https://doi.org/10.24867/GRID-2024-p90 Original scientific paper

INVESTIGATION OF THE INFLUENCE OF WATER TREATMENT IN BOOK CONSERVATION PROCESSES ON THE COLOUR CHARACTERISTICS OF PAPERS

Iskren Spiridonov [1], Rumyana Boeva [1], Iordanka Ivanova [2]
[1] University of Chemical Technology and Metallurgy, Department of Printing Arts, Pulp and Paper, 8 Kliment Ohridski blvd., Sofia 1756, Bulgaria
[2] "St. St. Cyril and Methodius" National Library of Bulgaria, 88 Vasil Levski blvd., Sofia 1504

Abstract: *The conservation and restoration of books, documents and manuscripts is aimed at prolonging the life of our written cultural heritage, mainly written on paper, leather and parchment. The main aim of conservation is to preserve the integrity of the object and to prolong its life. In the present experiment, a study was conducted to evaluate the effect of water treatment in the conservation treatment of books on the colorimetric characteristics of paper. Unrestored books were selected from the archive of the Bulgarian National Library "St. St. Cyril and Methodius", and the study was conducted in the restoration center of the library. Water treatment of all pages of the book have been done and the colorimetric characteristics before and after water treatment have been measured with a spectrophotometer. Color difference - ΔE, lightness difference - ΔL and hue difference - Δh, between samples before and after water treatment have been calculated. From the obtained results, the effects and changes of the all investigated colorimetric parameters were determined. These results are important from a practical and scientific point of view. The results could be used as valuable information for restoration centers worldwide.*

Key words: Restoration, conservation, color characteristics, color difference, water treatment of papers

1. INTRODUCTION

Each paper, over time, changes its physical-mechanical and chemical properties, i.e. paper ages (Sonderegger et al., 2015). The durability of paper depends primarily on its composition, but also on the conditions of receipt and storage (Saoud et al., 2018). Book and paper conservation involves preserving and stabilizing the material as it is, while preserving as much of the original materials as possible. Conservation differs from restoration, which involves returning a book or manuscript to new condition using more invasive techniques and less preservation of original materials (Clarkson, 2015). Soaking paper in water removes water-soluble compounds originating from hydrolysis and oxidation of the paper, metabolism of microorganisms, atmospheric pollution, use, etc., since some of the removed compounds are acidic[3]. Deacidification is the main strategy for chemical stabilization of paper. It is considered the most important conservation intervention that relates to the long-term preservation of paper (Egorov & Slinkov, 2014; Baty et al., 2010).
Deacidification refers to chemical treatments meant to slow down the acid hydrolysis and embrittlement of books and paper documents that had been printed on acidic paper. From the early 1800s up to about 1990, papermakers used aluminum sulfate, an acidic compound, in most printing papers. Conservation and restoration of books, manuscripts and documents is an activity dedicated to prolonging the life of objects of historical and personal value, made mainly of paper, parchment and leather. The main aim of conservation is to prolong the life of the object as well as to preserve its integrity (Bansa, 2002; Ivanova, Spiridonov & Lasheva, 2022; Małachowska et al., 2021).

2. METHODS

For the present experiment, a book entitled ''Companion Talks on the Service of a Junior Officer'' dated 1898 with signature number 67.015 from the archives of the National Library of St. St. Cyril and Methodius (Figure 1). It is valuable and not restored. Twelve sheets of the book were selected. Two different fields were selected on each of pages without printing on them. Field 1 being the lightest area of the paper and Field 2 being the darkest area of the paper (zone with advanced oxidation). Colorimetric measurements were made in CIE* Lab and CIE Lch with a X-Rite spectrophotometer. The measurement conditions were standard illuminant CIE D50, 2ºstandard observer, measurement geometry 45/0, measurements without polarization filter. The individual sheets of the book were subjected to aqueous

immersion with warm water, with 4 washes every 10 min. After 40 min, borax-phosphate buffer was added to deacidification the paper for another 10 min and the sheets were removed to filter paper until completely dry. The working solution of the buffer was 19.5 g. Borax and 13.5 g acid potassium phosphate in 2 liters of water (Figure 2). Measurements were taken before treatment and after water treatment. Color difference calculations (CIE ΔE*ab and CIE ΔE_{2000}) were performed. Mean values for L, C, h were also calculated. The effect of preservation treatment between pre-treatment and post-water treatment was investigated for lightness ΔL, saturation Δc, color tone Δh, color difference ΔE*ab and ΔE_{2000}.

