International Biodeterioration & Biodegradation 133 (2018) 42–51

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

Vapourised hydrogen peroxide (VHP) and ethylene oxide (EtO) methods for disinfecting historical cotton textiles from the Auschwitz-Birkenau State Museum in Oświęcim, Poland

Wawrzyk Anna[a], Gutarowska Beata[b], Rybitwa Dorota[a], Pietrzak Katarzyna[b], Machnowski Waldemar[c], Wrzosek Henryk[c], Papis Aleksandra[a], Walawska Anetta[d], Otlewska Anna[b,*], Szulc Justyna[b], Adamiak Justyna[b]

[a] Auschwitz-Birkenau State Museum, Więźniów Oświęcimia 20, 32-603 Oświęcim, Poland
[b] Institute of Fermentation Technology and Microbiology, Lodz University of Technology, Wólczańska 171/173, 90-924 Łódź, Poland
[c] Department of Material and Commodity Sciences and Textile Metrology, Lodz University of Technology, Żeromskiego 116, 90-924 Łódź, Poland
[d] Textile Research Institute, Brzezińska 5/15, 92-103 Łódź, Poland

ARTICLE INFO

Keywords:
Disinfection
Historical cotton textiles
Vapourised hydrogen peroxide
Ethylene oxide
Biodeterioration
Auschwitz-Birkenau state museum

ABSTRACT

The research aims were: to assess the microbiological contamination of historical cotton textiles from the Auschwitz-Birkenau State Museum in Oświęcim, Poland; to establish the antimicrobial effectiveness of vapourised hydrogen peroxide (VHP) and ethylene oxide (EtO); to determine concentration and time of VHP disinfection and to assess the impact of VHP and EtO on the new and historical cotton textiles properties. The microbiological contamination of historical cotton textiles were 3.1×10^4–4.6×10^4 CFU/100 cm^2 (bacteria) and 7.5×10^3 - 1.8×10^4 CFU/100 cm^2 (fungi). VHP was more effective against fungi and had similar biocidal effect to EtO. The optimal parameters of VHP disinfection were: concentration 300 ppm, time 20 min. VHP and EtO did not affect the fibre morphology, chemical composition or colour of the new and historical cotton fabrics. Both methods changed the strength parameters and cellulose polymerisation degree of new fabric. Increasing the time (30 min) or concentration (400 ppm) gave a similar biocidal effect but resulted in a decrease in strength parameters and cellulose polymerisation (new fabric) and colour change (historical fabric). VHP is an effective and safe method for historical textiles and can be applied in mass treatment.

1. Introduction

Textiles are one of the numerous types of objects in the collections of the Auschwitz-Birkenau State Museum in Oświęcim, Poland (A-BSM). The textile products are made from different types of fabric, with the predominance of natural fibres such as cotton and linen, some of them having extra wool and viscose fibres. The collection has over 2200 artefacts consisting of both clothes and other useable textile products. The first group in the collection includes prisoners' clothes (sweatshirts, coats, dresses, trousers, caps, functional prisoners' bands, camp number patches), civilian's clothes (coats, jackets, dresses, hats, underwear), SS uniforms and accessories (uniform badges, hats, flags) and children's wear (Fig. 1 a). Striped camp clothing is the largest group (approximately 370 objects) of clothing in the A-BSM collection. Prisoners arriving at KL Auschwitz-Birkenau were deprived of their clothes and received clothes made of a drill fabric (a strong, thick cotton fabric made in a diagonal weave with a triple warp) in blue-grey stripes. The striped camp clothing, distinguished the prisoners from afar and prevented them from hiding in case of an escape. The museum's collection also includes a smaller group of infant's and children's civilian clothes (approximately 80 objects). This group includes sweaters, matinee jackets, dresses, underwear, gloves, hats and socks, which children most likely wore in the camp (Iwaszko, 2000).

