RESTAURATOR

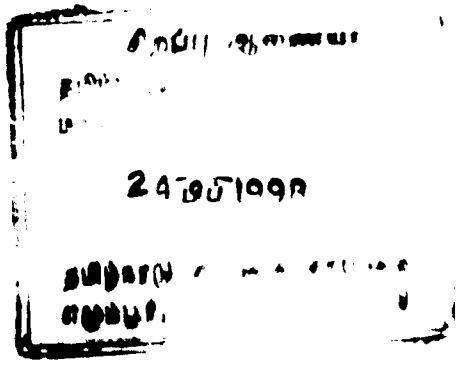
International Journal for the Preservation
of Library and Archival Material

Volume 19 · Number 2 · 1998

RESTAURATOR (ISSN 0034-5806) is published quarterly by K. G. Saur Verlag GmbH & Co. KG, Ortlerstr. 8, D-81373 München, Germany.

RESTAURATOR

International Journal for the Preservation of Library and Archival Material
Vol 19 (1998), No 2, pages 61–114 ISSN 0034-5806



Contents

Indexed in:
Chemical Abstracts
Current Contents
Information Science Abstracts
Library Literature
Library Science
Social and Educational Science
Citation Index

The chemical agents are not discussed in this work, if not for their characteristics of biological relevance.

Inherent properties. Fibrous materials

The use of chemical pulp and/or wood pulp is not compatible with the maximum permanence and durability of paper. Hence, UNI 10332 deals with the use of a fibrous mixture consisting of cotton cellulosic fibres and/or linters and/or hemp and/or ramie, with an average polymerization degree not lower than 1000. The cellulose polymerization degree of the above vegetables, that is higher than that of wood pulp by chemical extraction, and the high degree of cristallinity provide paper with a good ability to resist the deterioration process[3] and the yellowing due to the oxidation reactions and give paper good properties of mechanical endurance.

Sizings

The sizings are indispensable to give paper the appropriate properties for writing and printing without off setting of ink. They can be classified in reactive (alkenylsuccinic anhydride, stearic anhydride and alkyl diketene) and non reactive (e.g. colophon, acrylic resins, starches, gelatine) depending on the presence of covalent bonding with paper.

The sizing method with colophon, dating back to the beginning of the XIX century, still finds a wide use in the paper industry and represents an important inherent factor of paper deterioration. The colophon is added to the fibrous mixture and is then precipitated with aluminium sulfate (referred to as alum) that allows the fibres to absorb the sizing agent. The precipitation pH value of the sizing agent on the fibres has its optimum range between 4.7 and 5.5[4]. The acid pH value of these papers is detrimental to permanence and durability because the cellulose, in an acid context, swells, hydrolyzes and oxidizes thus provoking a chain reaction and accelerating the deterioration process[5].

The origin of this problem is of chemical nature, but it also has a biological aspect. The pH value of paper sized with colophon and alum is generally equal to the optimum pH value of the cellulases of most cellulolytic fungi. Therefore, permanent and durable paper, conforming to UNI 10322 must not contain acid substances, e. g.. those deriving from the above sizing and the pH of its aqueous extract must range between 7.5–10.0.

UNI 10322 also provides for the introduction of an alkaline reserve, a substance capable of neutralizing the acidity due for example to the atmospheric pollution. Among the fillers, calcium carbonate is suggested for this scope: insoluble in water or in neutral-alkaline range, and soluble in acid range it gives the possibility to buffer a pH value drop. When added to the fibrous mixture it also buffers at a pH of 7.5–8.0[6] thus improving the action of many synthetic sizes. Research proved that chemical pulp paper with 2–3% of calcium carbonate, is suitable for books or documents to be preserved for a long time[7].

Iron and copper content

The presence of some chemical substances such as iron, copper and manganese has, for different reasons, a negative effect on the long term preservation of paper.

External factors of biological nature

The microflora of fungi (over 200 species) and a limited quantity of bacteria are often the main cause of damages to paper materials. The bacteria that more frequently develop on paper belong to the genus *Cytophaga, Sporocytophaga, Cellfalcicula, Cellvibrio.* As to the microfungi that are often found on books and documents also from other countries with different climatic conditions they belong to the following genus: *Penicillium, Aspergillus, Chaetomium, Mucor, Rhizopus, Fusarium, Stemphylium, Cladosporium, Stachybotrys, Trichoderma, Trichothecium* [8].

Statistic surveys show that the microbial degradation processes occurring in libraries are caused in 30% cases from *Aspergilli* and in over 30% cases from Penicilli[9]. The damages caused by microbial agents on paper can have different aspects and relevance and can be summarized as follows[10]:

- chromatic changes
- structural changes in the constituent materials
- change in the basic additive constituents.

The chromatic changes are caused by mycelium, by pigmented spores, or by fungus or bacterial pigments. They present different characteristics both for colour (yellow, red, purple, brown, green, black) and for shape. It is not possible to detect the microbial agents from the colour stains. The pigment of the same microbial species has in fact different hues and intensity according to the chemical composition of the support (e.g. pH, traces of metallic elements) and according to the possible and contemporary presence of micro-organisms at different growth rate.

The structural changes, due to the enzymes (cellulases, proteases) have the most deleterious effect and may cause embrittlement if not the destruction of paper, that often takes a felt-like aspect.

In some cases, micro-organisms may grow on substances that like the sizings are indispensable for a good use of the material – without being the main component. Because of the deterioration of such components, the materials lose some of their characteristics and become useless.

Enzymatic deterioration of cellulose

The structural changes of paper basic components by microfungi are possible thanks to the production of extracellular enzymes, the cellulases that hydrolyze cellulose thus producing sugars soluble in water. The cellulases are a complex enzymatic compound consisting of esoglucanase, endoglucanase and β-glucosidase.

The enzymatic deterioration of crystalline cellulose is possible, thanks only to the synergetic interaction among the enzymatic components of the complex. A great number of the cellulolytic fungi, incapable of synthesizing the enzymes with esoglucanasic activity, act only with amorphous cellulose.

The enzyme of the cellulase complex can be inducted. In principle, their synthesis is inducted in the presence of cellulose and repressed by glucose[11]. Anyway, being cellulose a polymer insoluble in water, it cannot be used as inductor; the cellulolytic fungi can exert their action thanks to a moderate synthesis of cellulase so that the soluble products of cellulose hydrolysis when entering in the microorganisms cells, can act as inductors. The cellobiose is one soluble product.

Generally, the pH in the acid range stimulates the fungi growth[12]. The optimum pH value of the cellulase changes according to the fungus species, and it ranges between pH 3.0 and 8.0.

Factors promoting the degradation processes

The biodegradability of paper and the presence of vital spores are concerning factors but not sufficient conditions causing damages. They generally occur when air relative humidity is higher than 65% and the moisture content of paper approaches 10%[9 13 14].

Paper composition (possible presence of lignin, nature of cellulose, sizings, fillers etc.) affects its hygroscopicity and the higher is its hygroscopicity the lower will be the relative humidity to which 10% of free water can be reached.

RESEARCH

Scope

The scope of this work is to determine how paper degradability to microfungi may be changed by two of the most widely used synthetic sizings (alkenyl succinic anhydride and alkyl diketene) and one natural size (starch). As already pointed out, according to UNI 10332 permanent and durable paper must not contain acid materials, e.g. those deriving from colophon-alum sizing, but the compounds to be used for the sizing processes are not indicated.

The two tested synthetic materials are reactive sizings that form covalent bonds with hydroxyl groups of cellulose molecules. They have a hydrophobic part consisting of an aliphatic chain, and are partially reactive to cellulose; this structure allows the formation of one monomolecular layer of fibre lining, with the hydrophobic parts outward[15]. The alkyl diketene and akenyl succinic anhydride are best indicated for the sizing in neutral-alkali range (pH 7.5–9.0) and opposite to acid sizing by colophon-alum, this sizing presents the following advantages:

- possible use of calcium carbonate that is an alkali reserve at competitive cost if compared to the charges for colophon sizing;
- higher mechanical endurance of paper compared to colophon sized papers
- energy savings during refining because fibres refines more easily in alkali range
- reduced corrosion of the plant.

1 PREPARATION OF PAPER SAMPLES

Four kinds of paper conforming UNI 10332 were prepared in our laboratory (Table 1); one unsized paper sample to be used as reference sample and three samples sized with the following materials:

Table 1. Paper samples (cotton linters) manufactured for this research

	Unsized	Starch sized	AKD sized	ASA sized
Charge	10% $CaCO_3$	10% $CaCO_3$	10% $CaCO_3$	10% $CaCO_3$
pH UNI 9074	8.2	8.2	8.2	8.2
% sizing agent	/	5	5	0.6
$Cobb_{60}$ UNI 6437	/	/	25.0 g/m^2	26.8 g/m^2

- natural potato starch, Merck (70–80% amylopectin, 20–30% amylose);
- Alkyl diketene based sizing agent (AKD), produced by AKZO, trade mark Graphsize D100;
- mixture 1:1 Alkenyl succinic anhydride based sizing agent (ASA7540) and polyacrylamide based polymer emulsifier (84-PR-339), produced by NALCO.

2 BIODEGRADABILITY TESTS

The sizings applied on glass and paper were tested in order to determine their biodegradability both on an inert support and on an hygroscopic surface that could by themselves represent a possible nourishment for the micro-organisms. As far as the inert substances are concerned, tests were carried out according to the Standard ASTM D4300-88 "Ability of adhesive films to support or resist the growth of fungi" and according to Block method[16] that consist in leaving paper under different micro climatic conditions, some of which particularly favourable to microbial growth.

2.1 Materials. Microfungi tests

- *Aspergillus niger* v. Tiegh ATCC n.9642
- *Penicillium pinophilum* Thom ATCC n.9644
- *Chaetomium globosum* Kunze ex Steud ATCC n.6205
- *Aspergillus terreus* Thom

Culture medium

- PDA (Potato Dextrose Agar) Difco
- Sabouraud – 4% maltose agar Merck
- Czapek – Dox broth+5g/l yeast extract DIFCO
- PDA broth DIFCO
- MSA (Mineral Salt Agar) prepared in laboratory according the following composition:
  - KH_2PO_4 0.7 g/l
  - NH_4NO_3 1.0 g/l
  - $FeSO_4 \times 7H_2O$ 0.002 g/l
  - $MnSO_4 \times 4H_20$ 0.001 g/l
  - $MgSO_4 \times 7H_20$ 0.7 g/l
  - NaCl 0.005 g/l
  - $ZnSO_4 \times 7H_2O$ 0.002 g/l
  - Agar 15 g/l

2.2 Methods

The testing conditions for the sizing agent biodegradability on inert support or on paper are given below.

2.2.1 Preparation of the spore's suspensions

The four microfungi, inoculated in test tubes on potatoes dextrose agar were incubated at 25°C ± 0.5. Fungal suspension were thus obtained adding 10 ml of sterile distilled water containing a surface-active agent (0.05 of Tween 80) to 14 days old cultures of each species and then removing spores or conidium with a sterile loop. The suspension was successively filtered through cotton. The dilution ratio necessary to have a spore content of 1.10^6/ml in each suspension was determined using the Thoma chamber. The inoculum according to 2.3 and 2.4 was obtained with suspensions of the single species.

2.2.2 Accelerated ageing of sizings on glasses and of sized or unsized papers

In order to determine the possible variations of biodegradability with the passage of time, it was necessary to carry out some tests also on samples that underwent accelerated ageing in a climatic chamber under the conditions provided for by UNI 10256 "Paper and Paperboard – Accelerated ageing": Proposed test at 80°C and 65% RH, ageing time: 24 days.

2.2.3 Cool sterilization

The glass samples covered by a sizing film as well as sized and unsized papers were cold sterilized with ethylene oxide under the conditions provided for by Table 2, before the inoculum with microfungi test.

The process results were controlled by chemical ("Thermalog G") by PyMaH Corp. and biological indicators (Raven Biological Laboratories inc.). The biological indicators are strips of paper with spores of *Bacillus subtilis*, var. *niger* – order 10^6. The inoculum of the sample was carried out 10 days later, after the complete disposal of gas residues.

Table 2. Conditions of cool sterilization

Gaseous mixture	Ethylene oxide dose	Temperature	Relative humidity	Gas exposure	Changes of air
88% CO_2 12% ETO	500 g/m3	25–30°C	50–60%	22 hours	12

2.2.4 Growth of microfungi in culture medium at different pH

A preliminary test, preceding the biodegradability test, was conducted in order to determine the possible growth of microfungi (a) at an alkali neutral pH similar to that of paper sized with the above materials, (b) on acid sizings applied to glass. It is worth stressing that even with an acid pH, paper sized as above indicated is a neutral-alkali paper, as the reaction producing the bond between the sizing agent and cellulose is favourable in a pH ranging between 7.5 and 9.0.

As to the Deuteromycetes *Aspergillus terreus, Aspergillus niger* and *Penicillium pinophilum*, whose optimum growth is in acid range, the Czapek-Dox medium + 5g/L yeast extract, was used for the culture and the neutral alkali pH values were changed according to Table 4.

Considering the acidity of the sizing agent applied to glass (pH 4.5 for AKD and pH <2.0 for ASA) and considering that the *Chaetomium globosum* has its optimum growth at the pH interval 7.1 e 10.4[17], a preliminary test was conducted for the growth in PDA medium at the values indicated on Table 5. The culture medium (15 ml. for each test tube) was inoculated with 100 ml of the fungal suspensions according to 2.2.1 and incubated for 15 days at 28°C ± 0.5. The results were examined on three test tubes for each test, according to the absence or presence of any fungal growth.

2.3 Biodegradability tests of sizings applied on glass

The ASTM D4300-88 method was adopted. The following sizings were applied with a brush in a thin layer, slides on 3 mm thick and 25X25 mm wide.

- starch 5% p/V
- AKD in accordance with the manufacturer's instrutions
- ASA as above
- mixture 1:1 of ASA and 84-PR 339 emulsifier

Three slides of the same sizing were prepared for each fungus species and then placed in Petri's dish (9 cm. in diameter) and containing MSA medium (15 ml) as indicated in 2.1. Each Petri dish was inoculated with the spores of a fungal suspension (prepared according to 2.2.1) following the conditions given below:

- 100 µl of suspension was spread on the surface of the Mineral salt agar with a sterile loop;
- 10 µl of suspension, in 3/4 drops, were inoculated on the sizing agent layer on the slide. The Petri dish was placed in a thermostat at 30.0°C ± 0.5 for 21 days after the inoculum;

The growth of the fungus species was controlled 7, 14 and 21 days after the inoculum according to the principles provided for by the international standard as given below:

- NG: no growth on the slide and absence zone of inhibition
- SG: spread growth on the slide
- LG: low growth on the slide
- MG moderate growth on slide
- HG: high growth on the slide.

2.4 Biodegradability tests on paper samples

For the purpose of this test the vulnerability to the four microfungi was tested on paper samples sized with synthetic sizes and natural sizings as specified in Section 1. It was carried out as follows:

- Exposure of the samples to different micro climate for 140 days (16);
- Control of spore's life of the micro-organisms test after 140 days of exposure to different climates.

2.4.1 Exposure of samples to different microclimates for 140 days

The Block method was adopted according to which the materials inoculated with the microfungi test were exposed to different climatic conditions. Experiments were conducted at 20°, 30°C, values often recorded in libraries during the year. As to the hygrometric value a wide range was considered, between the optimum conditions for paper conservation (<65% R.H) and the critical conditions that might occur over longer or shorter periods of time in given environments. Aged and unaged paper samples (cm 3x3), placed in Petri dishes, were inoculated with 50 µl of spore suspensions as specified in Section 2.2.1. The test was carried out in triplicate. After 24 hours, the Petri dishes were stored in dryers containing on bottom saturated salt solutions as specified on Table 3, which at 20°C and 30°C created microenvironments with relative humidity between 53% and 100%.