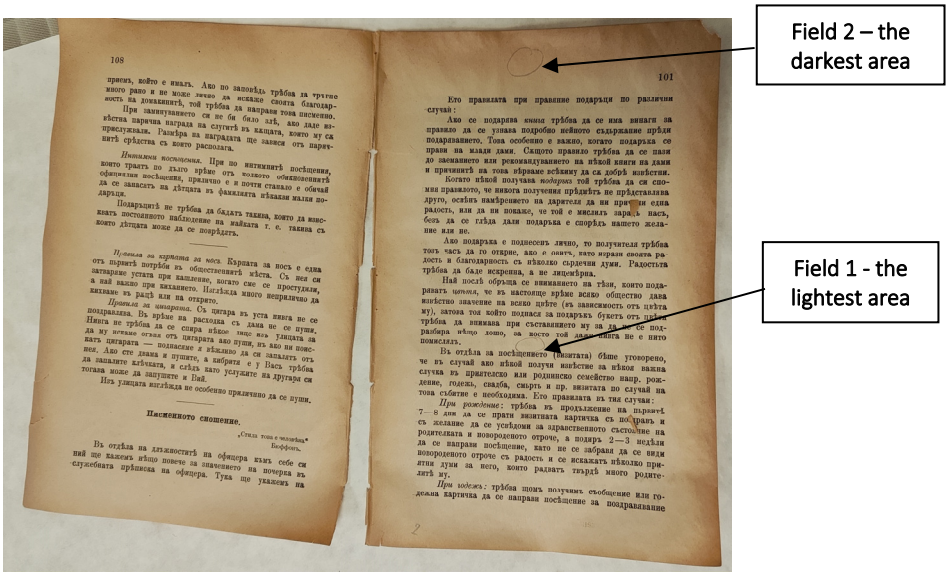

Figure 1: Sheet 1 and 2 of the book and selected fields

Figure 2: Water treatment of selected pages from the book.

3. RESULTS

Measured data from the color characteristics of documents provide information on the color change of paper manuscripts in the aging process during their storage and use. In previous research, it was found that the most suitable colorimetric systems for evaluating the aging of manuscripts are CIE L*c*h* and CIE L*a*b* and (Ivanova, Spiridonov & Boeva, 2024). Each of these color systems defines color using three color coordinates: CIE L* - lightness coordinate indicating the changes in the light tones of the paper to which the human eye is particularly sensitive (this characteristic is common and the same for the L*a* systems b* and L*c*h*); CIE a* – red-green color coordinate; CIE b* – yellow-blue color coordinate;

CIE c* – colorimetric coordinate responsible for saturation (in the present study defined as Δc – change in saturation); CIE h* – hue (in the present study defined as Δh – hue change of color tone). In order to better interpret the results regarding the analysis of the changes in the color parameters of the primary color coordinates, the saturation and the changes in the hue, both colorimetric systems – CIE* Lch and CIE* Lab – were used in the study.

3.1 Investigation of the effect of water treatments on the color characteristics of selected fields of the book pages, expressed by color difference (CIE ΔE*ab and CIE ΔE2000)

The processes of changing the color characteristics in the water treatment process in the conservation treatment were investigated and their quantification was done by determining the two most commonly used color difference formulas, CIE ΔE*ab and CIE ΔE_{2000}. CIE ΔE*ab is the classical method for determining color change, while CIE ΔE_{2000} is a method that is adapted to the specific characteristics of human perception (Kachin & Spiridonov, 2004). The CIE ΔE_{2000} color difference also gives more accurate results in white and neutral color shades, such as book paper. Figure 3 shows the influence of the color difference (CIE ΔE*ab) and (CIE ΔE2000) before and after water treatment of the twelve pages of the book for the advanced oxidation zone - Field 2 (darkest zone). Figure 4 shows the color differences in the lightest area of paper (Field 1) with less degree of oxidation.