The second group consists of tallisim and ataras (Jewish prayer shawls and ornamental belts), straw mattresses, furniture elements and selected objects made by prisoners, such as a felt Christmas tree, a commemorative shawl and a puppet (Fig. 1 b–c). Furthermore, in addition to the textile collection, selected fragments of some objects from set of objects in mass quantities, such as shoes, suitcases and prostheses, are made of textiles (Fig. 1 d–e). In the collections of the A-BSM, there are approximately 3800 suitcases made of various materials, including fabrics (cotton, linen, jute, hemp and artificial silk). Fabrics were used

* Corresponding author.
E-mail address: anna.otlewska@p.lodz.pl (O. Anna).

https://doi.org/10.1016/j.ibiod.2018.05.016
Received 3 April 2018; Received in revised form 9 May 2018; Accepted 29 May 2018

Fig. 1. Samples of textile objects from Auschwitz-Birkenau State Museum: a. prisoner's clothes; b. tallit; c. Christmas tree; d. suitcase; e. shoe (author: a-b. Michał Dziewulski; c-e. Adam de Sas Topolnicki).

in suitcases to cover the top of the suitcase and as a lining. Suitcases brought by prisoners to the camp were thoroughly inspected to steal hidden valuable items and money in favour of the Third Reich. Empty suitcases, together with footwear and leather goods, were collected in the camp warehouses and outdoor (Strzelecki, 2000).

Historical objects are susceptible to destruction by microorganisms that come from soil, water and air. These microorganisms may lead to biodeterioration, which is a multistage and complex phenomenon that causes undesirable changes in the physical properties of materials. As a result of microbiological decomposition, stains, deposits, structural weakness and colour changes may appear in historical textile objects. The progress of this process depends primarily on the chemical composition of the textile materials and storage conditions (relative humidity and temperature of the air) (Szostak-Kotowa, 2004). Stable microclimatic conditions that maintain the air temperature at approximately 20 °C and the relative air humidity (RH) below 60% should inhibit the biodeterioration process (Wolf, 2002). Literature examples indicate that the historical textiles most susceptible to biodeterioration are archaeological textiles in permanent contact with water and soil, such as mummies, textiles in graves, tombs, crypts, sunken ships and soldiers' uniforms (Gutarowska et al., 2016). Additionally, textiles made of cellulose and keratin-based fibres are more susceptible to biodeterioration than fibroin and sericin-based fibres (Pekhtasheva et al., 2012).

Microorganisms involved in the biodeterioration of historical textiles produce extracellular enzymes (cellulolytic and proteolytic), pigments and acids. Biodeterioration involves two processes: assimilation – when fibres are used as a nutrient source; and/or degradation – when fabrics are damaged due to the growth of microorganisms and secretion of metabolites. The degradation of cellulosic and proteinaceous archaeological textiles is mainly connected with filamentous fungi, while silk is primarily destroyed by bacteria (Pekhtasheva et al., 2012).

Suitcases and children's clothes from the A-BSM collections are stored in storage warehouses in which the environmental conditions are monitored and at the exhibition. The biodeterioration process depends on the objects' storage location and on the type of material from which they are made. The suitcases from the exhibition show greater signs of biodeterioration than those stored in storage warehouses. Microorganisms from the environment and those introduced by visitors may be the reason for their more extensive deterioration. Due to the period from which the suitcases originated (the first half of the 20th century), most of the fabrics used to make suitcases are made from fibres of natural origin. Therefore, they are more susceptible to biodeterioration.

Disinfection of historical objects is a difficult process because it should be effective, not negatively affect the historical objects and also be safe for people and the environment. Many methods of chemical (e.g., alcohols, quaternary ammonium compounds, azoles, essential oils, nanometals and ethylene oxide) and physical (high and low temperature, pressure, modified atmospheres and irradiation) disinfection of historical textile objects are currently available. All of the mentioned disinfection methods have some disadvantages, such as changes in pH, colour, or structure and the occurrence of depolymerisation, hydrolysis, acidolysis and accelerated ageing, or they pose a threat to human health, while some of them cannot be used for mass treatment (Paulus, 2004; Sequeira et al., 2012; Gutarowska et al., 2016).

Thus, there is a need to find new, effective and safe methods for mass disinfection that are adjusted to the specificity of historical textiles and inhabiting microorganisms. Due to the need for historical objects (textiles, suitcases) from the A-BSM to be protected from the destruction caused by biodeterioration, new research has been started on the use of hydrogen peroxide in the gas form (vapourised hydrogen peroxide - VHP) to find an effective and safe technique for fabric disinfection.

The biocidal properties of hydrogen peroxide (H_2O_2) have been known for over 100 years and are widely used in the food, medical and