The microscopic examination was carried out after 7, 14, 21, 28, 42, 70 and 140 days. The determination of the fungus attack extent was performed according to the scale from 1 to 5 adopted by Block and hereunder indicated:

- 0 = No growth
- T = sparse of growth
- 1 = very light growth
- 2 = light growth
- 3 = moderate growth
- 4 = heavy growth
- 5 = very heavy growth.

2.4.2 Control of spore's life at different microclimates

After 140 days exposure to different microclimates, the paper samples with no growth were tested in order to determine if the spores of the microfungi inoculat-

Table 3. Saturated salt solutions

Relative humidity	Temperature 20°C	Temperature 30°C
100 %	H_2O	H_2O
92 %	KNO_3	$BaCl_2 \times 2\ H_2O$
85 %	Li_2SO_4	Li_2SO_4
75 %	NaCl	NaCl
63 %	$NaNO_2$	NH_4NO_3
53 %	$Mg(NO)_3 \times 6\ H_2O$	$Mg(NO)_3 \times 6\ H_2O$

ed were still vital and capable of developing. The samples placed in Petri dishes (9 cm ∅) containing 18 ml of Sabouraud medium – 4 % maltose agar, specified in Section 2.1 – were incubated for 14 days at 28°C ± 0.5. The final evaluation was based on the principle presence/absence of growth.

3. Determination of the higroscopicity of papers

For the purpose of this test it is necessary to determine the percent of free water content in different types of paper, as specified in Table 1, in equilibrium with different thermohygrometric conditions. Samples of paper of 1 grams, were placed in dryers with saturated salt solutions as specified in Table 3, for seven days, that was long enough to attain the required equilibrium of paper with the microclimates. For each temperature, relative humidity and type of paper, the test was repeated in triplicate. The moisture percent content was determined using a thermal balance (105° for 5 minutes) and calculating the difference between dry and moisture weight.

4. Results

4.1. Microfungi growth: preliminary test

This test shows that the *Aspergillus terreus*, *Aspergillus niger* and the *Penicilium pinophilum*, whose optimum growth is in acid environment, can develop at neutral-alkaline pH similar to those of paper samples (Table 4).

The *Chaetomium globosum* whose optimum growth is in neutral-alkaline range, is influenced when the pH value falls below 4, as specified in Table 5. The interpretation of the test results according to Section 4.2 was carried out considering the above results.

Table 4. Fungi growth at neutral and alkaline pH

	Czapek - Dox broth + yeast extract								
pH	*Aspergillus terreus*			*Aspergillus niger*			*Penicilium pinophilum*		
6.96	+	+	+	+	+	+	+	+	+
7.31	+	+	+	+	+	+	+	+	+
7.48	+	+	+	+	+	+	+	+	+
7.97	+	+	+	+	+	+	+	+	+
8.51	+	+	+	+	+	+	+	+	+
9.41	+	+	+	–	–	+	–	–	–

Table 5. Fungi growth at acidic pH

	PDA broth		
pH	*Chaetomiumglobosum*		
3.78	+	–	–
4.69	+	+	+
5.73	+	+	+

4.2 Biodegradability of sizings on glasses

Table 6 reports the data on biodegradability of unaged and accelerated aged sizings applied on glass.

Biodegradability of unaged sizings

Maximum growth values were reached on starch. Experiments carried out on ASA size had the following results:

- with no emulsifier, the *Aspergillus terreus*, *Aspergillus niger* and *Penicillium pinophilum*'s growth was moderated and lower than on other materials;
- in mixture 1:1 with emulsifier (necessary for the sizing of paper) the growth was similar to that on starch and heavier than on AKD;

The *C. globosum* had no growth both on ASA and on ASA + emulsifier. It is thus suggested that the low pH of the two samples may play an inhibitory role; data concerning AKD showed a microfungi growth lighter than that supported by starch and by ASA + emulsifier.

RESTAURATOR
Vol 19 (1998), No 2, pages 61 – 114 ISSN 0034-5806

PUBLISHER

K. G. Saur Verlag GmbH & Co KG,
Ortlerstr. 8, D-81373 München
Federal Republic of Germany
Tel. (+49/89) 7 69 02-0
Telex 5 21 206 7 saur d
Fax (+49/89) 7 69 02-150

Komplementärin: R. R. Bowker (UK) Ltd., London (98,5 %) (Alleingesellschafter: Reed Publishing Ltd.)
Komplementärin: K. G. Saur GmbH, München (1 %)
Kommanditistin: Butterworth (Europe) Ltd., London (0,5 %)

ADVERTISING RATES

Advertising rate card Nr. 2
Advertising fact sheet with details of mechanical requirements and closing dates available upon request
Responsible for advertising:
Regina Noichl, K. G. Saur Verlag GmbH & Co KG, Ortlerstr. 8, D-81373 München

SUBSCRIPTION RATES (INCL. POSTAGE)

per annum DM 348,– / öS 2540,– / sFr 310,–
Single copies DM 107,– / öS 781,– / sFr 95,–

BANKING

K. G. Saur Verlag GmbH & Co KG, München
Postbank München,
Kto. Nr. 206 141-804 (BLZ 700 100 80)
Bayer. Hypotheken- und Wechselbank, München, Kto-Nr. 5 803 388 662 (BLZ 700 200 01)

ISSUED:

March, June, September, December

RESPONSIBLE: Dr. Helmut Bansa

Printed on acid-free paper

Production Editor and Typesetting:
Dr. Rainer Ostermann, Jakob-Klar-Str. 3, D-80796 München

Printed in Germany by:
DANUVIA Druckhaus Neuburg GmbH
Nördliche Grünauer Str. 53
D-86633 Neuburg/Donau

Restaurator 19 (1998) 61–84
Printed in Germany

RESTAURATOR
ISSN 0034-5806

Biological Investigation on Sizings for Permanent Papers

by F. GALLO, G. PASQUARIELLO & F. ROCCHETTI

INTRODUCTION

Paper is a complex material consisting of fibrous pulp and additives (mineral fillers, sizings, colorants), processed in order to obtain different products according to the use they are intended for (printing paper, wrapping paper, wall paper and so on). There is a great variety of more or less degradable printing papers (rag paper, chemical pulp paper with a varying percentage of mechanical pulp, coated paper and so on).

Over the last years research has been conducted in order to determine the chemical-physical properties of long term storage papers. The above research has led to the formulation of a new International Standard[1] and of the Standard by UNI for the manufacture of papers with "requirements for the maximum permanence and durability".[2] Permanence is referred to as the "ability of a paper to remain chemically and physically stable over long periods of time without significant deterioration under normal conditions of storage and use", durability is referred to as the "ability of a paper to resist the effects of wear and tear in use over long periods of time".

This Standard applies to the manufacture of papers for the printing of documents, books and any printed matter that for its historical, legal importance has to be preserved for a long time.

PAPER DETERIORATION

Papers of all times may undergo different deterioration processes due both to inherent properties and to external factors. As to the first ones, the basic components and the additives of paper – fibrous materials, sizings – can themselves cause chemical and physical changes or can promote the action of external factors, such as biological agents (insects and micro-organisms), physical agents (light, heat, humidity) and chemical agents (atmospheric pollutants, acid inks etc).

Biodegradability of aged sizings

Maximum growth values of microfungi were obtained on starch. Generally, AKD and ASA (without emulsifier) samples had an increased biodegradability after ageing; the ASA-emulsifier mixture only showed a reduced fungal growth because of its instability that resulted in an increased acidity due to size hydrolysis. It can be thus assumed that accelerated ageing reduces the pH of the samples thus creating a less favourable environment for the deutoromycetes and hostile environment for the *Chaetomium*.

It was also pointed out that the synthetic materials promote microfungi growth. It is assumed that they do not contain fungicide substances which would have otherwise prevented the growth both on adhesive films and on MSA culture medium around the glass (inhibition zone) on which was instead observed a moderate growth (MG) for every sample. The presence of fungicides would have influenced the results of the experiment.

Table 6. Biodegradability of sizings applied on glass (cf. Section 2.3)

Fungi	Sizing	Growth after 21 days: unaged sizings					accelerated aged sizings				
Aspergillus terreus	Starch	HG	HG	HG	HG	HG	HG	HG	HG	HG	HG
	AKD	MG	MG	MG	MG	MG	HG	HG	HG	HG	HG
	ASA	LG	LG	LG	SG	LG	LG	LG	LG	LG	SG
	ASA+Em	HG	HG	HG	HG	HG	LG	LG	LG	LG	MG
Aspergillus niger	Starch	HG	HG	MG	MG	HG	HG	HG	HG	HG	HG
	AKD	NG	MG	MG	LG	LG	LG	MG	MG	MG	MG
	ASA	SG	SG	LG	LG	LG	MG	LG	LG	LG	LG
	ASA+Em	MG	HG	HG	HG	MG	LG	LG	MG	MG	LG
Penicillium pinophilum	Starch	HG	HG	HG	MG	HG	HG	HG	HG	HG	HG
	AKD	MG	MG	LG	MG	MG	HG	HG	HG	HG	HG
	ASA	SG	LG	MG	LG	LG	MG	MG	MG	MG	MG
	ASA+Em	MG	HG	HG	HG	HG	LG	LG	LG	LG	LG
Chaetomium globosum	Starch	HG	HG	HG	HG	HG	HG	HG	HG	HG	HG
	AKD	MG	LG	LG	MG	MG	HG	MG	HG	MG	HG
	ASA	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
	ASA+Em	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG

NG no growth on disk SG sparse growth on disk LG light growth on disk
MG moderate growth on disk HG high growth on disk

4.3 Biodegradability of paper samples

4.3.1 Exposure of the inoculated samples to different micro climates

The data concerning the biodegradability tests on paper samples carried out under the conditions specified in Section 2.4.1, were summarized in Table 7 and 8.

Importance of temperature on paper biodegradability

Microfungi growth was never observed at 20°C temperature and at a relative humidity below 100%. Vice versa, at 30°C the microfungi attack was faster than at 20°C and on 6 samples with 92% relative humidity.

Table 7. Biodegradability of paper samples (incubation temperature 20°C)

Fungi	Sizings	Unaged paper 100 %RH Days*	Unaged paper 100 %RH Growth rate**	Unaged paper 92 %RH Days*	Unaged paper 92 %RH Growth rate**	Accelerated aged paper 100 %RH Days*	Accelerated aged paper 100 %RH Growth rate**	Accelerated aged paper 92 %RH Days*	Accelerated aged paper 92 %RH Growth rate**
Aspergillus terreus	–	/	/	/	/	14	1-(3)	/	/
	Starch	14	3-(5)	/	/	14	2-(5)	/	/
	AKD	28	1-(3)	/	/	14	1-(2)	/	/
	ASA	14	2-(4)	/	/	7	T-(4)	/	/
Aspergillus niger	–	28	T-(3)	/	/	21	1-(2)	/	/
	Starch	140	2-(2)	/	/	21	T-(T)	/	/
	AKD	/	/	/	/	70	T-(2)	/	/
	ASA	28	T-(3)	/	/	21	1-(2)	/	/
Penicillium pinophilum	–	70	1-(3)	/	/	14	2-(3)	/	/
	Starch	14	T-(4)	/	/	14	1-(5)	/	/
	AKD	70	1-(2)	/	/	14	1-(3)	/	/
	ASA	70	2-(2)	/	/	14	1-(3)	/	/
Chaetomium globosum	–	21	2-(3)	/	/	7	T-(2)	/	/
	Starch	21	1-(3)	/	/	7	1-(4)	/	/
	AKD	28	1-(2)	/	/	7	T-(3)	/	/
	ASA	21	2-(3)	/	/	7	T-(3)	/	/

/ = no growth, T= traces of growth, 1= very scant growth, 2= scant growth
3= profuse growth, 4 = strong growth, 5= very strong growth

* Days elapsed between the inoculum an the fungal growth more rapidly occurred during the triplicate test for each trial

** First value refers to the number of days indicated in the adjoining column. The second value (within brackets) refers to the maximum growth observed after 140 days

Table 8. Biodegradability of paper samples: incubation temperature 30°C

Fungi	Sizings	Unaged paper				Accelerated aged paper			
		100 %RH		92 %RH		100 %RH		92 %RH	
		Days*	Growth rate**	Days*	Growth rate**	Days*	Growth rate**	Days*	Growth rate**
	–	/	/	/	/	14	2-(3)	70	1-(1)
Aspergillus terreus	Starch	7	5-(5)	42	1-(3)	7	4-(5)	70	1-(1)
	AKD	14	3-(3)	/	/	14	1-(4)	/	/
	ASA	14	3-(5)	/	/	7	3-(5)	42	1-(2)
	–	14	1-(3)	/	/	21	1-(2)	/	/
Aspergillus niger	Starch	14	1-(4)	/	/	21	T-(1)	70	T-(1)
	AKD	/	/	/	/	21	1-(2)	/	/
	ASA	7	1-(3)	/	/	14	1-(3)	/	/
	–	70	1-(3)	/	/	14	2-(4)	/	/
Penicillium pinophilum	Starch	14	3-(5)	/	/	14	2-(5)	/	/
	AKD	70	1-(2)	/	/	14	1-(4)	/	/
	ASA	70	1-(4)	/	/	14	2-(5)	/	/
	–	7	3-(5)	/	/	7	T-(3)	/	/
Chaetomium globosum	Starch	7	5-(5)	/	/	7	1-(4)	28	T-(T)
	AKD	14	3-(4)	/	/	7	T-(4)	/	/
	ASA	7	4-(5)	/	/	7	T-(5)	/	/

Role played by the sizings

In most cases starch sized paper supported fungal growth which was faster and more intense compared to that on an unsized sample (with the only exception of *Aspergillus niger* that grew on an unaged sample at 20°C). Starch gave paper, also in comparison with samples sized with synthetic materials, a greater vulnerability to fungal attack as stated by our previous test results[18].

Paper sized with ASA supported a fungal growth in a similar if not equal way than that of unsized paper for samples inoculated with *Aspergillus niger, Penicillium pinophilum* and *Chaetomium globosum.* The only differences resulted from the comparison among samples inoculated with *Aspergillus terreus* and were particularly evident in case of unaged paper. In fact, paper sized with ASA had a fungal growth after 14 days, both at 20°C and at 30°C, while no growth was observed on the reference sample. For the above reasons, it is possible to affirm that ASA as well as starch, have increased paper biodegradability to different extent.

Among the tested samples, those sized with AKD gave the best results because they supported a reduced fungal attack compared to the other sizes. Moreover, the *Aspergillus niger, Penicillium pinophilium* and *Chaetonium globosum* had the same or similar difficulties to develop on paper sized with AKD, than on the unsized

reference samples at the above incubation temperatures. In particular, the samples inoculated with A. niger resisted the attack while on the reference sample the attack was observed after 28 and 14 days respectively at 20 and 30°C. The only exception to this trend is represented by the unaged sample inoculated with *A. terreus* at different temperatures; in this case growth was faster than growth on the unsized sample.