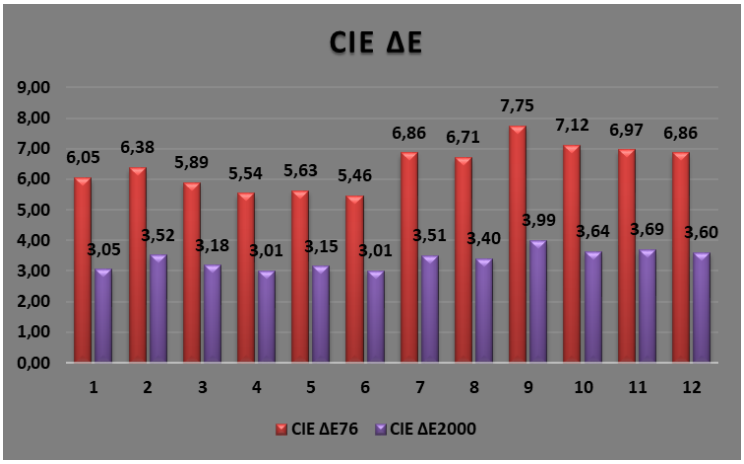

*Figure 3: Effect of color difference (CIE ΔE*ab) and (CIE ΔE*2000) before treatment and after water treatment of selected fields of paper sheets for the darkest area (advanced oxidation zones)*

It can be seen from the graphs that there is a highly noticeable color difference before treatment and after water treatment. The greatest change in color difference is observed in fields with advanced oxidation (the darkest area). In the lighter parts of the book's pages, there is a smaller difference, but noticeable.

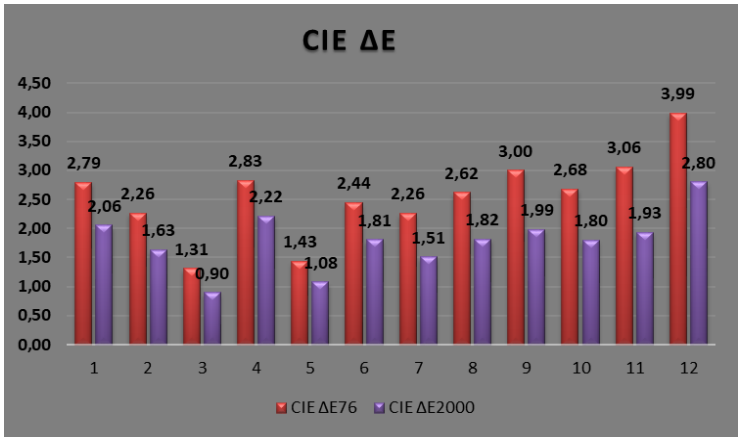

*Figure 4: Effect of color difference (CIE ΔE*ab) and (CIE ΔE*2000) before treatment and after water treatment of selected fields of paper sheets for the lightest area*

From the graph it can be seen that in the both color difference formulas - CIE ΔE^*_{2000}, which is high consistent with human perception, compared to classical formula - CIE ΔE^*_{76}. The biggest change is in the fields with advanced oxidation (Field 2) - ΔE^*_{2000} reaches up to 4 units, and ΔE^*_{76} reaches up to approx. 8 units. Less change is seen in the brightest area of Field 1 - ΔE^*_{2000} reaches up to 2,8 units, and ΔE^*_{76} reaches up to approx. 4 units.

