Fire Damaged Documents: Practical Aspects of Recovery

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Abstract:

Of the destructive elements that may cause disasters, the most dangerous is fire. Fire can completely destroy, in a matter of minutes, books and documents. In addition to damage from heat, books can also be severely damaged by smoke, soot and water. This study deals with the treatment and restoration of two carbonized documents. The purpose of the conservation treatments is to stop biological attack and to clean the surface of the document in order to protect it, to consolidate the support material, and to restore the documents to approximate its original condition.

Keywords*: cultural heritage; fire damage; carbonized documents; conservation; restoration*

Introduction

Devastating fires (accidental or deliberate) have a devastating effect over time on books or other writing materials. From the destruction by fire of the Libraries of Alexandria and Constantinople until today, many libraries, archives, and museums have lost forever their priceless collections. Unfortunately, recent history has many such examples.

In Europe, the damage caused by the war of 1870 and the First World War are nothing compared to the damage wrought by the Second World War. Two million volumes in France and Italy, ten million in Germany (libraries of Leipzig and Dresden), and twenty million in England (especially during the Blitz) disappeared in smoke (Polastron

2009). Recent examples have shown that there are not enough protective measures in place: in Weimar (Germany) in 2004, in Lyon in 1999, where 300,000 of the 450,000 documents of SCD of Lyon-II and Lyon–III universities of France were destroyed by fire. This fire showed that fire-fighting measures, *i.e.*, water damage, was equally as destructive as the fire itself (Laffont et al. 2005).

The past two decades have not spared the United States from such unwanted events either. In 1966, at Janish Theological Seminary in New York, arson claimed $3 million worth of books, either destroyed or heavily damaged. In 1971, at Radcliff Infirmary Oxford, a fire started by a short-circuit totally ruined one of the most important medical libraries in the world. The Central Library of Los Angeles fell victim to arson two times which led to: 400,000 works destroyed and 12,500,000 documents damaged by exposure to smoke and water (Alegbeleye et al. 1983).

The collections and services of libraries and related agencies, such as museums and archives, are important components of social and institutional memory. Unfortunately, recent events have demonstrated that not everyone shares this view. The pillage and burning of Iraq's National Library and its National Museum in the spring of 2003 sent cultural shock waves around the world. (Boyd Rayward 2007: 361-369). Also, at the beginning of 2015, the militants of a terrorist organization vandalized the libraries belonging to Mosul city and burnt thousands of rare books and valuable manuscripts, some of them being registered on a UNESCO rarities list (http://www.independent.co.uk/).

In Romania, during the Revolution of 1989, the Central University Library of Bucharest was set on fire, almost 500,000 books, maps, manuscripts and correspondences were destroyed and thousands of manuscripts by authors such as Eminescu, Caragiale and Coşbuc were completely compromised. It took 16 years for the building to be restored but the cultural heritage has never recovered (www.bcub.ro/home/istoric).

On January 8th 2015, a devastating fire burnt from the ground up the building of the "Metropolitan Dosoftei" Orthodox Theological Seminary in Suceava along with the offices of the Suceava and Radauti Archbishopric, destroying many documents therein.

Identifying and preventing potential dangers to one's patrimony and taking proactive measures, can limit losses or damages that potentially can occur (Oberländer-Târnoveanu 2009: 42).

Whatever the cause, fire and water are the main factors responsible for the damaging effects on the documents. Even if they are not primary causes, almost always they are secondary damaging agents.

The effect of high temperature on paper support

Fire is the result of a chemical reaction that requires the presence of three elements in an appropriate combination: a fuel source (any material that can burn), oxygen, and an ignition source, such as heat or a spark. This dynamic is often called the "fire triangle."

Emissions from a fire include gases (carbon dioxide, carbon monoxide, nitric oxide, etc.) and airbourne particles (soot, organic matter, etc.).

Thermal activation is the cause of some of the most important and noxious effects that temperature can cause to the well-being of cultural goods: a great number of chemical processes, oxidation mostly, determined through thermal activation affects greatly the state of preservation of some categories of goods such as books, manuscripts, graphical works, etc. and the irreversible character of the chemical processes renders the effects permanent (Melniciuc Puică and Ardelean 2010: 141).