Effects of accelerated ageing

The data reported in Tables 7 and 8 suggest a comparison among the growth values of unaged or accelerated aged paper at every temperature. At 100% relative humidity the growth of microfungi test resulted to be faster after the ageing. This is particularly evident for the samples inoculated with *Penicillium pinophilum* and in those case of unsized paper inoculated with *Aspergillus terreus* and of AKD sized paper inoculated with *Aspergillus niger.* After the test, the unaged paper did not support any growth in the last two cases. It was also pointed out that aged paper supported fungal growth in 5 cases at 30°C and 92% RH while in only one case with unaged paper.

Different microfungi growth rate

The *Chaetomium globosum* had a fast growth at 20°C and 30°C both on unaged paper samples and on accelerated aged samples, growth rate was higher than that of other microfungi in many cases.

4.3.2 Control of spore's life

Test results on spore's life, carried out under the conditions specified in Section 2.4.2, are shown in Table 9 and 10. Spore's life depend on the test fungus strains, on the ageing of the samples and on the temperature as well as on the relative humidity.

Vitality of the spores inoculated on unaged paper

After 140 days of incubation at 20°C, a life drop was observed at 63% relative humidity with only two exceptions: the *Aspergillus terreus* on unsized paper and paper sized with AKD and the *Aspergillus niger* on every sample. The *Aspergillus niger* proved to be the more vital as it developed also at other tested values of relative humidity.

A sharp drop of microfungi life was observed at 30°C and 63% relative humidity; the seeding ability was frequently lost (12 cases out of 16), even at 75% relative humidity and at 85% relative humidity (10 cases out of 16).

Table 9. Vitality of spores inoculated on unaged paper

		unsized % RH					starch % RH					AKD % RH					ASA %RH				
		92	85	75	63	53	92	85	75	63	53	92	85	75	63	53	92	85	75	63	53
Aspergillus terreus				+	+	+	+	+				+	+	+	+	+	+	+	+	+	+
Aspergillus niger	20°C	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus pinophilum		+	+	+		+	+	+	+			+	+	+		+	+	+	+		+
Chaetomium globosum		+	+	+		+	+	+	+			+	+	+		+	+	+	+		+
Aspergillus terreus						+	/					+	+			+	+	+			+
Aspergillus niger	30°C	+	+			+	+	+			+	+				+	+				+
Aspergillus pinophilum		+				+	+				+	+				+	+				+
Chaetomium globosum		+	+	+		+	+	+	+		+	+		+		+	+		+		+

Table 10. Vitality of spores inoculated on accelerated aged paper

		unsized % RH					starch % RH					AKD % RH					ASA % RH				
		92	85	75	63	53	92	85	75	63	53	92	85	75	63	53	92	85	75	63	53
Aspergillus terreus																	+				
Aspergillus niger	20°C	+				+					+	+				+	+				+
Aspergillus pinophilum																					
Chaetomium globosum						+					+				+						
Aspergillus terreus			/				/					+					/				
Aspergillus niger	30°C	+					/					+					+				
Aspergillus pinophilum		+										+					+				
Chaetomium globosum							/														

\+ vitality of spores

/ test not carried out because of growth on paper already occurred

Vitality of the spores inoculated on accelerated aged paper

The accelerated ageing of paper played a negative role. In fact, there was a spore's life drop of microfungi test at 85%, 75% and 63% relative humidity. At 53% RH only *Aspergillus niger* and *Chaetomium globosum* withstood their seeding ability, and at 92% also the Aspergillus niger in 3 cases out of 4. At 30°C the microfungi test could not withstand their seeding ability at 85%, 75%, 63%, 53% RH and in some case even at 92% RH.

For the preservation of spore's life, the temperature of 30°C and 63% relative humidity represent the less favourable thermo-hygrometric conditions. At 30°C the critical hygrometric condition range for the microfungi is wider especially for aged paper.

Table 11. Determination of moisture content (%) of unaged paper (mean values of three measurements)

	100%		92%		85%		75%		63%		53%	
paper	20°C	30°C	20°C	30°C	20°C	30°C	20°C	30°C	20°C	30°C	20°C	30°C
unsized	18,0	18,1	10,7	11,2	10,1	9,0	8,3	7,8	6,8	6,3	6,4	6,0
starch sized	18,4	21,7	12,5	12,4	10,8	10,7	9,2	8,6	7,9	7,3	7,0	6,8
AKD sized	16,7	16,5	9,9	9,9	9,4	9,65	7,9	7,6	6,6	6,9	6,0	5,0
ASA sized	16,3	17,8	11,0	10,2	9,0	9,6	8,1	7,5	6,6	5,7	5,7	5,0

Table 12. Determination of moisture content (%) of accelerated aged paper (mean values of three measurements)

	100%		92%		85%		75%		63%		53%	
paper	20°C	30°C	20°C	30°C	20°C	30°C	20°C	30°C	20°C	30°C	20°C	30°C
unsized	13,8	14,5	8,8	10,5	8,2	8,1	7,3	6,8	6,2	5,5	5,1	4,7
starch sized	17,1	16,8	11,1	11,9	9,3	9,5	8,1	7,3	7,2	6,8	6,3	5,4
AKD sized	15,5	14,2	9,9	9,1	7,5	7,5	6,8	6,6	6,9	6,6	6,4	4,7
ASA sized	14,5	14,3	9,7	9,7	8,2	8,2	7,1	6,5	5,9	6,4	6,3	4,2

4.4 Determination of paper hygroscopicity

The results of the measurements of the moisture percent content of paper samples in balance with different thermo-hygrometric conditions are shown in Table 11–12.

Influence of accelerated ageing

The paper samples that underwent accelerated ageing have a lower moisture content compared to the unaged samples; for example, the moisture percent content of accelerated aged samples is generally 2 points lower at 100% R. H., is one and half point lower at 53% RH.

Influence of sizings

The AKD and ASA synthetic sizes do not increase the paper hygroscopicity, indeed if compared to the unsized reference sample a reduced moisture percent content is observed. Whereas, starch increases the hygroscopicity.

5 DISCUSSION AND CONCLUSIONS

In the light of these results, we pointed out that paper samples conforming the characteristics for maximum permanence and durability do not promote the cellulolytic fungi growth under the thermo-hygrometric conditions suggested for paper conservation. Anyway, in most cases, the microclimates of the librarian and archival storehouses do not correspond to the ideal microclimates because of the absence of air conditioning systems. The results reported in 4.3.1 concerning the biodegradability test of paper samples at different microclimates, are somehow promising because the fungal growth occurred only at high hygrometric levels. In particular paper sized with AKD has never supported the microfungi growth below 100% relative humidity.

Remarks on the influence of the sizings

The results reported in Section 4.3.1 stress the importance of the choice of the best suited sizings. Indeed they can help or prevent the biodeterioration processes of paper, depending on the fact they constitute or do not constitute a trophic resource for the micro-organisms or they increase or decrease the hygroscopicity. The AKD, among others, is the best suited to meet these requirements. The AKD sized paper samples have never supported the growth of fungi at hygrometric values below 100% RH and when it occurred, the growth was in general slower and less heavy if compared to other samples. Data in Section 4.4 point out that the AKD sized samples with a few exceptions, have a lower moisture percent content than the unsized samples, at the same hygrometric values. The table of results shows that these samples are the only ones that at a relative humidity below 100%, never reach a moisture percent content over 10%.

The samples sized with the other synthetic size the alkenilsuccinic anhydride ASA, indicated on the one hand a moisture percent content lower than the unsized samples, on the other hand the microfungi test found the trophic resources necessary to support a faster and heavier growth than that on the reference samples. In the light of these results, the ASA can be considered less suited than AKD for the sizing of paper to be preserved as long as possible.

Finally, papers sized with starch have better supported the fungal growth than synthetic materials, and it was also pointed out that starch has two negative characteristics:

- it is a source of organic carbon more quickly available than cellulose as proved by a fast and heavy growth of microfungi (Table 7 and 8);

- it distinctly increases the moisture percent content of aged and unaged papers (Table 11 and 12) that was higher than that of other samples under every thermo-hygrometric condition.

We thus give a negative opinion as regards the use of starch for the sizing of papers conforming the requirements for "maximum permanence and durability" that according to UNI standard 10332 must not contain substances capable of degrading it.

It is a widespread opinion that the results concerning the sizings on an inert medium are similar to those obtained on a paper medium; in both cases AKD prevented growth of fungi more than ASA with emulsifier and vice versa, starch supported it better. Tests conducted on an inert medium and not those on paper medium, gave a new indication: the biodegradability of ASA size was deeply influenced when adding an emulsifier compound, the acrylamide polymer. In fact ASA without emulsifier recorded low values of growth, lower than those of other materials.

It is evident that nitrogen present in the emulsifier polymer helped the microfungi growth. It is thus suggested for the carrying out of future tests the possibility of replacing the above polymer with an alternative compound.

Remarks on the effects of neutral alkaline pH

Some remarks can be made on the effects of neutral alkaline pH of permanent paper samples ranging between 8.0 and 8.2, on biodegradability. The results in Section 4.3.1 show a difference among the microfungi tests as regards the growth rate. In particular the *Chaetomium globosum* had the fastest growth on nearly every paper sample. This is particularly interesting if we consider that *Chaetomium globosum*, being a Ascomycete fungus has a life cycle longer than the Deuteromycetes, *Aspergillus terreus, Aspergillus niger* and *Penicillium pinophilum* (asexual reproduction). In this case alkaline neutral pH of paper probably reduced the growth of the three deuteromycetes whose optimum growth is in acid environment but did not prevent the growth of *Chaetomium* whose optimum range is between 7.1 and 10.4[17]. This remark is confirmed by the result of a previous experiment[19] according to which alkalinity partially or totally inhibited the enzymes of the cellulasi complex of some microfungi. The *Aspergillus terreus*, for example, showed a progressively reduced cellulolytic activity passing from a culture medium (with cotton cellulose as only source of carbon) buffered at 4.5 pH to culture medium at 6.0 and 7.0 pH.

The presence of the alkali reserve of calcium carbonate renders the substrate less available to the microfungi attack because it causes a reduction of the acid hydrolysis process as well as the swelling of cellulose.

Remarks on the effects of thermo-hygrometric conditions

Paper samples never supported microfungi growth at a relative humidity below 100% and at 20°C temperature.

On the basis of the results obtained we reported the following:

- the rise in temperature hasten the microfungi growth (Table 7 and 8);
- the rise in temperature shorten the life span of the spores (Table 9 and 10).

As to the first point, the results in Section 4.3.1 show that in some cases the rise in temperature helped the biodegradation due to the microfungi growth at relative humidity below 100%, because the optimum temperature for the microfungi growth is at 30°C more than at 20°C. (*A. terreus* 35–40°C, *A. niger* 17–42°C, *P. pinophilum* 25–28°C and *C. globosum* 24–28°C).

As to the second point, the results in Section 4.3.2 pointed out that the lifespan of the spores is longer at 20°C than at 30°C. It is thus possible that higher values hasten the latent metabolism of the spores thus rapidly exhausting their resources.

The experiments indicated that the hygrometric values affect the vitality of spores as well as the temperature. At 85%, 75% RH and sometime at 63% RH a reduced capacity to germinate was observed. In most cases spore's life was preserved at 53% RH

On the basis of the above results, it can be affirmed that the life of the spores is longer under the microclimatic conditions suggested for paper conservation. This is confirmed by the results of a recent research conducted by the Istituto Centrale per la Patologia del libro[9].

Remarks on the effects of accelerated ageing

From the comparison between the growth values of accelerated aged and unaged paper it results that the growth on an aged material is faster at 100% RH and that it more easily occurs at 92% relative humidity. The above data can be explained considering that the accelerated ageing process adopted to simulate the effect of natural ageing causes significant changes in the structure of paper; cellulose tends to hydrolize and to swell while the main additives, like the sizings, may degrade.

The changes in the structure of cellulose cause a drop of the polymerization degree and a transition from crystalline form to amorphous form. A few researchers have stressed that these effects, regardless the causes, bring about an increase of the hydrolysis rate produced by the enzymes of the fungal cellulase. In fact, the depolymerization exposes a greater number of cellulose molecules to the action of the esoglucanasic component of the cellulase complex and the increased

percent content of amorphous cellulose makes the substrate easily accessible to the action of hydrolytic enzymes[3].

The results given in Section 4.4 indicate that the accelerated ageing causes a reduction of the moisture percent content. The above data, confirmed by previous experiments[20 21 22], clearly do not promote the metabolic activity of the biological substances causing the degradation of paper. It is reduced, but this is not sufficient to compensate the effects due to the reduction of the polymerization degree and the cristallinity degree of the cellulose.

Finally the experiments indicate that paper ageing has a negative effect on the preservation of spore's vitality. It can be assumed that this remark is to be correlated to the moisture percent content of aged paper which could cause the spores to exhaust more rapidly their reserves.

SUMMARIES

Biological investigation on sizings for permanent papers

We have conducted a research on the biodegradability of papers conforming to UNI 10332 "Carta per documenti – requisiti per la massima permanenza e durabilità" (Paper for documents – requirements for maximum permanence and durability) caused by the cellulolytic fungi. A particular importance was given to the effect of three sizings most widely used in the manufacture of papers intended for printing of documents, books and any printed matter that for its historical, legal importance has to be preserved for a long time. We prepared samples of paper in accordance with the Standard different only for the sizings. Successively we tested the biodegradability both of the sizings on an inert backing and of the samples of paper left in incubation at ranging temperatures (20°C and 30°C) and relative humidity (100%, 92%, 85%, 75%, 63%, 53%) for twenty weeks. We used for the tests fungus strains of the types most frequently isolated from paper materials. We then studied the effect of the sizings on paper hygroscopicity and the existing relationships between the thermo-hygrometric values of paper incubation and the incidence of the spore's survival. The results obtained were summarized as follows:

- The paper conforming to UNI 10332 supported the fungus attack only under particularly critical thermo-hygrometric conditions. Its neutral alkaline pH value has inhibited the growth of most cellulolytic fungi;
- The accelerated ageing helped cellulolytic fungi attack because of the degrading action on the cellulose fibres and on the sizings, despite the reduction of the moisture content available to micro-organisms;
- The thermo-hygrometric conditions of incubation and the accelerated ageing deeply affected the spore's life: in particular, it was pointed out that the spores survived for a longer time under the thermo-hygrometric conditions suggested for paper conservation;
- The choice of the sizings has sometimes strongly affected the paper biodegradability and its hygroscopicity: one sizing, in particular, was suited for the manufacture of the "permanent pa-

9. Gallo, F., P. Valenti, P. Colaizzi, M. Scorrano, M.C. Sclocchi, O. Maggi & A.M. Persiani: *Ricerca sulla vitalità delle spore fungine in relazione a diversi microclimi e materiali.* International Conference on Conservation and Restoration of Archive and Library Materials, Erice 1996.
10. Gallo, F.: *Il biodeterioramento di libri e documenti.* Rome: Centro Studi per la Conservazione della Carta and ICCROM 1992.
11. Eriksson, K.E., R.A. Blanchette & F. Ander: *Microbial and enzymatic degradation of wood and wood components.* Berlin 1990.
12. Siu, R.G. H.: *Microbial decomposition of cellulose*. New York 1951.
13. Privalov, V.F.: *Particularités de transfert d'humidité documents, milieu dans les magasins d'archives de différents types.* Archives et Bibliothèques de Belgique, Numéro spécial 12 (1974): 255–266.
14. Zaguliaeva, Z.A., & E.Ya. Perl'Shtein: *Condition of storage of documents in archives.* Preservation of Documents and Papers, ed. D.M.Flyate. Moscow: Acad. of Science of the USSR 1968.
15. Biermann, C.J.: *Essential of pulping and papermaking.* New York 1993.
16. Block, S.S.: *Humidity requirements for mould growths.*. Engineering Progress at the University of Florida 7 (1963): 10.
17. Domsch, K.H., W. Gams, & T.H. Anderson: *Compendium of soil fungi.* London 1980.
18. Gallo, F., C. Marconi, & M. Montanari: *Ricerche sperimentali sulla resistenza agli agenti biologici impiegati nel restauro dei libri VIII: Saggi sulla resistenza all'attacco microbico di adesivi.* Bollettino dell'Istituto Centrale per la Patologia del Libro 43 (1989): 105–120.
19. Nyuksha, Yu. P., & L.A. Kossior: The fungal *cellulasic activity depending on the pH level.* Mikologija i Fitopatologija 10 (1976): 477-484 (in Russian).
20. Attanasio, D., D. Capitani, C. Federici, C., M. Paci & A.L. Segre: *Electron paramagnetic resonance and ^{1}H ^{13}C NMR study of paper.* ACS Symposium Series 598 (1995): 333–353.
21. Gallo, F., C. Marconi & M. Montanari: *Indagine sulla resistenza all'attacco microbico di carte aventi diversa igroscopicità.* Bollettino dell'Istituto Centrale per la Patologia del Libro 34 (1977): 127–159.
22. Nyuksha. Yu. P.: *Resistance of experimental paper samples to mould attack.* Preservation of Documents and Papers, ed. D.M. Flyate. Moscow: Academy of Science of the USSR. In Russian. English translation done by the Israel Program for Scientific Translation. Jerusalem 1968: 54–59.