3.2 Study of the influence of water treatment on colorimetric characteristics - lightness (CIE* L), saturation (CIE* C), color hue (CIE* H)

For a more detailed analysis of color changes expressed as ΔE, all three coordinates in CIE* Lch were examined separately each by other to determine the effect of water treatment in conservation process for each of coordinate changes. By this analysis, it will be determined the influence of changes in lightness, saturation and hue separately on the resulting color differences in the book conservation processes. Effect of water treatment on paper lightness (CIE*L) of selected fields of book sheets - before and after water treatment. Figure 5 shows the change in lightness (CIE*L) before and after water treatment of the twelve pages of the book for the lightest area – Field 1, and Figure 6 for the darkest and oxidized area of paper – Field 2.

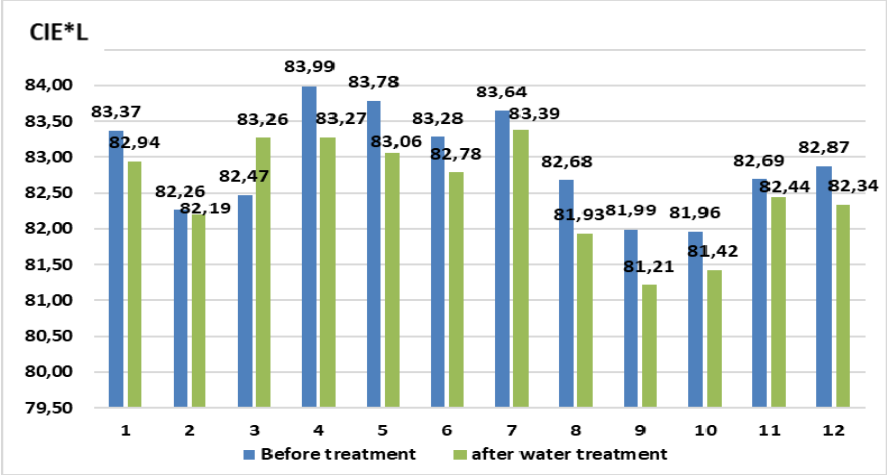

*Figure 5: Investigation of the change in lightness (CIE*L) of the papers under different treatments of selected similar fields 1 – lightest area of conservated paper*

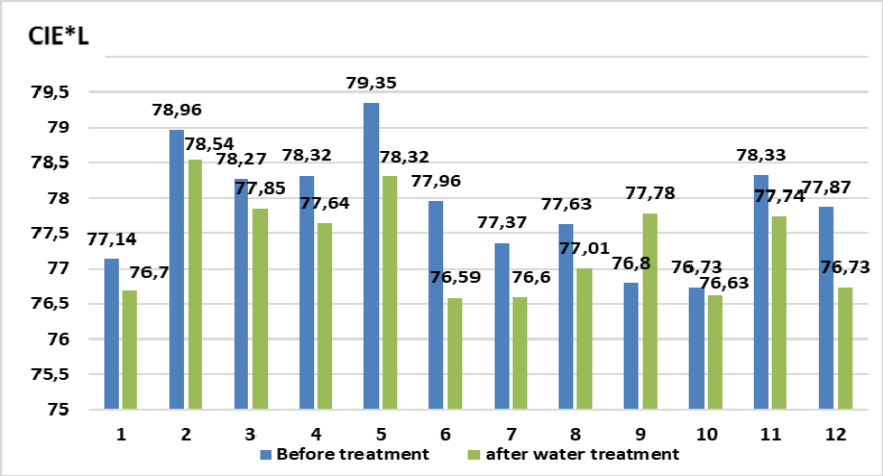

*Figure 6: Investigation of the change in lightness (CIE*L) of the papers under different treatments of selected similar fields 2-* darkest and oxidized area *of conservated papers*

From the graphs it can be seen that there is a slight change in the lightness of the paper for both areas which is almost imperceptible and is in range of 0,1 to 1 unit of CIE L. The water treatment in conservation processes very slightly decreases the lightness of paper. Effect of water treatment in book conservation treatment on paper saturation (CIE*C) of selected fields in the lightest area and the area with advanced oxidation (darkest area) – before and after water treatment. Figure 7 shows the change in paper saturation (CIE*C) of selected similar fields from the book pages in the darkest and more oxidized areas of paper, and Figure 8 in the lightest area of the paper.

