abiotic factors and levels were selected and are shown on Table 1.

The experimental design of the accelerated ageing was set up, in order five factors with two levels each (low – high) to be investigated. The order that samples were exposed to the two pollutants was examined, as a fifth factor, in order to evaluate whether the sequence of the pollutants is important to the deterioration process.

	Factors	**Levels**	
1.	Relative humidity	45 %	70 %
2.	Gaseous Pollutant (NO_2)	concentration: 10 ppm*	concentration: 25 ppm
3.	Gaseous pollutants (SO_2)	concentration: 10 ppm	concentration: 25 ppm
4.	Time	15 Days	30 Days
5.	Order	(2 levels)	

Table 1: Factors and levels used for the accelerated ageing of woollen samples

*Industrial and urban areas have gaseous pollutants of approximately 0,10ppm. The majority of the implemented researches referred to that and lower concentration. Nevertheless, Kobayashi and Yoshizumi (1994) made calculations concerning the concentration in order to achieve accelerated ageing relevant to many years of natural exposure. Thus, 10ppm in the current experimental design corresponds to almost 20 years of exposure, whereas 25ppm to 50 years.

The experimental design followed a fractional factorial design for time consuming and financial reasons (Dellaportas *et al.* 2014). Sixteen accelerated ageing cycles (experiments) were performed, as outlined in Table 2, in order to emulate ageing in a controlled manner. A special continuous flow apparatus featuring two reaction (ageing) chambers was constructed for this purpose, at the premises of the collaborating Department of Chemical Engineering of the University of Patras. The reaction chambers (constantly at 25^{o}C) had gas inlets and outlets for the feed and exit gas, thereby enabling the continuous flow operation of the system. The

accelerated ageing procedure lasted for almost a year and 80 samples were prepared (5 repetitions, 16 experiments).

No of experiment	RH	SO_2	NO_2	Time	Order
1	Low	High	Low	Low	N
2	High	Low	High	High	N
3	High	High	Low	High	N
4	High	Low	Low	High	S
5	Low	High	High	Low	N
6	High	Low	High	High	S
7	High	Low	Low	Low	N
8	Low	High	High	High	N
9	Low	High	Low	High	S
10	High	High	High	High	S
11	Low	Low	Low	High	N
12	Low	Low	High	Low	N
13	High	High	Low	Low	S
14	Low	High	High	Low	S
15	Low	Low	Low	Low	S
16	High	Low	High	Low	S

Table 2: Experimental design for wool accelerated ageing

CONCLUSION

The implemented experimental design concerning the accelerated wool ageing defined the research objectives in relation to the state of the art, the expected results and the methodology according to the available scientific and financial resources. It was approached and implemented by an interdisciplinary team (material scientists, conservators, chemical engineers, museologists and mathematicians). A novel approach, rarely happening in conservation field was the participation of the statisticians for the designing of the accelerated ageing protocol.

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