F. Gallo
Former Director of the Biology Laboratory of the Istituto Centrale per la Patologia del Libro
via Milano 76, I-00154 Roma
Italy

G. Pasquariello
Director of the Biology Laboratory of the Istituto Nazionale per la Grafica
via della Lungara 230, I-00185 Roma
Italy

F. Rocchetti
Istituto Poligrafico e Zecca dello Stato, Servizio Centrale Ricerche e Nuovi Prodotti
piazza Verdi 10, I-00198 Roma
Italy

Restaurator, 1998, 85–107
Printed in Germany · All rights reserved

RESTAURATOR
ISSN 0034-5806

Microbial Control in Archives, Libraries and Museums by Ventilation Systems

by NIEVES VALENTÍN, RAFAEL GARCÍA, OSCAR DE LUIS & SHIN MAEKAWA

INTRODUCTION

There are many historical buildings located in humid climatic regions where the average annual relative humidity is well above 80%. Architects in those regions have incorporated specific features and maintenance requirements in their building designs to deal with the moist environment. Users of the buildings also had to develop common sense procedures to maintain best possible environment. However, over the years many buildings and their surroundings were modified to meet changing occupant's requirements. Moreover, some of the structures were adapted to house archive, library and museum collections. Added requirements, such as security, compliance to local building and fire codes, and pest control, have gravely altered original provisions for climate controls. Thus, the present structures maintain microenvironments that aid the growth of micro-organisms, such as fungi and bacteria, on their collections.

Conservators and collection managers have been coped with the microbial contamination problem through chemical disinfection. To avoid hazards to collections and to professionals working with them it was considered necessary to search for a safe, effective and locally sustainable solution for the problem.

Fungi and bacteria

The activity of fungal and bacterial species is supported by a multitude of factors including: environmental relative humidity, temperature fluctuations, light, nature of nutrients on the support, moisture content in it, physical properties of the

surface of the object, moisture adsorption-desorption mechanism in the material, pH, osmotic pressure, environmental air movement and its depth of penetration in the objects, oxygen and carbon dioxide concentrations in the atmosphere, presence of microclimates that may induce condensation, dust, and, finally, exposure time to specific environmental conditions.

The moisture content in a material is one of the most important factors for microbial growth because it determines the water available for the germination of microbial spores. Many fungal and bacterial species start their development depending on the available moisture on the surface of an object. Therefore, the risk of microbial contamination in a material can be estimated by the water activity number (a_w), that indicates the amount of water available for biochemical reactions in cells. Most micro-organisms can grow in a range of a_w of 0.6–0.98. Bacteria require a_w higher than 0.95, and fungi need lower a_w for their development (commonly in a range of 0.70 – 0.85). *Aspergillus niger, A. glaucus, A. nidulans, Fusarium oxysporum, Penicillium commune* require a_w of 0.71 – 0.80 for their growth[1]. Florian (1993)[2] investigated the relationship between moisture contents of a substrate and the availability of water for germination of spores.

Paper

The relationship between the environmental relative humidity (RH) and the equilibrium moisture content of Whatman paper at different temperatures was reported by Gallo (1992)[3]. She indicated that paper exposed to 50% RH had a moisture content of 7.4% at 22° C. Over the years, these conditions have been considered to be ideal for paper conservation. In contrast, paper exposed to 63% RH at 20° C had a moisture content of 7.9% level which has been considered as a risk for fungal growth.

Caneva *et al.* (1991)[4] describe the chemical alteration of historic materials by micro-organisms as due to their metabolic products including organic and inorganic acids, alkalis, chelating agents, enzymes and pigments. In fact, exoenzymes cellulases, proteinases, tannases, ß-glucosidase and many organic/inorganic acids produced by microbial cells play an important role in the hydrolysis of cellulose and proteinaceous materials. Many *Penicillium* and *Aspergillus* strains are particularly harmful to paper because they have a high level of cellulolytic activity and grow in materials with a moisture content of 7–8%. These conditions can be produced in cellulose objects exposed to 63–65% RH (Table 1). The micro-organisms also produce the metabolic water, which increases the moisture content in the material and favours microbial growth. A pH ranging from 4 to 6 is adequate for the development of many fungal strains.

Table 1. Micro-organisms with a high cellulolytic activity commonly isolated from paper and environment: Conditions required for the growth. Data by Schlegel[1], Upsher[17], Gallo[3] and Valentin[15].

Micro-organisms	Temperature (°C)			RH (%)		Water activity	Moisture content of paper (%) required to grow	minimum RH (%) allowing growth	Minimum time needed to grow on paper (days)
	Opt.	Min.	Max.	Opt.	Min.				
Bacillus subtilis	25–35	5	50	90–100	65	> 0.9	> 10–12	90	2 at 100% 5 at 90%
Penicillium commune	24–30	–5	50	65–100	50	>0.7	>7	83.5% at 10° 77.0% at 15° 72.5% at 25°	5 at 100% 120 at 70%
Aspergillus niger	24–30	–10	50	75–100	50	>0.8	>7-8%	95% at 10° 90% at 15° 85% at 25°	7 at 100% 130 at 85%

The effect of environmental RH on the chemical deterioration of paper was investigated by Erhardt (1994)[5]. He showed that the rate of hydrolysis of paper is minimized by reducing the RH. However, cross-linking of cellulose chains can start at low RH levels. To avoid this effect, Erhardt suggests that RH be maintained above 25% for papers. However, the hydrolysis of cellulose was increased by a RH higher than 50%. Thus, Erhardt recommended a RH between 25–50% as the optimum range for paper conservation.

Parchment

Anaerobic bacteria are the most deleterious micro-organisms to parchment. The slightly alkaline pH of parchment induces bacterial growth. Collagen can be easily hydrolyzed by collagenase produced by bacteria such as *Clostridium*[6]. Strains of *Bacillus, Pseudomonas, Sarcina* and *Bacteroides* induce collagen degradation in anaerobic conditions. Other proteins and lipids of parchment may also be altered by enzymes that are products of aerobic fungal and bacterial species. According to Petushkova *et al.* (1996)[7] *Bacillus subtilis* exhibits the highest activity in hydrolyzing native collagen which occurs above 95% RH. Petushkova *et al.* indicated that *Bacillus* requires a minimum environmental RH of only 65% for its germination. However, most of *Bacillus* needs a RH above 90% for optimum reproduction and development. She observed an increased growth rate of anaerobic bac-

per": paper sized with it has supported the fungus development at only 100 % relative humidity, both before and after the accelerated ageing.

We hope this work is a practical contribution to the choice of the sizings that from biological view point, are best suited for the manufacture of paper to be preserved as long as possible.

Recherches biologiques sur les colloïdes pour la permanence du papier

Nous avons mené des recherches sur la biodégradabilité des papiers conformément à UNI 10332 (Papier pour documents - exigences maximum relatives à la permanence et à la durabilité) causée par des moisissures cellulosiques. Une importance toute particulière a été consacrée à trois substances colloïdales différentes qui sont utilisées fréquemment dans la fabrication du papier dont on se sert pour confectionner livres et documents qui en raison de leur valeur historique et juridique doivent être conservés pendant très longtemps. Des échantillons de papiers ont été préparés – selon les standards respectifs – qui ne se différenciaient que par la substance colloïdale. Ensuite on a analysé la biodégradabilité des colloïdes sur support inerte comme sur le papier. Les échantillons ont été imprégnés de champignons de moisissure que l'on trouve fréquemment sur le papier et exposés pendant 20 semaines à différents degrés de températures (20°C et 30°C) et d'humidité (100%, 92%, 75%, 63%,53%). Puis on a étudié l'effet des colloïdes sur l'hydrophilie du papier ainsi que le rapport entre les données thermohygrométriques de l'imprégnation du papier et de la vitalité des spores. Les résultats ainsi obtenus sont sommairement les suivants :

- Le papier conforme à UNI 10332 n'a propagé l'attaque de champignons que dans certaines conditions thermo-hygrométriques critiques. Sa valeur pH alcaline neutre a inhibé la croissance de la plupart des champignons de moisissure cellulosiques.
- Le vieillissement accéléré a favorisé l'attaque des champignons cellulosiques à cause de son action de dégradation sur les fibres cellulosiques et sur les colloïdes bien que l'absorption d'eau, nécessaire au développement des micro-organismes, soit réduite.
- Les conditions thermohygrométriques et le vieillissement accéléré influencent fortement la vitalité des spores. On a mis en particulier en évidence que des spores, placées sous certaines conditions thermohygrométriques recommandées pour la conservation du papier, restaient vitales plus longtemps.
- La nature du colloïde a une forte influence sur la biodégradabilité et l'hydrophilie du papier. Une certaine sorte de colloïde semble particulièrement adaptée pour assurer la permanence du papier: le papier traité avec celui-ci n'a propagé l'attaque de champignons qu'à un degré d'humidité de 100%, avant comme après le vieillissement accéléré.

Il ne reste plus qu'à espérer que cet article contribuera à éclairer le choix du colloïde à utiliser d'un point de vue biologique afin que le papier puisse être conservé le plus longtemps possible.

Biologische Untersuchung der Leimung für alterungsbeständiges Papier

Es wurde eine Untersuchung zur biologischen Abbaubarkeit von dauerhaftem Papier nach UNI 10332 (Papier für Dokumente – Anforderungen an die höchste Alterungsbeständigkeit und Dauerhaftigkeit) durch cellulolytische Schimmelpilze durchgeführt. Besondere Aufmerksamkeit wurde der Wirkung der drei Leimungsmittel gewidmet, die vielfach zur Herstellung von solchem Papier

eingesetzt werden, das für Bücher und Dokumente eingesetzt wird, die wegen ihres bleibendem historischem oder juristischem Wert lange aufzubewahren sind. Es wurden – nach dem entsprechenden Standard – Proben von Papier vorbereitet, die sich nur in der Leimung unterschieden. Anschließend wurde die biologische Abbaubarkeit der Leimungsmittel sowohl auf inerter Unterlage als auch auf dem Papier untersucht. Die Proben wurden mit den am häufigsten auf Papier gefundenen Schimmelpilzen beimpft und 20 Wochen lang verschiedenen Temperaturen (20°C und 30°C) und verschiedenen Feuchtigkeiten (100 %, 92 %, 85 %, 75 %, 63 %, 53 %) ausgesetzt. Weiterhin wurde die Wirkung der Leimungsmittel auf die Wasseraufnahmefähigkeit des Papiers und das Verhältnis zwischen den thermohygrometrischen Gegebenheiten der Inkubation und der Sporenvitalität untersucht. Die Ergebnisse lassen sich wie folgt zusammenfassen:

- Papier nach UNI 10332 befördert einen Schimmelangriff nur unter bestimmten kritischen thermohygrometrischen Bedingungen. Sein neutrales bzw. alkalisches pH behindert das Wachstum der meisten cellulolytischen Schimmelpilze.
- Wegen des dabei auftretenden Celluloseabbaus befördert eine beschleunigte Alterung den Schimmelangriff, obwohl sie die Aufnahme von Wasser, das für Mikroorganismen notwendig ist, reduziert.
- Die thermohygrometrischen Bedingungen und die beschleunigte Alterung beeinflussen nachdrücklich die Lebensfähigkeit der Sporen. Insbesondere zeigte sich, daß die Sporen unter den thermohygrometrischen Bedingungen, die für die Konservierung von Papier empfohlen werden, länger vital bleiben.
- Die Art des Leimungsmittels hat einen starken Einfluß auf die biologische Abbaubarkeit und die Wasseraufnahmefähigkeit. Ein bestimmtes Leimungsmittel erscheint besonders geeignet für alterungsbeständiges Papier: das mit ihm geleimte Papier beförderte einen Schimmelangriff nur bei 100 % rF, sowohl vor als auch nach beschleunigter Alterung.

Es bleibt zu hoffen, daß dieser Bericht dazu beiträgt, für alterungsbeständiges Papier die Leimung zu wählen, die es, vom biologischen Standpunkt aus gesehen, am besten für die längstmögliche Konservierung ausrüstet.

REFERENCES

1. *ISO 9706 – Information and documentation – Paper for documents – Requirements for permanence.* February 1994.
2. *UNI 10332: Documentazione e informazione – Carta per document – Requisiti per la massima permanenza e durabilità.* 1994.
3. Gascoigne, J.A., & M.M. Gascoigne: *Biological degradation of cellulose.* London 1960.
4. Botto Micca, G., E. Grandis, E.: *Carta.* Società editrice internazionale 1968.
5. Chiavarini, M., & S. Palazzi: *Spegnere il lento incendio:la deacidificazione di libri e biblioteche.* Media Plus News 6 (October 1994).
6. Javicoli, E.: *Carta neutra, una svolta, una realtà, un'opportunità.* Proceedings XV Italian Technical Association for Pulp and Paper Meeting, Florence 1982.
7. Grandis, E.: *Aspetti teorici e pratici della collatura neutra.* Proceedings XV Italian Technical Association for Pulp and Paper Meeting, Florence 1982.
8. Nyuksha, Y.: *The biodeterioration of paper and books.* Recent Advances in Biodeterioration and Biodegradation, ed. K.L. Garg et al., Calcutta 1993.

teria in a newly manufactured parchment when its environment was changed from 55% to 98% RH and this resulted in doubling the moisture content of the material.

Hansen *et al.* (1992)[8] studied the gelatinization or hydrolysis of collagen. They indicated that the hydrolysis rate increases at RH between 40 and 100%. The rate of gelatinization decreased at the RH between 25 and 40%. Highly desiccated collagen (exposed at RHs lower than 25%) may not be completely rehydrated and thus becomes permanently deformed. For this reason, Hansen suggested a value of 30% RH as the optimum for the storage of proteinaceous materials composed of collagen. Valentin *et al.* (1990)[9] showed that only 10 hours of exposure of parchment at 45% RH in a 0.1% oxygen environment was required to initiate a decrease in microbial growth. Obviously, anaerobic bacteria can grow in an oxygen excluded environment; however, they require an a_w of 0.98. According to these data, a low oxygen atmosphere with low RH was found to be effective in preventing microbial development in historic objects.