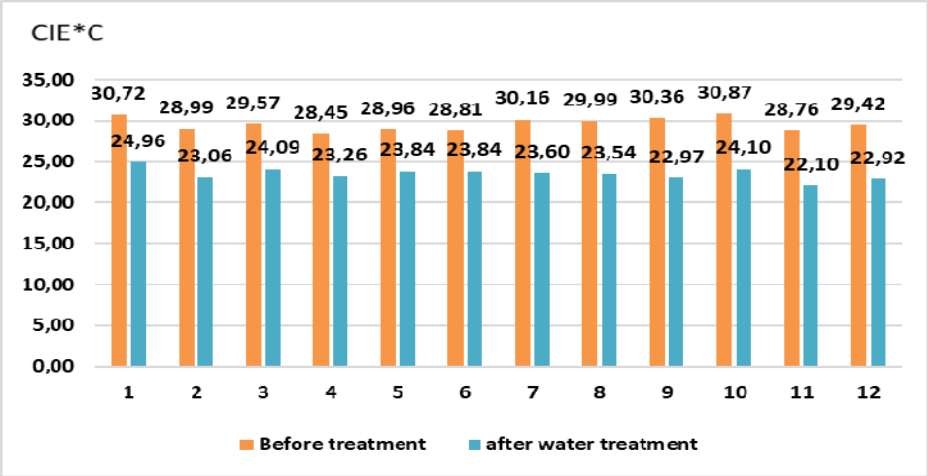

*Figure 7: Study of the change in saturation (CIE*C) of the book pages before and after water treatment for the darkest and more oxidized areas of paper*

Figure 7 shows that there is a significant change in the saturation of the paper (CIE*C) of the selected fields of the book pages in the area of advanced oxidation of the paper (darkest area) after water treatment. The water treatment reduces the saturation of oxidized paper by 6-7 units of CIE C. This change in the saturation values visually feels like a decrease in the intensity of the yellow-brown color of the oxidized paper after the water treatment process is done, which improves the good visual feeling when reading the book. Figure 8 shows a small change in saturation of light and non-oxidized area of paper. The obtained results show, that after the water treatment, the saturation of the darker and lighter areas of the paper become closer in value because the darker yellow spots on the paper fade and become closer in color to the lighter and less affected by oxidation sections of the paper.

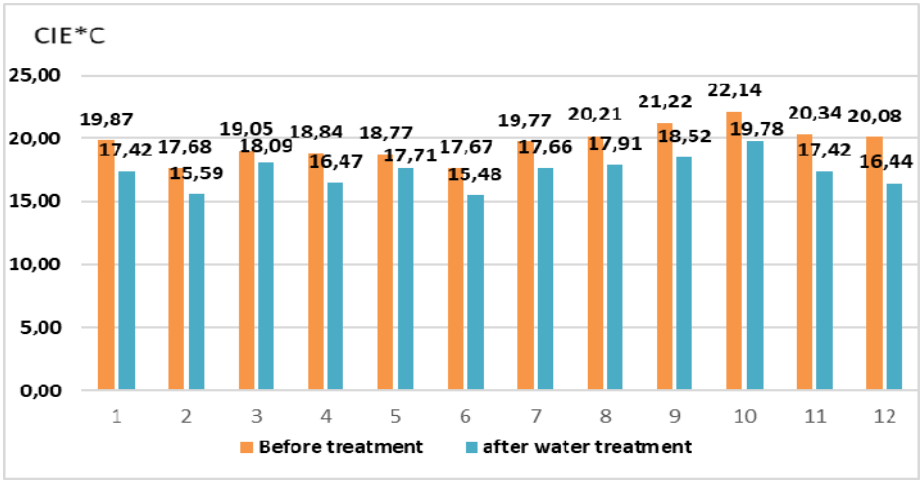

*Figure 8: Study of the change in saturation (CIE*C) of the book pages before treatment and after water treatment for the lightest area*

3.3 Study of the change in hue (CIE* h) before and after water treatment of book pages

Figure 9 shows the change in hue (CIE*h) before and after water treatment of selected fields of book pages in the more oxidated areas (darkest areas), and Figure 10 in the lightest area.