The thermal decomposition of cellulose from paper materials is a complex competitive process and the formation of volatile compounds and coal from cellulosic materials are thought of as being in a reciprocal relationship.

Cellulosic combustion takes place in two stages: (*i*) gaseous combustion, in which the degrading products start burning and then (*ii*) explosive combustion, in which the carbonated residues are pyrolyzed leading to CO, CO_2 and water vapour emission. (Price 1997: 511-524). Since the exothermicity of oxidative degradation is about ten times as large as endothermicity of the pyrolysis reaction, the overall degradation of the paper is slightly exothermic in air as long as the oxygen supply to the degrading paper is sufficient. If the oxygen supply is not sufficient, the ambient oxygen concentration near the paper would be reduced

(Kashiwaghi 1992: 345-368). Mok et al. (Mok 1992: 1162-1166) observed that either a high concentration of vapour products or added water increases char yield and decreases the temperature of the onset of decomposition. Subsequent analysis of these data (Varhegyi 1993: 159-174) led to the suggestion that the water produced in thermal dehydration reactions contribute to hydrolysation of the unreacted cellulose. The results indicate that combustible gases, total hydrocarbons and CO, in the degradation products are relatively small, about 23% for the pyrolysis reaction and 16% for the oxidative degradation (mass base). The rest of the degradation products are noncombustible (Kashiwagi 1992: 345-368).The chemistry of the primary competitive reactions of cellulose thermal decomposition is illustrated in Figure 1.

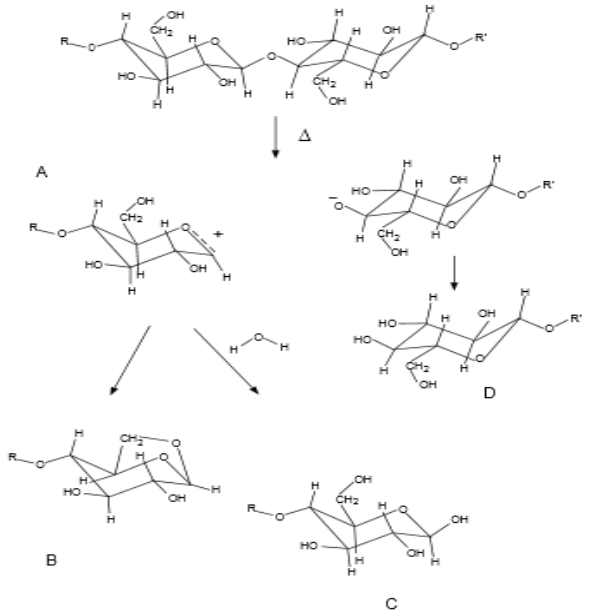
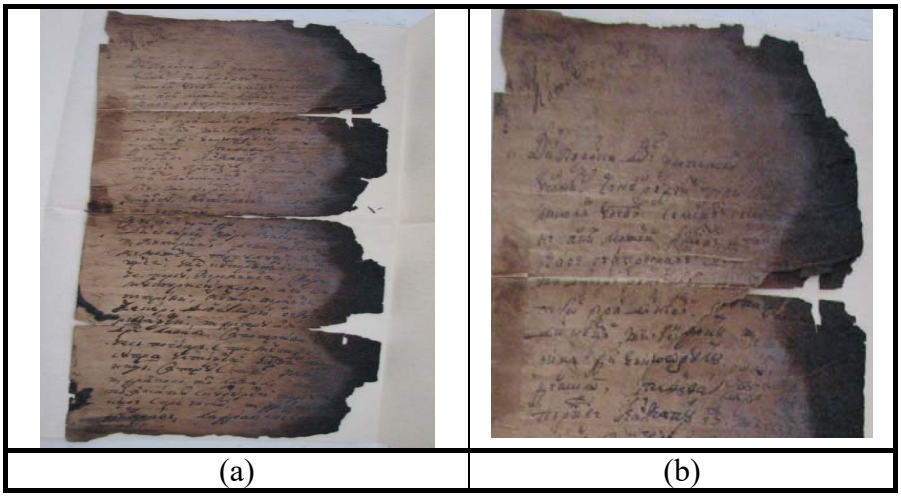


Fig. 1. The primary competitive reactions of cellulose thermal decomposition. (A) - the carbonium ion; (B) - a levoglucosan end; (C) - a reducing end; (D) - non-reducing end (Ball 2008)

The initial step is considered to be heterolytic thermal scission of glycosidic linkages, a trandom chain located in amorphous regions of the cellulose. The carbonium ion (A) may form a levoglucosan end (B) via

intramolecular nucleophilic attack, or a reducing end (C) when intercepted by a water molecule. In both cases a non-reducing end (D) is also formed. There are those species which are believed to undergo the subsequent dehydration, decarboxylation, and cross-linking reactions that produce the char (Ball 2008).