Ventilation drying

Outside air can enter a building either intentionally, through ventilation, or unintentionally, through infiltration. The rate of ventilation or infiltration is normally expressed in air exchange rate, I, and has unit of 1/time. It is expressed as

$$I = Q / V$$

where Q = volumetric flow rate of air into space, and V = interior volume of space. If we select hour as the time unit, the rate is called air changes per hour (ACH). Therefore, one ACH represents the ventilation rate whose hourly volumetric flow rate is equivalent to the interior volume of the space. The higher the ACH, the more ventilation the space will have. A normal air condition (HVAC) system provides 8 to 10 ACH for an occupied office space, and a well designed cross ventilation produced by a pair of open windows can achieve over 20 ACH[10]. The ventilation rate (ACH) is a spatial average value, and local values may vary significantly throughout the room if the air is poorly mixed in the space.

The literature describes research to assess and predict changes of moisture content by transfer among different materials located in buildings at a high RH. Cuningham (1992)[11] and Scott (1994)[12] reported that the diffusion rate, hygroscopic characteristics of the substrate and its thickness determine the change of a material moisture content.

The literature shows that microbes do not grow when surrounding air is in motion at a low relative humidity[13 14]. Preliminary analyses by Valentin (1996)[15]

indicated that this phenomenon is dependent on the temperature, rate of ventilation and the physical-chemical properties of the materials[16]. However, the isolated effect of ventilation on microbial growth has not been investigated as a method of control of biodeterioration specifically on historic materials.

OBJECTIVES

The present work was, therefore, carried out to quantify requirements for ventilation which control microbial activity on historic materials in museum, library, and archive buildings that are located in humid climatic regions. Therefore, the aims were as follows:

- Determine the efficacy of ventilation rates and environmental conditions in arresting microbial growth and decreasing its activity in contaminated environments and historic materials.
- Explore the behaviour of specific fungal and bacterial strains commonly isolated from historic materials when they are exposed to different environmental conditions.

MATERIALS AND METHODOLOGY

Materials

Analyses were carried out using groups of 6 cm x 6 cm samples (Whatman no. 1) as a substrate for the development of inoculated micro-organisms. Non-inoculated paper samples were used as controls.

Design of an environmental chamber

An environmental chamber of approximately 500 liters was made of methacrylate, and a small pre-chamber with a double door to avoid external contamination was attached to the main body of the case (Fig. 1). In the experiments, the chamber was purged using dry air supply (C-45, Carburos Metálicos, Spain). To establish a desired RH in the chamber, part of the air flow was divided to pass to a flask (F1) where it was humidified by bubbling through water. Dry and humidified air were mixed in the second flask (F2). The ratio of wet to dry air was controlled using a needle valve and flow regulators. The combined air flow entered

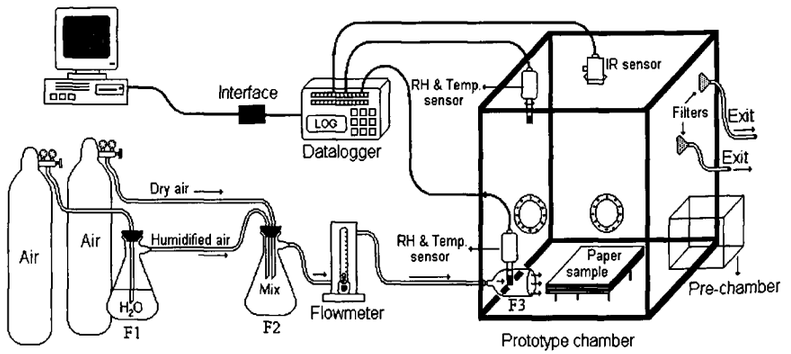


Fig. 1. Experimental environmental chamber

the third flask (F3) that had a humidity and temperature transmitter (Vaisala Inc.). From the mixing flask (F2), the air was passed to the test chamber using a flow meter to control the mixed air flow. Another relative humidity and air temperature transmitter was placed in the chamber to measure the environmental parameters in it.

Paper samples, inoculated with selected microbial contaminants, were placed in the chamber for exposure to various environmental conditions established by the combinations of parameters as following:

- environmental temperature: 20, 22, and 24° C
- environmental relative humidity in the chamber: at different ranges of 60–65, 65–70, 70–75, 75–80 and 80–85% respectively.
- air relative humidity: in ranges of 55–60, 60–65 and 65–70
- ventilation rate: 0.12, 0.24, 0.48, 0.71, 0.96, and 1.2 ACH, corresponding to 1, 2, 4, 6, 8 and 10 L/min respectively used to purge the environmental chamber.
- exposure time: maximum of 25 hours

To indirectly detect changes (moisture content and microbial activities) in the materials without disturbing the exposure of the paper, an infrared (IR) temperature transducer (Omega Engineering Inc.) was used to measure temperature changes on the paper surface. Thus, the correlation among microbial growth, environmental parameters and temperature on the paper surface was analyzed. A datalogger (Campbell Scientific Inc.) was installed to collect data that were then graphically processed and evaluated. Both samples of air in the chamber and of the papers were analyzed for microbial contamination. The quantitative results

were expressed in colony forming units (CFU) per sample, that reflect the number of colonies developed from each microbial cell.

The measured parameters were as follows:

- environmental relative humidity (RH%)
- environmental temperature (T° C)
- ventilation rate (air exchange/hour)
- air relative humidity (air RH%)
- air temperature (T° C)
- temperature on the paper surface (IRT° C)
- environmental microbial contamination in the chamber (CFU)
- microbial contamination in inoculated paper (CFU)
- microbial contamination in non-inoculated paper controls (CFU),
- exposure time (hours).

Microbial analysis

During the author's previous work (Valentin 1996)[15], fungal and bacterial species were isolated from air samples and contaminated objects in museums and archives in Spain. Tables 2 and 3 show the most common genera identified, their metabolites affecting biodeterioration and the minimum RH required for growth. *Penicillium commune* produces cellulase, protease, organic and inorganic acids. *Bacillus subtilis* mainly produces collagenase and organic and inorganic acids. Moreover, they grow at low a_w levels. *P. commune*, *Aspergillus niger* and *B. subtilis* were found to be particularly common in books and bundles of documents located in Spanish archives and libraries. Table 3 shows the conditions required for the development of these organisms including the cellulolytic *A. niger* reported by Schlegel (1981)[1], Upsher (1984)[17], Gallo (1992)[3] and Valentin (1996)[15]. Based on these results, *P. commune* and *B. subtilis* were selected in the present work as inocula for infecting both the air environment and paper samples.

Inoculum preparation and analyses of contaminants

Spores from colonies of *P. commune* growing on agar-czapek dox were used as fungal inocula. Bacterial cells from *B. subtilis* growing in nutrient agar were also utilized to infect paper samples. Each inoculum was respectively placed in 10 ml

Table 2. Common fungi isolated from cellulose, proteinaceous materials and from environment and their metabolic products secretion involved in biodeterioration.

Fungi	Isolated from	Enzyme Production	Acid Production	Cellulolytic activity	*mRH (%)
Penicillium	paper parchment leather environment	cellulases lipase proteases	oxalic	++	73
Aspergillus	paper parchment leather environment	cellulases glucose oxidase amylase	citric oxalic gluconic lactic	++	85
Trichoderma	paper environment	cellulases	acetic	+++	80
Cladosporium	paper leather parchment environment	lipase amylase	acetic	+	80
Alternaria	paper parchment environment	proteases amylases	gluconic	+	80
Fusarium	paper leather parchment	proteases	lactic fumaric	+	85

Table 3. Common bacteria isolated from cellulose, proteinaceous materials and from environment and their metabolic products secretion involved in biodeterioration

Bacteria	Isolated from	Enzymes production	Cellulolytic activity	*mRH
Bacillus	paper parchment leather environment	proteases amylase	+	90
Streptomyces	parchment leather	protease	+	90
Actinomyces	most organic materials environment	protease	+	90
Streptococcus	paper leather parchment	protease		95
Pseudomonas	parchment leather environment	glucase oxidase lipase proteases		98

* mRH: Minimum RH required for bacteria to grow in Whatman paper at 22±2°C

of sterile 0.9% sodium chloride. The initial dilution used to infect the sets of samples was diluted to reach 60–70 spores/ml of *P. commune* and 200–250 bacterial cells *B. subtilis*. Groups of sets of paper samples were inoculated with 1 ml of suspension containing a homogeneous population of fungal and bacterial organisms, respectively. Non-contaminated paper samples were used as controls. The paper samples were then placed in the chamber and exposed to 95–98% RH and 22 ± 2° C in still air for 2 weeks to induce microbial growth in the cellulose support. Finally, the samples were used in various test environments.

The microbial contamination of paper was qualitatively evaluated by diluting the sample in 10 ml of 0.9% NaCl solution. The number of cells/ml. was assessed using Petrifilm® sheets made of polypropylene with a nutrient gel adequate for the development of specific groups of micro-organisms.

Measurements of the environmental contamination in the chamber were performed using a microbial air sampler (MicroBio MB1 Bioser) passing 300 liters of air per sample. The air sample directly impacted the culture media, agar czapeck to evaluate the development of fungi and agar nutritive to assess bacterial activities.

RESULTS AND DISCUSSION

Table 4 summarizes a list of environmental conditions (simulated microclimate M-1 to M-18) in the chamber and ventilation rates that were tested in the present work.

The data correspond to average values obtained from each experimental set. Fig. 2a, 3a and 4a, show changes of environmental conditions including the IR temperature on the paper surface during the experiments. Fig. 2b, 3b and 4b were plotted using a finer scale to enhance the temperature variations. The dashed line in the figures indicates a period of time (6 hours) used for sampling microbes and conditioning the appropriate RH and temperature of air flow.

Comparative data showed that IR temperatures on contaminated papers were almost always lower than air temperatures. The difference reduced as the ventilation rate was increased, and it finally reached almost zero at 1.2 ACH. An increased air movement resulted in equilibrating temperatures between the environment and the paper by convection. Table 4 shows the IR temperature on non-inoculated paper exposed to still air. We could not find a trend between the case temperature, case RH, IR temperatures of inoculated and non-inoculated papers. The IR temperature sensor was found to be a sensitive tool to detect the level of air movement at the paper. However, it was not possible to detect changes of water contents of the samples.

Table 4. Microbial contamination in air and paper samples using different microenvironments (M-1 to M-18) and ventilation rate for 25 hours exposure time.

Test samples	Air °C	%	ACH*	Case °C	%	IR °C Inoculated paper	contamination Environmental initial CFU*** final CFU	Inocul. paper initial CFU final CFU	Control** initial CFU final CFU
M-1	22.9	55-60	0.12	23.4	80-85	22.5	55.3 58.5	80.4 120.0	6.7 6.8
M-2	22.2	60-65	0.12	22.8	60-65	22.0	35.3 40.1	68.3 110.7	4.5 3.6
M-3	22.8	65-70	0.12	23.3	70-75	21.5	55.4 58.8	75.9 160.4	3.9 4.3
M-4	21.7	55-60	0.24	22.3	65-70	21.6	65.5 30.3	80.3 54.3	4.6 3.1
M-5	22.7	60-65	0.24	22.5	70-75	22.3	78.1 42.8	85.1 62.7	2.7 0.8
M-6	22.8	65-70	0.24	23.3	70-75	22.6	60.0 34.3	75.8 65.7	4.5 5.2
M-7	23.2	55-60	0.48	23.6	75-80	22.9	48.6 10.9	95.1 40.4	4.6 3.9
M-8	23.8	60-65	0.48	22.5	75-80	22.1	37 8.5	70.3 50.9	1.5 0.7
M-9	22.3	65-70	0.48	21.8	65-70	20.2	40.1 12.3	82.5 48.0	2.2 2.4
M-10	22.9	55-60	0.71	22.5	75-80	22.6	50.4 6.3	130.3 75.8	5.6 3.1
M-11	22.5	60-65	0.71	22.8	65-70	22.3	45.5 5.3	115.5 65.3	2.1 3.2
M-12	22.8	65-70	0.71	23.3	80-85	22.0	40.7 6.1	95.5 60.8	1.6 2.1
M-13	21.8	50-55	0.96	22.4	60-65	22.2	85 4.0	115.4 60.3	6.2 4.7
M-14	22.4	60-65	0.96	22.9	65-70	22.6	65 8.1	80.5 60.3	5.2 1.8
M-15	22.5	70-75	0.96	22.9	75-80	22.7	70.4 6.2	120.4 55.3	3.5 4.1
M-16	23.2	55-60	1.2	23.5	65-70	23.6	85.0 2.4	123.2 50.5	0.8 0.6
M-17	21.2	60-65	1.2	21.4	70-75	21.4	92 5.0	95.7 45.4	3.2 1.2
M-18	20.4	65-70	1.2	21.3	75-80	21.6	80 4.0	114.1 60.8	6.2 4.5

* ACH = Air changes per hour

** Non-inoculated paper was considered as control

*** CFU = Colony forming unit

Environmental measurements using 0.12 ACH at 55-60% RH

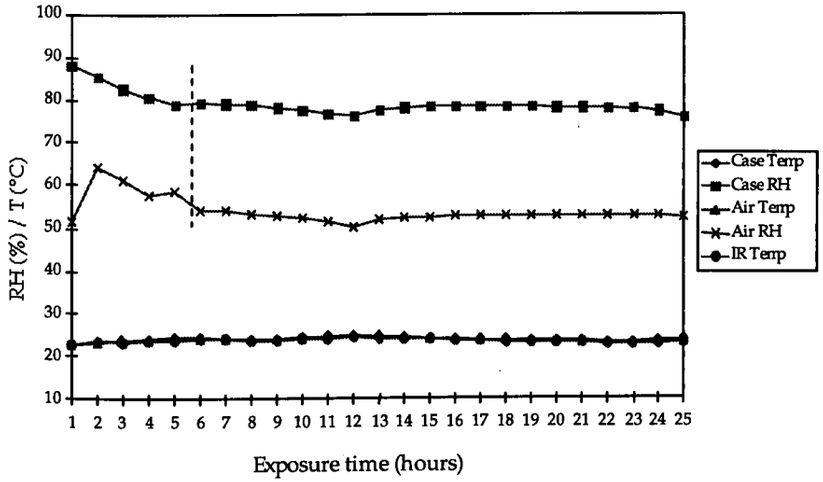


Fig. 2a. Changes of environment under the ventilation of 0.12 air exchange per hour at 55–60% RH.

Temperature variation using 0.12 ACH at 55-60% RH

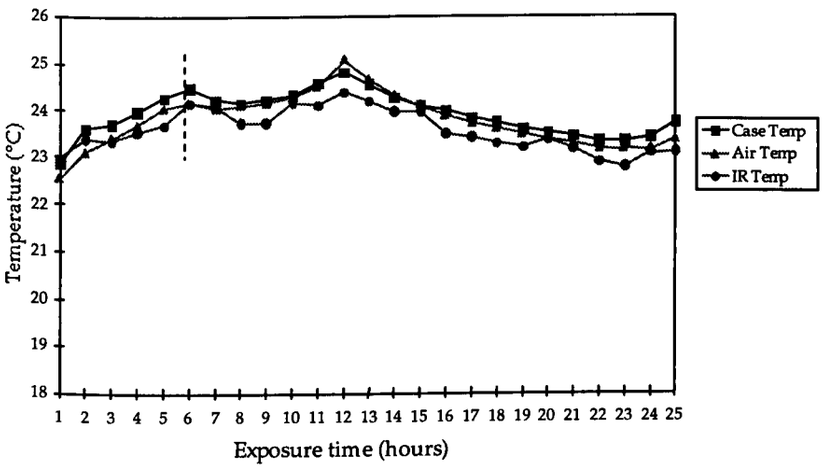


Fig. 2b. Temperature variation under the ventilation of 0.12 air change per hour at 55–60% RH.