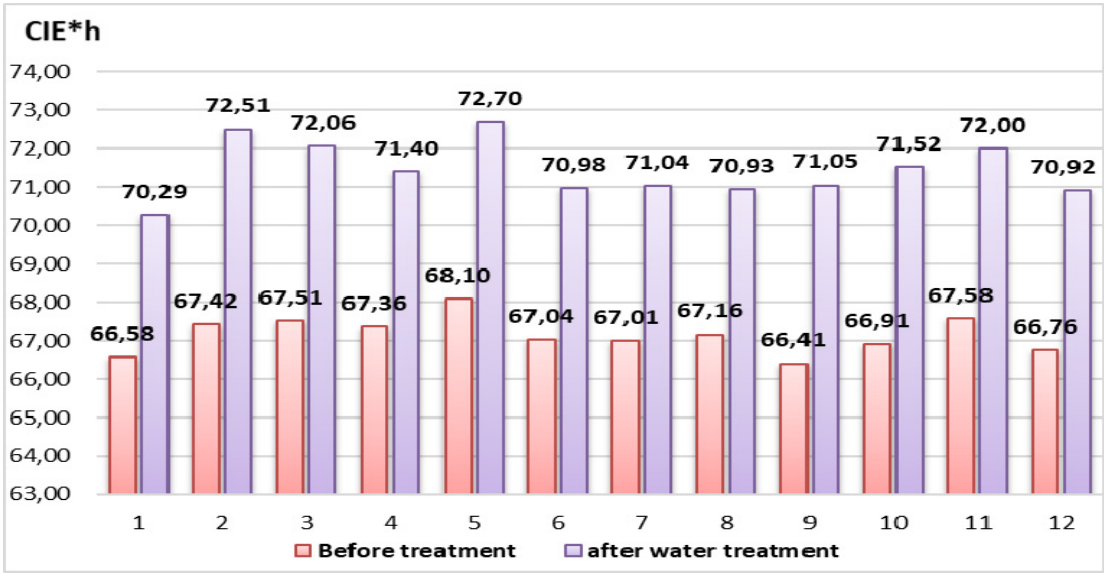

Figure 9: Change in hue (CIE h) before and after water treatment of the book pages for the darkest area*