Books and graphical documents are predisposed to burn slowly. Carbonized paper is fragile, browned and at the slightest touch it turns to dust (Figure 2) (Ardelean and Melniciuc- Puică 2015: 94).



(a) (b)

Fig. 2. Carbonized document after fires
Overview (a) and in-detail (b)

It is known that the high temperature changes the cellulosic structure, and weakens the structure even in unburnt paper.

Even if the documents do not come in direct contact with the flame, smoke and soot will affect the colours, settling on the surface of the paper, as well as that of the leather and parchment.

Wet paper is more resistant to high temperatures than dry paper but it undergoes deformations and welds. The single sheets are quickly charred while those books, being compact, suffered the most severe damage on margins and lesser damage inside. (Cauliez 2011: 12) Tightly stored books on a shelf may remain relatively without damage, probably having soot deposits or discoloration on the upper edge. Storage furniture

like closed cabinets also may provide short-term protection against fire damage.

Of the destructive elements that may cause disasters, the most dangerous is fire. The fire can completely destroy, in a matter of minutes, the goods inside a room. In addition to damage from heat, books can also be strongly damaged by smoke, soot and water.

Fire emits smoke and dry soot which can seep into the paper. Smoke is a complex mixture of different gases and particles, which results from the various materials that burn during a fire (Bolstad-Johnson 2010: 2). When books covered with soot are wrongly handled, the soot risks being steeped more into surfaces. Soot and smoke which are deposited on the objects contain products of the gas-phase combustion process, and are very difficult to remove with the passing of time. Showcases can protect books and documents from the destructive effects of soot.

That is why it is imperative to understand the behaviour of fire and take all cautionary measures to prevent it.

Many times, because there wasn't an adequate intervention plan in place, the books, although not touched by flames, have been deteriorated or gotten wet during the fire extinguishing process.

In the event of fire, rescue operations of old books and documents are expensive and delicate. The least expensive solution is prevention. When establishing backup plans for these collections, discuss with preservation specialists, better prevention and the most reliable possible rescue techniques.

Procedures for the preservation of charred documents are covered under specific standards (ASTM E2710-11e1). These procedures include evaluation of the adequacy of the materials used for preservation.

Case study: The conservation and restoration of carbonized documents

The purpose of conservation treatments is to stop biological attack, and to clean the surface of the document in order to provide it with lasting protection and to consolidate the support material and to bring the documents to an original condition.

The documents submitted to conservation treatment and restoration are two manuscripts.

The first document (1) is a manually obtained fragment of paper, written in black insoluble ink (Figure 3). The document is covered with a layer of smoke and dust, which strongly adhered to the paper support. What is noticed is that the document has, probably before the fire, a blot of oil, which covered approximately 80% of the fragment's surface. On this surface, the presence of the fat substance with the dust particles which studded it, there was extended a powerful microbial attack, which after biological investigation it was proven to be caused by *Aspergilus flavus.*

Fig. 3. The investigated document (1) when it was brought to a laboratory

The disinfection treatment was accomplished by dry cleaning through easy dusting with a fine brush, then by light erasing with gauze buffers. After that came the removal of the dust storages with gel made of cellulose ether (Figure 4), also cleaning with ethylic alcohol, avoiding the areas covered with ink.

Fig. 4. Removal of dust storages on the document's surface (1)

After the ink's solubility was verified, the wet cleaning was performed. The wet cleaning was realized through application of a compress made of filter papers soaked in distilled water, compress which have changed since these has not presented any remains caused by the abstraction of colored compounds of degradation of the paper's structure (Figure 5a).