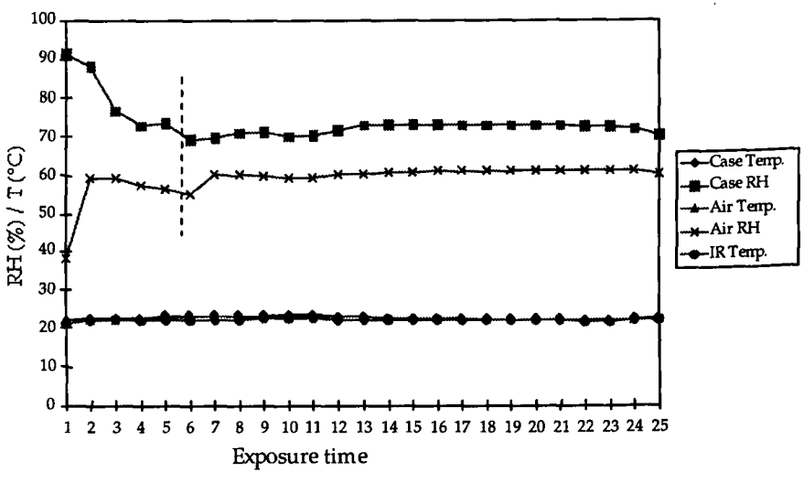


Fig. 3a. Changes of environment under the ventilation of 0.48 air change per hour at 55–60 % RH.

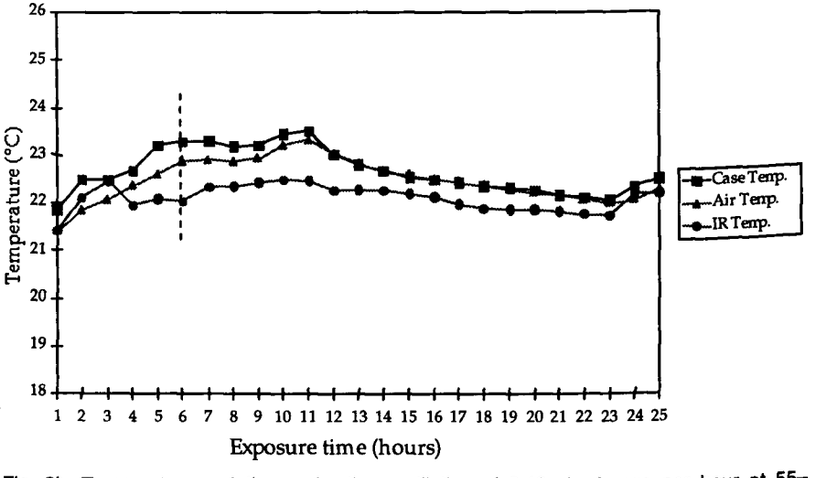


Fig. 3b. Temperature variation under the ventilation of 0.48 air change per hour at 55–60 % RH.

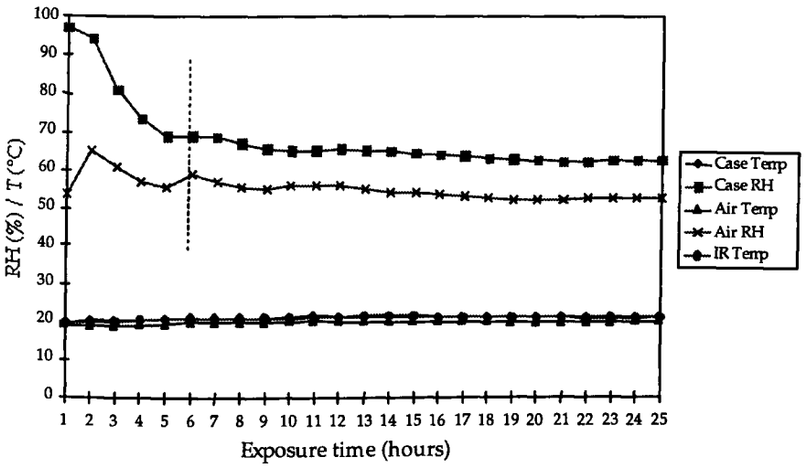


Fig. 4 a. Temperature variation under the ventilation of 1.2 air change per hour at 55–60 % RH.

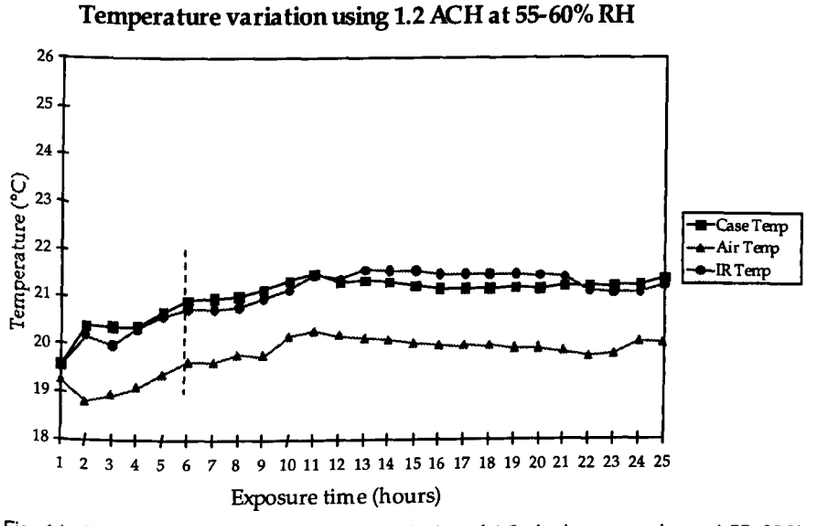


Fig. 4 b. Temperature variation under the ventilation of 1.2 air change per hour at 55–60 % RH.

Table 4 shows the level of contamination in the air and paper samples exposed to various environmental conditions. The data indicate decreases in environmental contamination in all ventilated samples. Fig. 5a, 6a and 7a, show increases in environmental contamination when a low ventilation (RH in a range of 55–70%) rate, only 0.12 ACH, was used for 25 hours. Paper samples required a ventilation rate above 0.48 ACH to detect a significant decrease microbial growth (Figs. 5b, 6b and 7b).

High ventilation rates may have resulted in the removal of spores from the cellulosic support by the shear force of the air movement and subsequent purging or drying of the support by the supply of drier air.

The minimum ventilation rate to decrease environmental contamination was 0.24 ACH at environmental RH 60–70%. Upsher (1984)[17] reported that in the external environment, moulds grow only when RH is above 80% for more than 125 hours or higher than 87% for more than a week. In these cases, the effect of ventilation and temperature will have a decisive influence on old growth.

It was shown that fungal contamination in air samples was higher than bacterial growth during the first 6–9 hours of exposure at a ventilation rate above 0.24 ACH. This effect could be caused by major processes: 1) the air movement. When the chamber is purged, fungal conidia on the paper may have been transported by the venting air and resulted in increasing the level of environmental contamination or simply resulted in reduced moisture contents of the samples. The overall contamination in the air will then decrease due to the replacement of contaminated atmosphere by purging clean air. 2) Fungal spores require a lower water activity than bacteria for the germination. Consequently, depending on the conditions, bacterial growth is more sensitive to changes of the water activity in a shorter period than fungi.

Experiments showed a drastic decrease in microbial activities as a result of the ventilation at 0.96–1.2 ACH over the 25 hours, even in 85% RH environment (Table 4). However, a normal high bacterial growth was recorded when the ventilation was interrupted for 6 hours and the temperature rose to 24° C. It indicated that a combination of temperature and RH fluctuations in non-ventilated environment stimulated microbial reproduction in a very short period. The effect of temperature on growth rates of many micro-organisms has been described in classic microbiological studies. The value of the activation energy for microbial growth of common fungi is in a range of 20–37° C. In the case of many bacteria, it is in a range of 23–37° C. Therefore, it is probable that higher ventilation rates should be utilized in warmer climatic regions to stop biological cell reproduction.

Table 5 indicates the level of contamination in the air and paper samples ed to non-ventilation environment. These data were considered as control and show increases in microbial growth in non-ventilated samples. It was detected that en-

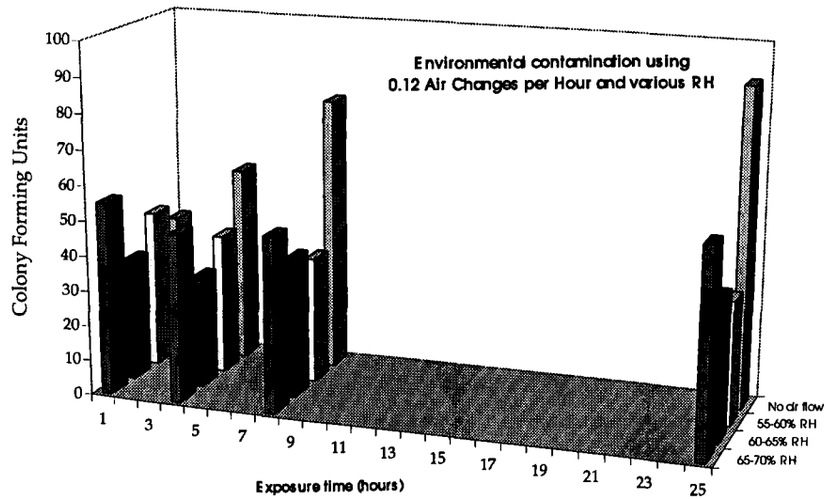


Fig. 5a Changes of environmental contamination under the ventilation of 0.12 air change per hour at various relative humidities.

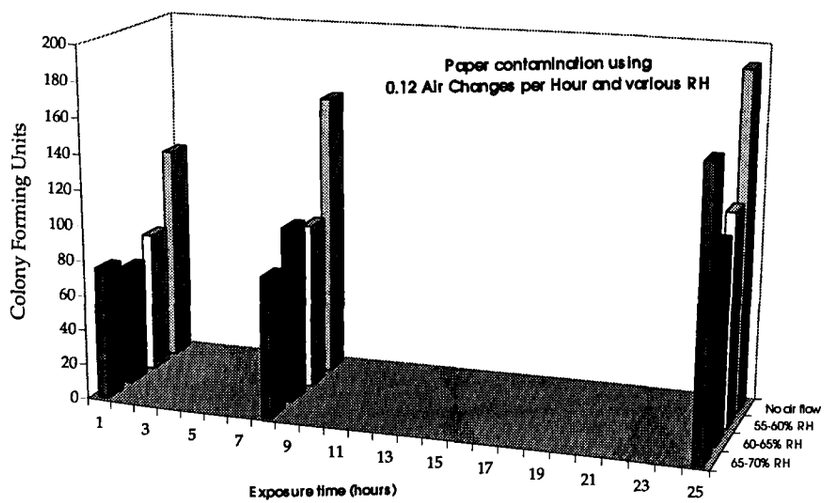


Fig. 5b Changes of contamination in paper under the ventilation of 0.12 air change per hour at various relative humidities

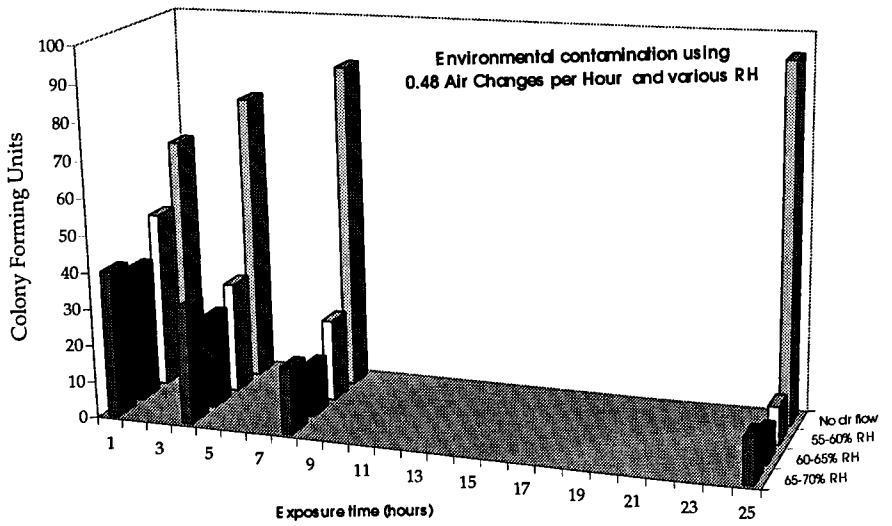


Fig. 6a. Changes of environmental contamination under the ventilation of 0.48 air change per hour at various relative humidities

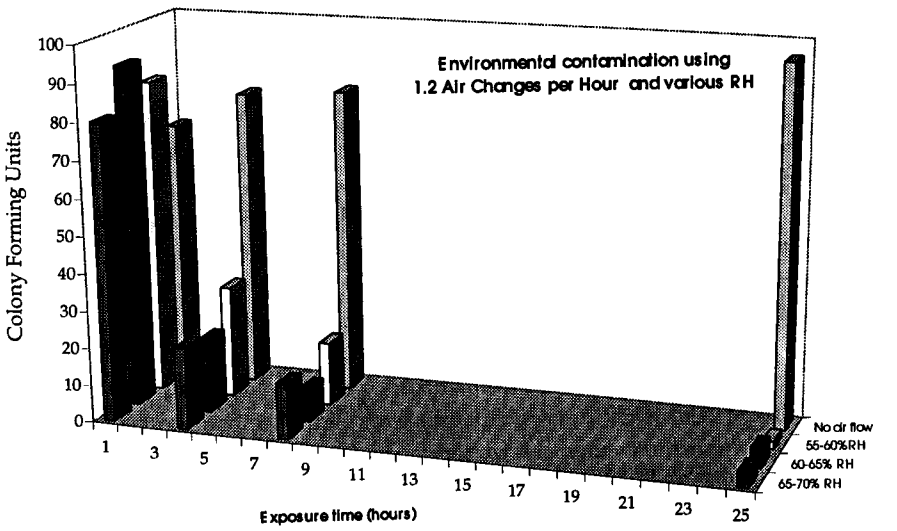


Fig. 7a. Changes of environmental contamination under the ventilation of 1.2 air change per hour at various relative humidities

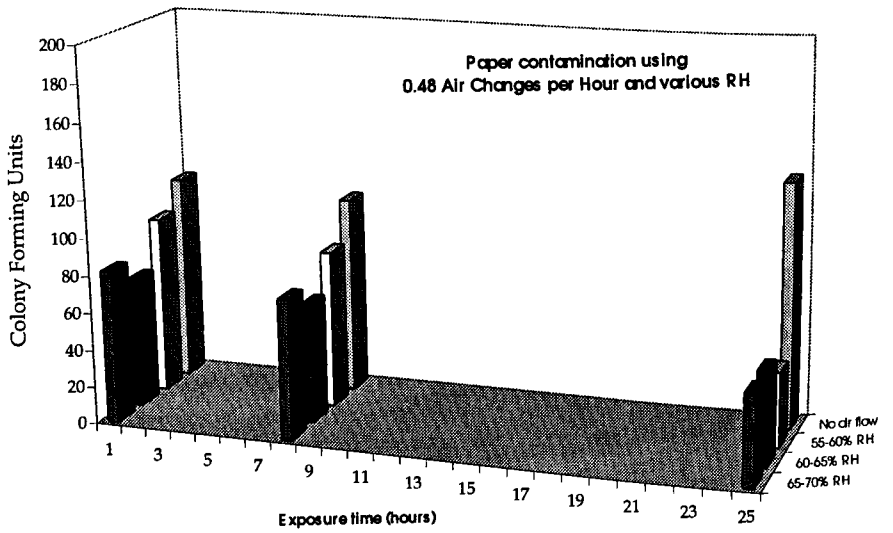


Fig. 6b. Changes of contamination in paper under the ventilation of 0.48 air change per hour at various relative humidities