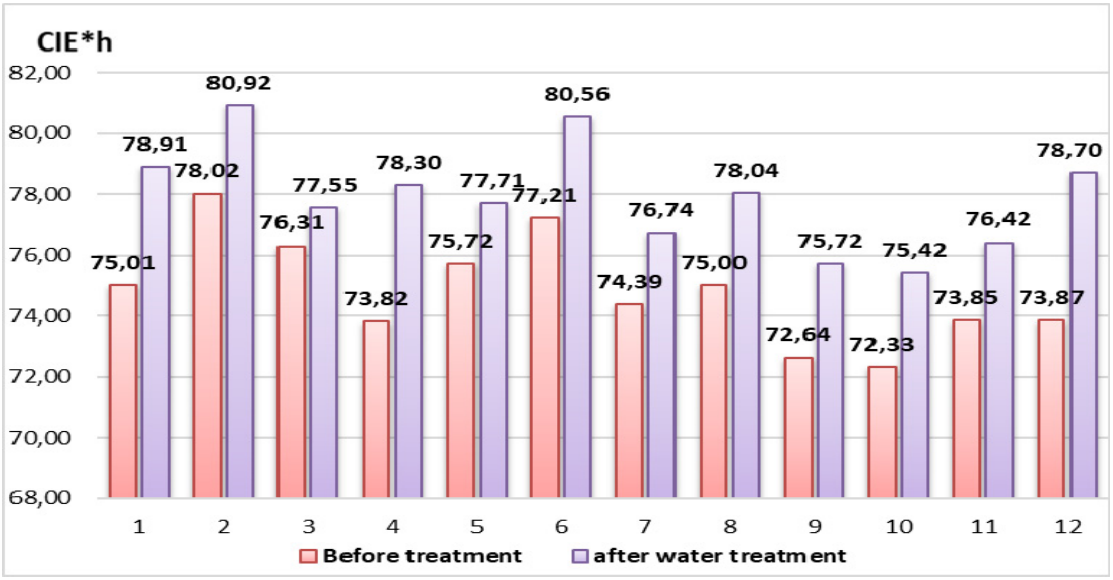

Figure 10: Change in hue (CIE h) before and after water treatment of book pages for the lightest area*

The hue changes after water treatment are bigger in the areas of advanced oxidation. The change in color hue as a result of the water treatment is approx. 3-4 units for the dark oxidized fields, and 1-3 units for the light parts of the paper. These changes in color tone are not visually significant because the color saturation is not high, especially for lighter fields of paper.

4. DISCUSSION

From an examination of the color difference (ΔE*ab and ΔE2000) of papers between original un-conservated book pages and after water treatment of selected different kind of investigated fields (light and oxidized-darker), it was found:

- The change in ΔE*ab (before and after water treatment) for the lightest selected area of the pages is between 1.31 and 3.06 and ΔE_{2000} is between 0.90 and 2.60 depending on the pages.
- The change in ΔE*ab (before treatment and after water treatment) for fields with advanced oxidation of the paper (darkest area) is between 5.44 and 7.75 and ΔE_{2000} is between 3.01 and 3.99 depending from the pages. Based on the study of the influence of water treatment on the colorimetric characteristics - lightness (CIE* L), saturation (CIE* C) and hue (CIE* h) it was found:
- The change in mean ΔL value (before and after water treatment) for the lightest selected area of the pages is between 0.07 and 0.78 and for the fields with advanced oxidation (the darkest area) is between 0.10 and 1 .37 depending on the pages of the book.
- The change in Δc (before and after water treatment) for fields with advanced oxidation of the paper (darkest region) is between 5.12 and 7.38 and for fields in the lightest region Δc is between 0.97 and 3.64 depending on the pages.
- The change in mean Δh value (before and after water treatment) for the lightest selected area of the pages is between 1.24 and 4.84 and for the fields with advanced oxidation (the darkest area is between 3.71 and 5 .08 depending on the pages of the book.

5. CONCLUSIONS

From the study made of the color characteristics of the book before and after water treatment of the paper, it was found that the conservation treatment gives a serious effect on the areas with advanced oxidation. The lightest areas of the papers (those least affected by the aging process) are very slightly affected by the conservation processes and practically change color characteristics in relatively small dimensions. From the calculation made of the color difference (ΔE*ab and ΔE2000) between before treatment and after water treatment of selected fields from the pages of the book, it was found that the highest values were obtained in the fields with advanced oxidation.