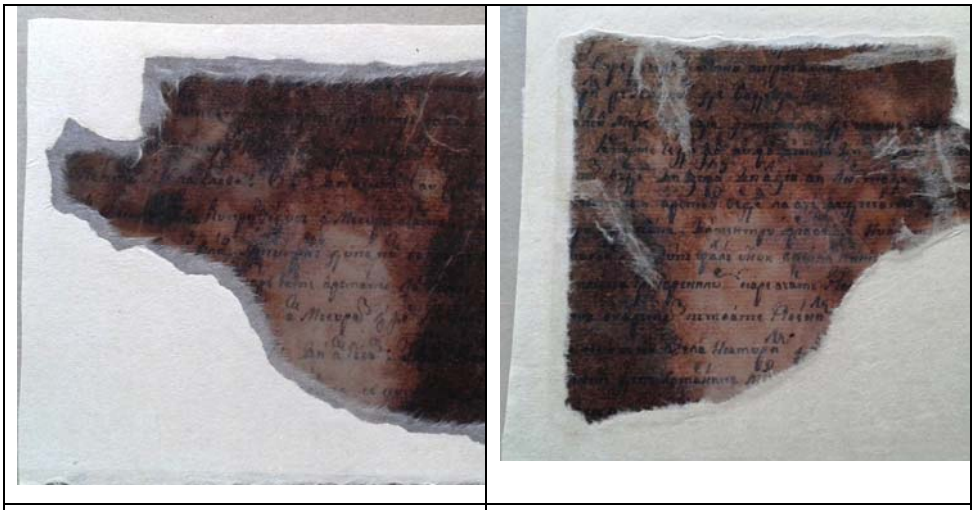
De-acidification has been achieved through the application of a compress of filter paper moistened with a solution of calcium hydroxide $Ca(OH)_2$ that has been maintained on the surface of the paper for 15 minutes.

(a) (b)

Fig. 5. Wet cleaning through the application of the compress from filter paper (a); document (1) consolidation (b)

The document has been consolidated with a layer of Japanese paper 18g/m^2 and 2% carboxymethyl cellulose (CMC) solution through the technique of "doubles", then was left to dry (Figure 5b). After drying and pressing the excess Japanese paper was removed so that all its text should be legible.

Figure 6 presented the document (1) after restoration treatments.

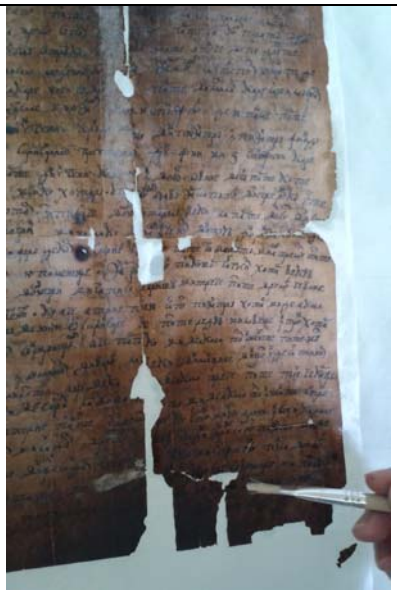


(a) (b)

Fig. 6. The document (1) after restoration: front (a) and back (b)

The second document (2), folded on its length, having large carbonized areas, was particularly fragile and the areas where it had been folded over time (probably before fire) were cracked or even fractured. The procedure was the same as in the case of the document presented above, with the difference was that here the document's fragility was significantly higher, and severe cracks determined the detachment of numerous fragments of the original support (Figure 7a).

After dry and wet cleaning, fragments of the document were placed on a support of silk veil covered with a layer of Japanese paper of 11g/m^2 and a layer of 2% CMC solution. After mounting all fragments (Figure 7b) the document has been covered with Japanese paper of 11g/m^2.



(a) (b)

Fig. 7. The document (2) before restoration (a); Mounting fragments on the support of Japanese paper (b)

In the areas with cracks or in lacunar areas there was applied an adhesive layer with a 3% CMC solution (Figure 8a). After the drying of the assembly, this was detached from the glass and pressed for 48 hours. After pressing, the excess Japanese paper was removed (Figure 8b), and the document recovered its original form and could be easily handled for documentary valorization.

(a) (b)

Fig. 8. Applying the adhesive layer in consolidating areas (a); Removal the excess of Japanese paper (b)

Fig. 9. The document (2) after restoration

Figure 9 presented the document (2) after restoration treatments.