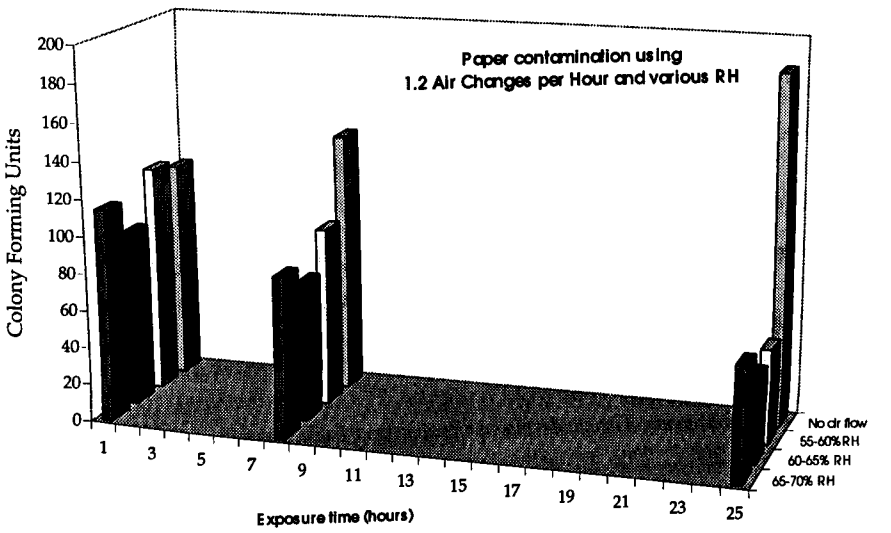


Fig. 7b. Changes of contamination in paper under the ventilation of 1.2 air change per hour at various relative humidities

Table 5. Microbial contamination in the air and paper samples using non-ventilated microenvironments for 25 hours (considered as control).

Test samples	Case		Temperature on paper		Contamination		
			Inoculated	Non-inoculated	Environmental	Paper	
						inoculated	Non-inoculated
	°C	%	°C	°C	initial CFU final CFU	initial CFU final CFU	initial CFU final CFU
Control High RH	22.6	85-90	21.8	22.5	42.2 65	75.1 136.2	5.4 6.6
Control Low RH	21.5	45-50	21.6	21.4	38.5 44.1	65.3 78.2	2.8 2.9
Room Low RH	21.5	45-50	-	-	18.1	-	1.5
Control M1-M2-M3	23.3	80-85	22.9	23.1	40.6 90.4	123.6 190.4	3.8 5.7
Control M4-M5-M6	22.3	70-75	22.0	22.3	50.7 95.3	110.5 145.7	3.6 3.4
Control M7-M8-M9	21.8	75-80	21.4	22.0	65.5 95.3	110.2 130.4	4.8 5.1
Control M10-M11-M12	23.3	75-80	23.7	23.1	65.6 95.8	118.7 185.5	2.8 5.5
Control M13-M14-M15	22.9	70-75	22.9	22.2	75.6 98.3	90.4 190.6	2.6 3.9
Control M16-M17-M18	21.4	75-80	21.6	21.1	70.5 96.3	118.1 135.0	5.6 5.2

vironmental contamination occurred lower in the room than in the chamber at identical conditions (45% RH and 21.5^0 C). This effect should be considered in historic objects exhibited in showcases.

Analyses carried out to identify micro-organisms in the air and paper samples indicated that the fungi: *Aspergillus fumigatus, Penicillium commune, Rhizopus oryzae, Cladosporium herbarum Thrichoderma viride* stopped their growth at 0.96 to 1.2 ACH, 60% RH and 20° C. The growth re-started when the ventilation rate was reduced to 0.12 ACH under identical conditions.

Recently, Gallo *et al.* (1996)[18] have evaluated the viability of fungal spores which settle on different materials. Their results showed that the viability of fungal spores varies amongst species. Each species is influenced by the nature of the support and by the microclimate. Gallo indicated that there could be a more rapid latent metabolic activity and, consequently, more rapid exhaustion of reserve substance when the inoculated paper is exposed to a high RH. Fungi can decrease or disappear when the thermohygrometric values have been brought back to equilibrium.

Comparing our results with Gallo's data, we conclude that maintaining the RH in a range of 60–80% and a ventilation flow above 0.48 ACH, would arrest and decrease the microbial development in a short time (25 hours exposure). Moreover, using a longer exposure time, under these conditions, could be expected to produce non-viable spores.

A ventilation rate will define the moisture availability in a material and the minimum exposure time required for spore germination. Therefore, traditional requirements for display and storage environments, i.e. lower than 70% RH for avoiding biodeterioration, could be simplified for humid regions where very costly equipment could be required to maintain this condition. The microbial activities can be controlled in humid environments (even in environment whose average RH is 80% or higher) simply by providing adequate ventilation when the outside air is dryer than inside, a far less expensive procedure than air conditioning.

CONCLUSIONS

The use of even a low ventilation rate in a range of 0.48-1.2 ACH has been found to be effective in decreasing environmental contamination in a test chamber as well as in paper samples at 55–85% RH and room temperature of 20–24° C. The germination of fungal spores is preventable. However, slightly higher fungal and bacterial activities were observed at temperatures above 24° C. The above ventilation rate is not difficult to achieve in a room, however, it is needed to maintain the air movement even in a difficult area where ventilating air may not normally reach.

A high contamination by fungal mycelia causes retention of moisture in paper. In addition, metabolic water produced by fungi increases the moisture content of paper and the water activity level which induces germination of spores. Consequently, a decrease in temperature was detected in contaminated papers and measured by an IR temperature transducer.

The IR temperature transducer has been found to be a sensitive tool to detect the influence of local air movements on contaminated paper surfaces, although it was not possible to detect the change of the moisture content of the paper samples. The higher the ventilation rate, the closer the environmental and surface temperatures. Consequently, biodeterioration risk is higher if a large temperature difference is detected between the two. Therefore, measurements of the temperature on cellulosic materials could be used as an indicator for the microbiological risk.

It was found that cellulose materials are more susceptible to be biodeteriorated when they are exposed to non-ventilated environments, although the RH and temperature are acceptable. This negative effect should be considered in historic objects exhibited in showcases.

Aspergillus fumigatus, Penicillium commune, Rhizopus oryzae, Cladosporium herbarum and *Thrichoderma viride* stopped their growth at specific environmental conditions (ventilation rate above 0.71 ACH, 60% RH and 20° C). They re-started their activities when the ventilation rate was reduced to 0.12 ACH. This emphasizes the need for relatively continued ventilation.

The use of ventilation is a safe, reliable and low-cost alternative to air conditioning for maintaining a preventive environment against biodeterioration of collections in humid regions. In addition, it avoids risks of possible build up of an unhealthy environment for occupants in buildings. This approach against fungal and bacterial infestation rather than use of dangerous chemicals will protect both collections and professionals from exposure.

ACKNOWLEDGEMENT

We thank Mr. Rufo Martín, Centro de Conservación y Restauración de Bienes Culturales de la Comunidad de Castilla y León, for his technical assistance in this work.

SUMMARIES

Microbial control in archives, libraries and museums by ventilation systems.

Many archive, library and museum in hot and humid regions of the world constitute microenvironments in the building that are conducive to the growth of micro-organisms, on their collections. Conservators have often dealt with the problem through an extensive disinfection and cleaning of the collections which use harsh and toxic chemicals. Consequently, it became necessary to search for a safe, effective and locally sustainable solution for the problem.

It is commonly considered that high relative humidity environments are the main factor for activity of micro-organisms on collections. However, ventilation has been proved to moderate the biodeterioration even when the objects contained high enough moisture for microbial activity. In the present work the efficacy of ventilation to arrest microbial growth and reduce activity in both contaminated air and historic objects has been investigated. Laboratory experiments were carried out using a 500-liter environmental chamber to simulate contaminated rooms in buildings. Specific ventilation requirements to control fungal and bacterial activities in the air and paper samples have been established. These constitute a safe, reliable, and low cost control method for fungal and bacterial contamination of historic objects. In addition, ventilation is an appropriate alternative to air conditioning for those buildings located in humid regions. Most importantly, it avoids the use of chemical disinfecting treatments.

Prévention contre l'attaque de microbes dans les archives, les bibliothèques et les musées grâce à des systèmes de ventilation

Un grand nombre d'archives, de bibliothèques et de musées situés dans des zones climatiques chaudes et humides sont confrontés à une température ambiante qui est propice à une attaque des collections par des microbes. Les conservateurs se sont souvent défendus contre ce problème en adoptant des mesures radicales de désinfection et de nettoyage utilisant des produits chimiques agressifs et toxiques. Il était donc indispensable de chercher des solutions sûres, efficaces et applicables dans les divers contextes locaux.

On considère généralement qu'une forte humidité de l'air favorise l'attaque microbienne des collections dans les musées. Mais on s'est aperçu aussi qu'une bonne ventilation réduit le risque même lorsque les objets contiennent la quantité d'humidité propice à la croissance des microorganismes. Dans l'analyse présentée ici on étudie comment la ventilation peut stopper l'attaque microbienne et réduire son activité dans les objets et dans l'atmosphère environnante. Des expériences en laboratoire ont été faites utilisant une chambre environnementale de 500 litres pour simuler une contamination des pièces d'un bâtiment. Des équipements spécifiques de ventilation ont été installés pour contrôler les activités fongiques et bactériennes dans l'air et sur les échantillons de papier. Ceci constitue une méthode sûre, fiable, peu onéreuse pour contrôler la contamination fongique et bactérienne d'objets historiques. Accessoirement, on s'est aperçu que la ventilation était une vraie alternative à la climatisation pour les bâtiments localisés dans des zones climatiques chaudes et humides. Il faut souligner qu'une ventilation correcte permet d'éviter de recourir à des mesures de désinfection chimiques.

Schutz vor Mikrobenbefall in Archiven, Bibliotheken und Museen durch Belüftung

Viele Archive, Bibliotheken und Museen in der feuchtwarmen Klimazone sind mit einem Raumklima konfrontiert, das einen Mikrobenbefall der Sammlungen begünstigt. Die Konservatoren sind dem Problem oft mit intensiven Desinfektions- und Reinigungsmaßnahmen begegnet unter Einsatz von scharfen und giftigen Chemikalien. Hieraus ergab sich die Notwendigkeit, nach sicheren, wirksamen und – unter den diversen örtlichen Gegebenheiten – einsetzbaren Lösungen zu suchen.

Es wird allgemein angenommen, daß vor allem eine hohe Luftfeuchtigkeit den Mikrobenbefall von musealen Sammlungen befördert. Es hat sich jedoch herausgestellt, daß eine gute Belüftung ihn auch dann reduziert, wenn die Objekte die Feuchtigkeitsmenge enthalten, die mikrobiologisches Wachstum ermöglicht. In der hier vorgelegten Studie wird untersucht, wie eine Belüftung den Mikrobenbefall stoppen und seine Aktivität in den Objekten und in der umgebenden Luft reduzieren kann. In einer 500 Liter fassenden Klimakammer wurde das Klima von mikrobenbefallenen Räumen hergestellt. Dann wurden Hilfsmittel zur Ventilation eingesetzt, um den Befall der Luft und von Proben aus Papier mit Schimmel und Bakterien unter Kontrolle zu bringen. Sie stellen eine sichere, zuverlässige und kostengünstige Methode des Schutzes von historischen

Restaurator, 1998, 108–114
Printed in Germany · All rights reserved

RESTAURATOR
ISSN 0034-5806

Preservation Education

A Pilot Project on Preservation Awareness Training in the University of Botswana Library

BY JACOB C. KUFA

INTRODUCTION

The primary motive in the preservation of resources is the idea that in preserving there might be some benefit in future. Underlying this is the sense of the utility of knowledge which generations can pass on to their children[1]. It is against this background that Sir Seretse Khama, the first President of Botswana made his famous speech from which the following quotation is taken.

> "A nation without a past is a lost nation and a people without a past is a people without a soul"[2].

This statement is as valid to Botswana as it is for any other country with regard to national cultural heritage. Books and other documentary resources are preserved because it is expected that the information contained in them will be of some value in the future. The precise nature of that value is probably debatable but it is common knowledge that the documentary heritage of a nation provides a collective memory and a record of the history of that nation in particular and of human civilization in general.

HISTORICAL BACKGROUND

Many books have been written on the subject of preservation especially on the causes of the deterioration of paper but neither research nor the writings of the period led to the development of formal conservation training programmes[3]. The coming of new media format into library and archival institutions does not make the task easier. The explanation for this state of affairs appears to be that preservation training was still very much under the apprenticeship training system during the 19th and early part of the 20th century[4]. Preservation education is still not part of the curricula of library and archival school in the Southern African Development Community region (SADC).

Restaurator 19: 108–114 © 1998 Saur, Munich etc.

The Florence Flood of 1966

The significance of the Florence floods of 1966 which damaged priceless collections in Bibliotheca Nationale, Italy was that preservation was gradually catapulted into becoming an essential part of collection management thus signifying the integration of preservation into library activities. 1966 can therefore be regarded as a beginning of a move to the broader perception known as preservation in which conservation problems were raised and became critical in the preservation of library and archival resources. The Florence Flood therefore laid the ground work for raising consciousness of the library and archival profession at large about the importance preservation and conservation. The 1966 Florence Flood did not however bring about the formal incorporation of preservation education into libraries and library schools. It only laid the basis for developments in that direction.

The Ratchiffe Report

The Ratchiffe Report of 1984[5] marked a turning point in the history of conservation and training in the United Kingdom and beyond especially in Anglophone Africa. Ratcliffes report especially emphasized the need to create conservation awareness in all library staff at all levels[6]. At the international level, IFLA's section on conservation and preservation was very active and set up a Working Group in conjunction with the IFLA section on education and training which devised guidelines for the teaching of preservation and conservation. Even more importantly IFLA set up the Preservation and Conservation Core Programme (PAC)[7] to deal with specific issues on Preservation. Interact in preservation and conservation education was also shown by international and world bodies[8].

FURTHER DEVELOPMENT IN AFRICA

In 1993, UNESCO, the International Council on Archives and the International Federation of Library Association joined together to organize the Pan African Conference on Preservation and Conservation of Library and Archival materials in Nairobi, Kenya during the period 21–25 June 1993. During this conference it was agreed that a significant percentage of library and archival materials in Africa were facing severe dangers as a result of the deterioration of book and documentary resources in their care. Participants agreed that a systematic co-ordinated approach was important in the development and implementation of good conserva-

Objekten vor Schimmel- und Bakterienbefall dar. Als Nebenergebnis zeigte sich, daß in Gebäuden der feuchten Klimazone Belüftung eine sinnvolle Alternative zur Raumklimatisierung ist. Besonders wichtig ist, daß durch richtiges Belüften chemische Desinfektionsmaßnahmen vermieden werden.