- The change in ΔE*ab (before and after water treatment) for the lightest selected area of the pages reached 3.06, and for fields with advanced oxidation of the paper (the darkest area) to 7.75, showing a highly noticeable difference.
- The change in ΔE2000 (before and after water treatment) for the lightest selected area of the pages reached 2.60, and for fields with advanced oxidation of the paper (the darkest area) to 3.99, indicating that there is a noticeable difference expressed by the more sophisticated color difference formula - ΔE2000. The biggest changes of the color characteristics - lightness (CIE* L), saturation (CIE* c), color tone (CIE*h), are in the fields with advanced oxidation. Based on the results obtained, it was found that the water treatment processes mostly affect the saturation (CIE* c), less affects on hue (CIE*h) and lesser extent the lightness (CIE* L) of paper.
- There is slight change in the lightness of the paper for both light and darker areas which is almost imperceptible and is in range of 0,1 to 1 unit of CIE L. The water treatment in conservation processes very slightly decreases the lightness of paper.
- There is a significant change in the saturation of the paper (CIE*C) of the selected fields of the book pages in the area of advanced oxidation of the paper (darkest area) after water treatment. The water treatment reduces the saturation of oxidized paper by 6-7 units of CIE C. This change in the saturation values visually feels like a decrease in the intensity of the yellow-brown color of the oxidized paper after the water treatment process is done, which improves the good visual feeling when reading the book. The obtained results show, that after the water treatment, the saturation of the darker and lighter areas of the paper become closer in value because the darker yellow spots on the paper fade and become closer in color to the lighter and less affected by oxidation sections of the paper.
- The change in color hue as a result of the water treatment is approx. 3-4 units for the dark oxidized fields, and 1-3 units for the light parts of the paper. These changes in color tone are not visually very significant because the color saturation is not too high, especially for lighter fields of

paper. From a scientific and applied point of view, the obtained results are important, as they provide valuable information on the effect of water treatment on the color characteristics of paper in the book conservation process. The study also proves that despite the advent of electronic media, paper remains the main material for storing and transmitting information. Therefore, in the future, care for the storage, conservation and restoration of written materials will remain the main priority of libraries, museums, archives, and private collections.

6. REFERENCES

Bansa, H. (2002) Accelerated Ageing of Paper: Some Ideas on its Practical Benefit. *Restaurator. International Journal for the Preservation of Library and Archival Material.* 23 (2), 106-117. Available from: doi: 10.1515/REST.2002.106

Baty, J. W., Maitland, C., Minter W., Hubbe M. A. & Jordan-Mowery, S. (2010) Deacidification for the conservation and preservation of paper-based works: A review. *BioResources*. 5 (3), 1955-2023. DOI: 10.15376/biores.5.3.1955-2023.

Clarkson, C. (2015) Mininum Intervention in Treatment of Books. In: Cloonan, Michele Valerie (eds.) *Preserving our Heritage*. Chicago, American Library Association.

Egorov, V. P. & Slinkov, A. B. (2014) *Preservation, restoration and preservation of documents.* [in Russian]. Moscow. Available from: https://www.labirint.ru/books/633370/ [Accessed 13th August 2024].

Ivanova, I., Spiridonov, I. & Boeva, R. (2024) Study of the influence of conservation treatment on the chromatic characteristics of arabic manuscripts. *Journal of Chemical Technology and Metallurgy*. 59 (3), 591 – 598. Available from: doi: 10.59957/jctm.v59.i3.2024.12

Ivanova, I., Spiridonov, I. & Lasheva, V. (2022) Spectroscopic technique for studying the characteristics of paper, pigments and inks in the aging process (REVIEW). *Journal of Chemical Technology and Metallurgy.* 57, 1, 101-113.

Kachin, N. & Spiridonov, I. (2004) Optical density and colour difference in printing on different types of paper. *Cellulose Chemistry and Technology*. 38 (3-4), 255-264.

Małachowska, E., Dubowik, M., Boruszewski, P. & Przybysz, P. (2021) Accelerated ageing of paper: effect of lignin content and humidity on tensile properties. *Heritage Science*. 9 (132). Availale from: doi: 10.1186/s40494-021-00611-3

Saoud, K. M., Saeed, S., Al Soubaihi, R., Samara, A., Ibala, I., El Ladki, D. & Ezzeldeen, O. (2018) Application of Mg $(OH)_2$ nanosheets for conservation and restoration of precious documents and cultural archives. *BioResources*. 13 (2), 3259-3274. Available from: doi: 10.15376/biores.13.2.3259-3274

Sonderegger, W., Kránitz, K., Bues, T. C. & Niemz, P. (2015) Aging effects on physical and mechanical properties of spruce, fir and oak wood. *Journal of Cultural Heritage.* 16 (6), 883-889. Available from: doi: 10.1016/j.culher.2015.02.002