Conclusions

In the restoration laboratory, it is necessary for any art object to be subject to scientific investigation, as it will provide important data regarding the state of conservation of the object. Following the investigation, restoration will be performed in order to extent the object's life.

While performing the investigations, making the diagnosis and treatment proposals for older books, multiple specialists must be on site and reach a consensus: restorers, conservators, chemists, physicists, biologists, museographers, art historians, palaeographers, philologists, codecology experts, librarians, considering the complexity of the required

information and the number of materials that makes up the book or document.

Of any destructive elements that may cause disasters of written materials, the most dangerous is fire. The fire can completely destroy, in a matter of minutes, books and documents. Also the high temperature may cause various irreversible damages to constituent materials of books and documents.

In many cases though, the writing becomes illegible, the burnt paper areas will break at the slightest touch and thus information may be lost. The documents' restoration treatment in the event of fire are expensive and delicate. The least expensive solution is prevention.

That is why it is imperative to understand the behaviour of fire and take all cautionary measures to prevent it.

Acknowledgements

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References:

- Alegbeleye, B. 1993. *Disaster Control Planning for Libraries, Archives and Electronic Data Processing Centres in Africa.* Ibadan: Options Book and Information Services Ed.
- Ardelean, E. and Melniciuc Puică, N. 2015. "Considerations about disasters impact on libraries and archives." In *Current Topics, Concepts and Research Priorities in Environmental Chemistry*, 4th vol., edited by C. Zaharia. Iaşi: Editura Universităţii "Al. I. Cuza" din Iaşi.
- ASTM E2710-11e1. Standard Guide for Preservation of Charred Documents, http://www.astm.org/Standards/forensic-science-standards.html (accesssed 13.10.2015).
- Ball, R., McIntosh, A. C., Brindley, J. 2008. *Feedback processes in cellulose thermal decomposition. Implications for fire-retarding strategies and treatments*, http://arxiv.org/pdf/physics/0207101.pdf (accessed 3.10.2015).
- Biblioteca Centrală Universitară Bucuresti, *www.bcub.ro/home/istoric* (accessed 20.10.2015).
- Bolstad-Johnson, D. 2010. *The Hidden Hazards of Fire Soot*, AIC News 35, 5.
- Boyd Rayward and W., Jenkins, C. 2007. "Libraries in Times of War, Revolution, and Social Change." *Lybrary Trends* 55, 3.

- Cauliez, N. 2011. *Les facteurs de degradation des documents d'archives.* Paris: Archives Nationales.
- Kashiwagi, T. and Nambu, H. 1992. "Global Kinetic Constants for Thermal Oxidative Degradation of a Cellulosic Paper." *Combustion and Flame*, 88.
- "Isis burns thousands of books and rare manuscripts from Mosul's libraries." *Independent*, http://www.independent.co.uk/ (accessed 26.09.2015).
- Laffont, C. and Mouren, R. 2005. "Les ennemis du livre." *Rechercher dans le BNF*, 1.
- Melniciuc Puică, N. and Ardelean, E. 2010. *Aspecte ale degradării materialelor celulozice – lemnul şi hârtia*. Iaşi: Performantica.
- Mok, W. S.-L., Antal, M. J., Szabo, P., Varhegyi, G., Zelei, B. 1992. "Formation of charcoal from biomass in a sealed reactor." *Ind. Eng. Chem. Res.* 31.
- Oberländer-Târnoveanu, I. 2009. *Un viitor pentru trecut. Ghid de bună practică pentru protejarea patrimoniului cultural*, CIMEC 2002 (digital edition).
- Polastron, L.-X. 2009. *Livres en feu, Histoire de la destruction sans fin des bibliothèques*, coll. *Folio essais*. Paris: Gallimard.
- Price, D., Horrocks, A.R, Akalin, M., Faroq, A.A. 1997. "Influence of flame retardants on the mechanism of pyrolysis of cotton (cellulose) fabrics in air." *J. Anal. Appl. Pyrolysis* 40–41.
- Varhegyi, G., Szabo, P., Mok, W. S. L, Antal, M. J. 1993. "Kinetics of thermal decomposition of cellulose in sealed vessels at elevated pressures. Effects of the presence of water on the reaction mechanism." *J. Anal. Appl. Pyrolysis* 26.