REFERENCES

1. Schlegel, H.: *Prokaryotes and their habitats.* In Prokaryotes: Handbook on Habitats, ed. M. Starr. New York 1981.
2. Florian, M.-L.: *Conidial fungi (mould) activity on artifact materials – a new look at preservation, control, and eradication.* ICOM. Committee for Conservation 10th Triennial Meeting, Washington 1993: 868–874.
3. Gallo, F.: *Il biodeterioramento di libri e documenti.* Centro di Studi per la conservazione della carta. Rome: ICCROM 1992: 55–80.
4. Caneva, G., M.P. Nugari & O. Salvadori: *Biology in the Conservation of Works of Art.* Rome: ICCROM 1991: 26–43.
5. Erhardt, D., & M. Mecklenburg: *Relative humidity re-examined.* ICOM Committee for Conservation 10th Triennial Meeting. Washington 1994: 32–38.
6. Kowalik, R.: *Micro-organisms in library materials.* Restaurator 2 (1980): 99–114.
7. Petushkova, J., & J. Koestler: *Biodeterioration studies on parchment – and leather – attacking bacteria in the commonwealth of socialist states.* International Conference on Conservation and Restoration of Archive and Library Materials. Erice 22–29 April 1996: 161–175.
8. Hansen, E., S. Lee & H. Sobel: *The effects of relative humidity on some physical properties of modern vellum: implications for the optimum relative humidity for the display and storage of parchment.* Journal of the American Institute for Conservation 31 (1992): 325–342.
9. Valentín, N., M. Lidstron & F. Preusser: *Microbial control by low oxygen and low relative humidity environment.* Studies in conservation. 35 (1990): 222–230.
10. *ASHRAE Handbook. Fundamentals.* American Society of Heating, Refrigerating and Air-Conditioning Engineers 1997: 25.1–25.3.
11. Cunningham, M. J.: *Effective penetration depth and effective resistance in moisture transfer.* Building and Environment 27 (1992): 379–386.
12. Scott, G.: *Moisture, ventilation and mould growth. Preventive Conservation Practice, Theory and Research.* International Institute for Conservation of Historic and Artistic Works. Ottawa 1994.
13. Brokerhof, A.: *Control of fungi and insect in objects and collections of cultural value.* The Central Research Laboratory. Amsterdam 1989: 4–10.
14. Wellheiser, J.: *Non-chemical Treatment Processes for Disinfestation of insects and fungi in libraries collections.* IFLA Publications 60 (1992): 5–7.
15. Valentín, N.: *Assessment of biodeterioration processes in organic materials. Control methods.* International Conference on Conservation and Restoration of Archive and Library Materials. Erice 22–29 April 1996: 195–206.
16. Valentín, N., & S. Maekawa: *Microbial control by air ventilation systems.* The Getty Conservation Institute. Internal report 1996.
17. Upsher, F. J.: *Fungal colonization of some materials in a hot-wet tropical environment.* International Biodeterioration 20 (1984): 73–78.

18. Gallo, F., P. Valenti, O. Maggi, A. Persiana & F. Vincenzoni: *Research on the viability of fungal spores in relation to different microclimates and different materials.* International Conference on Conservation and Restoration of Archive and Library Materials. Erice 22–29 April 1996: 177–194.
19. Valentín, N.: *Contaminación biológica en materiales arqueológicos y su erradicación por medio de tratamientos no tóxicos.* Conservación Arqueológica. Cuadernos. Sevilla: Instituto Andaluz de Patrimonio Histórico 1993: 133–119.

Nieves Valentín *
Instituto del Patrimonio Histórico Español
El Greco 4
28040 Madrid
Spain

* Author to whom the correspondence should to be addressed.

Rafael García, Oscar de Luis
Centro de Investigaciones Biológicas (C.S.I.C.)
Velazquez 144
28006 Madrid
Spain

Shin Maekawa
The Getty Conservation Institute
1200 Getty Center Drive, Suite 700
Los Angeles, CA 90049-1684
U.S.A.

tion and preservation programmes. This resulted in the formation of a Joint Committee on Preservation in Africa (JICPA) with a Secretariat in Kenya. One of the functions of the Secretariat is to catalyze awareness growing in African countries and to co-ordinate identification of training needs.

One way of achieving this was to form National Preservation Committees in each African country. It is against this background that Botswana representatives came back from the conference to set up an Ad Hoc Committee on Preservation and Conservation (Standing Committee on Preservation and Conservation – SCOPAC) at the end of 1993. This committee, set up as a National Preservation Committee in terms of the joint ICA/IFLA Committee for Preservation in Africa (JICPA), had the following terms of reference:

- to sensitize and create awareness on the need for preservation and conservation of national cultural heritage generally, among government department, non-governmental organizations, parastatal and the private sectors
- to co-ordinate all aspects of preservation and conservation of all media of cultural heritage
- to advocate for the establishment of co-ordinated policy, guidelines for preservation and conservation, and where necessary, advocate for the creation of a legal framework through existing governmental structures and laws.

To demonstrate its practical support for Preservation Programmes UNESCO gave the Botswana Standing Committee on Preservation and Conversation US$ 20,000 to organize a conference on Preservation and Conservation in 1995. The Conference was held in Gaborone on 7–10 July 1997 and brought together experts on preservation and conservation in Botswana and the sub-region and selected policy and decision makers to discuss critical issues on the importance of preservation and conservation of cultural heritage.

The goal of the conference was to sensitize policy makers on the importance of cultural heritage in its various forms (e.g. information preserved through records, archives, research publications, artefacts computer tapes and by individuals) for development of national assets, enrichment of national identity values and culture.

The target groups of the Conference were:

- professionals involved in gathering and processing of cultural heritage for preservation and conservation for posterity
- policy and decision makers who generate cultural heritage in any format and are interested, so far in its current value
- resource persons in preservation and conservation of all media.

The outcomes of the Conference are envisaged as:

- Creation of awareness of posterity and enhanced value of currently generated data, artefacts
- identify strategies for:
  - marketing preservation and conservation programmes nationally and sub-regionally
  - supporting existing structures involved in gathering processing and preservation of cultural heritage
  - identification of priorities for training
  - identification of potential sources of funding.

It is intended that after the Conference there would be follow up activities, especially:

- establishment of national sustained awareness raising programmes
- training projects within groups of units
- sharing of preservation and conservation successes and problems to supply expertise and information on specialist to sources sub-regionally
- database on existing training manuals; their production and expert trainers.

PRESERVATION AWARENESS TRAINING

The Standing Committee on Preservation and Conservation (SCOPAC) has its membership drawn from all documentary and cultural institutions in Botswana and plays an advisory role to its members some of whom have gone further to implement preservation awareness programmes such as the one at the University of Botswana Library. The Preservation Awareness Training at the University of Botswana is an attempt to put into practice preservation awareness ideas obtained at SCOPAC and other fora for inculcating preservation awareness to both the workers and the users of information. Secondly, the project is a fulfilment of one of the goals in the mission statement of the University of Botswana Library which seeks to provide facilities, programmes and procedures for the security care and preservation of University of Botswana Library resources.

The objectives of the project are:

- to promote general preservation awareness among both library staff and library users
- to create an understanding of materials in the library and what causes their deterioration

- to create an understanding of the various remedies that can be applied to preserve library materials
- to train UB library staff on book handling procedures, good housekeeping and in undertaking minor repairs.

CONTENT OF THE TRAINING PROGRAMME

The content of the Preservation Awareness Training Programme at the University of Botswana Library reflects the need to create an understanding of library materials and what causes their deterioration. Besides a brief historical background on the origins and nature of paper the following aspects were included:

- The causes of deterioration of library documentary resources including the electronic media
- Recommendations on prolonging the life of these documentary resources especially in relation to
  - proper book handing procedures at circulation and during shelving
  - identification of books needing repair
  - proper procedures for undertaking minor book repairs in the library.

In addition to the lectures and video shows on preservation, the following brochures were prepared and distributed to the target groups:

- Preservation of Library Resources.
  This brochure was a follow up and consolidation of important preservation issues raised in the awareness training programme. It was widely circulated not only to the target groups but to all members of the University community and other users.
- Manual of undertaking minor repairs, book cleaning and book handling in the UB Library.
  This manual is developed for and intended to provide guidance to staff undertaking these functions. It is simplified and easy to read.
- The Preservation Awareness Exhibition.
  This is an annual event and is normally mounted at the beginning of the academic year to sensitize new students on preservation issues.
- The New Media.
  These include magnetic tapes, diskettes, cassettes, compact disks, optical disks, microfiche/microfilms. University of Botswana is getting highly computerized and it is important that users of its electronic media are aware of the preservation requirements of these resources especially in relation to temperature and humidity, requirements, storage requirements and the lifespan of each type of media to facilitate efficient inspection.

CONCLUSION

Preservation training and awareness is crucial to the survival of our cultural heritage and requires co-operation at both regional and national levels. At the national level National Preservation Committees will increasingly play an important role of sensitizing key sectors of the nation on preservation issues. At the regional level the Joint ICA/IFLA Committee for Preservation in Africa (JICPA) will play the role of co-ordinating the National Preservation Committees in the various African countries and also raise awareness in African countries.

It is in this context that the Preservation Awareness Training Programme at the University of Botswana was held and will continue to be held periodically in the University of Botswana Library to cater not only for library staff and all levels but will be extended to users especially students at appropriate times. The first training programme received a good evaluation report. Useful suggestions for improvement were received and will be incorporated in future programmes.

SUMMARIES

Preservation education: a pilot project on preservation awareness training in the University of Botswana Library

Preservation of documentary resources no longer occupies the periphery of information management but is at the core of and is a crucial strategic element in the preservation of our cultural heritage for present and future generations. Preservation awareness training aims raising consciousness of the entire library staff and should transcend all levels in the structure of information centres and documentary institutions so that a new perception for handling library resources is developed and is sustained by both librarians and archivists on the one hand and users of this information on the other.

Formation au métier de conservateur de musée: un projet-pilote d'entraînement et de prise de conscience à la Bibliothèque de l'Université de Botswana

La conservation de documents écrits a cessé d'être un domaine annexe de la gestion de l'information, elle s'est au contraire constituée comme un élément stratégique important, central et décisif pour la préservation de notre héritage culturel aujourd'hui et pour les générations futures. L'incitation à prendre conscience du problème doit s'adresser à tout le personnel de tous les

échelons administratifs des archives, des bibliothèques et des centres d'information afin qu'une nouvelle perception puisse s'établir en ce qui concerne le comportement vis-à-vis des objets chez les bibliothécaires, archivistes et aussi chez les utilisateurs.

Erziehung zur Konservierung: ein Pilotprojekt zur Bewußtseinsbildung an der Universitätsbibliothek von Botswana

Die Konservierung schriftlicher Dokumente ist nicht länger ein Randgebiet der Informationsverwaltung. sondern hat sich zu einem zentralen und entscheidend wichtigen strategischen Element der Bewahrung des kulturellen Erbes für die Zukunft entwickelt. Die Erziehung zu einem entsprechenden Problembewußtsein soll das gesamte Personal ansprechen und alle Verwaltungsebenen von Archiv, Bibliothek oder Informationszentrum durchdringen, so daß eine neue Haltung beim Umgang mit den Objekten wachsen kann, sowohl beim Bibliothekar und Archivar als auch beim Benutzer.

References

1. Cloonan, Valerie Michele: *Global perspectives on preservation education.* München: K. G. Saur, 1994 (IFLA Publication No. 69).
2. Sir Seretse Khama in speech to the nation 1980.
3. Many books have been written on the subject of preservation and conservation the most notable of which are: *Preservation in Libraries: principles, strategies and practices.* Ed. Harvey Ross. London: Bowker-Saur 1993. – Dureau, J. M. & D.W. Clements: *Principles for preservation and conservation of library materials.* The Hague: IFLA 1986.
4. Coonan, Michele Valerie (cf. ref.1): 2.
5. Ratchiffe, F. W.: *Preservation policies and conservation in British Libraries. Report of the Cambridge Library Conservation Project.* London: The British Library 1984: 64.
6. Feather, John, & Anne Lusher: *Education for Conservation in British library schools: current practices and future prospects.* Journal of Librarianship 21,2 (1989): 129–138.
7. Feather, J.: *IFLA Working Group to study preservation education.* International Preservation News 1988: 9–10.
8. Clements, D. W. G.: *Preservation and conversation of library documents: a UNESCO / IFLA / ICA inquiry into the current state of the world's patrimony.* Paris: UNESCO 1987: 13.

Jacob C. Kufa
University of Botswana
Library and Information System
P.O.B. 00390
email ub lib @ noka.ub.bw
Gaborone
Botswana

Editorial Notice

RESTAURATOR, *International Journal for the Preservation of Library and Archival Material,* presents original papers, as well as reviews and news of interest to scientists, conservators, archivists, and librarians.

Authors submitting a paper do so on the understanding that the work has not been published before, is not being considered for publication elsewhere and has been read and approved by all authors. The submission of the manuscript by the authors means that the authors automatically agree to assign exclusive copyright to K. G. Saur Verlag if and when the manuscript is accepted for publication.
The work shall not be published elsewhere in any language without the written consent of the publisher. The articles published in this journal are protected by copyright, which covers translation rights and the exclusive right to reproduce and distribute all of the articles printed in the journal. No material published in the journal may be stored on microfilm or videocassettes or in electronic databases and the like or reproduced photographically without the prior written permission of the publisher.

Articles for RESTAURATOR are published in English, with Summaries (Abstracts) in French and German. Contributors are particularly asked for linguistic and stylistic accuracy. All articles are linguistically revised by the publisher before publication. Authors alone are responsible for the opinions expressed in their articles.

Manuscripts should be provided in a machine-readable form on a floppy disk if possible; a printed, doubled-spaced copy must accompany the disk. Copy the files onto newly formatted disks and clearly label the journal, author and title, file content, format, software and program version number. Manuscripts must be carefully revised, as alterations are expensive. The paper must be non-absorbent. The author's name must be accompanied by the title, full address, telephone and telefax number (if any) of the workplace or institution. Summaries should be written on a separate page, included with the manuscript; should not exceed 200 words; and should be written in the same language as the articles.

All graphs, drawings, or photographs are to be referred to as figures (abbr: Fig.) and should be numbered in sequence with Arabic numerals. Each figure should be identified with a figure number on the back. Any lines, numbers, or lettering that are to appear in the illustrations should be large enough for the necessary reduction. Line drawings should be drawn or printed with black India ink on white paper and should be about twice the size of the finished blocks. Graphs can be plotted on plain white or blue squared paper; grid lines should be inked in black. In general, photographs should be about 1½ times the size of the final block and must be submitted as mounted glossy enlargements showing good detail and adequate, but not excessive, contrast. Authors should indicate in the text the approximate position of figures.

Italics are used for emphasis, especially for distinguishing titles of books and papers.

References within the text should be indicated by numbers corresponding to those in the list of references. The list should be placed at the end of the paper. For example:

1. Miles, C.: *Wood coatings for display and storage cases.* Studies in Conservation 31 (1986): 114–24.
2. Hon. D. N.-S.: *Yellowing of modern papers.* In: Williams, J. C., ed. Preservation of paper and textiles of historic and artistic value II. Advances in Chemistry Series, 193. Washington, DC: American Chemical Society, 1981: 119–42.

Fifty offprints of each article will be sent to the author free of charge.

Editorial Address

Manuscripts and review copies of books should be sent to the editorial office: RESTAURATOR, Dr. Helmut Bansa, Elisabethstraße 23, D-80796 Munich, Germany.

ISBN 3-598-01118-0