INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 7, Special Issue 1, 2016: 349-356 www.ijcs.uaic.ro

DISADVANTAGES OF USING SOME POLYMERS IN RESTORATION OF OLD ICONS ON WOODEN PANELS

Marius MUNTEANU[1*], Ion SANDU[1,2], Viorica VASILACHE[1,2], Irina Crina Anca SANDU[3]

[1] „Al. I. Cuza" University of Iasi, Phd School of Life and Earth Sciences, ARHEOINVEST Platform, Blvd. Carol I 11, 700506, Iasi, Romania
[2] Romanian Inventors Forum, Str Sf. Petru Movila 3, L11, III/3, 700089, Iasi, Romania
[3] Universidade de Evora, Laboratorio Hercules, Palacio de Vimioso, Largo Marques de Marialva, no 8, 7000-809, Evora, Portugal

Abstract

*The present paper presents some disadvantages of using acrylic polymers in the restoration of old icons on wooden panels. Two acrylic polymers were taken into study: Paraloid B72 and Paraloid B67. These two acrylic polymers were chosen for several reasons, being well known and used by the majority of the restorers' community, due to their dissolution properties and availability. The two acrylic polymers were used to consolidate samples of old wood (2x2x1cm). The samples were taken from heavily degraded wooden panels which would not undergo restoration. The three samples of lime-tree and three samples of oak-tree were then consolidated each with three different polymeric solutions. In order to determine the way that this type of consolidation can influence the wood and the disadvantages of using these acrylic polymers, the following analytical techniques were used: optical microscopy (OM), CIEL*a*b* colorimetry and scanning electron microscopy (SEM).*

Keywords: *Acrylic polymers; Consolidation; Disadvantages; Old icons; Wooden panels*

Introduction

One of the major problems that affects the conservation state of wooden artifacts or artworks (paintings, icons) is the loss of the wood's structural resistance, due to xilophagous attacks or dehydration. In order to resolve this problem, wood conservators and scientific researchers have proposed, tested and analyzed various materials over time. The solution on which the restorers community agreed was the use of synthetic polymers, most often reported being Paraloid B67, Paraloid B72 and Paraloid B44 [1-7].

Even though these synthetic polymers have some advantages (reversibility, elasticity, commercially available etc.), they also have serious drawbacks [8-10].

The purpose of this paper is to present some of the disadvantages of using synthetic polymers in wood consolidation and to remind the necessity of implementing new consolidation systems for wooden artworks, with new consolidant products that would not present such drawbacks.

* Corresponding author: munteanu.maryus@gmail.com

Analytical Methods

In order to present the negative effects that consolidation processes with synthetic polymers can have on wooden panels of old icons, six pieces of wood were selected and treated with two synthetic polymers, Paraloid B67 and Paraloid B72. These two polymers were chosen due to their frequent use in Romania in woode panel consolidation and their low cost and wide commercial availability.

The consolidation polymeric solutions were obtained by dissolving the two synthetic polymers (Paraloid B67 and B72) each in three different solvents: acetone, turpentine and xylene.

In order to determine the modifications that take place after the consolidation process, the following analytical techniques were implemented: OM, SEM-EDX, and CIE L*a*b* colorimetry.

The wood pieces and samples taken from them were analyzed, both before and after the consolidation treatment, by using a CARL ZEISS AXIO IMAGER A1m microscope, with AXIOCAM camera attached (5X-20X), a scanning electron microscope VEGA II LSH, made by TESCAN, Czech Republic, coupled with an X-ray spectrometer, model QUANTAX QX2, made by BRULER/PROENTEC, in Germany.

The chromatic modifications were measured by comparison between before and after consolidation stages, through CIE L*a*b* colorimetry, using a LOVIBOND 300 Reflectance Tictometer.

An initial measure was performed for each surface of the six pieces of wood and the L*, a* and b* readings were used to calculate the initial ΔE* or the position in the color scheme, before the consolidation treatment [11-18]. After the consolidation treatment was performed on all six pieces, six new CIE L*a*b* measurements were performed on each piece, on the same place at different time intervals (0, 4, 8, 24, 48, 72h).

The colour difference indicator ΔE* is calculated according to the commonly used equation:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

In order to determine the chromatic evolution, the deviation was calculated for every coordinate (L*, a* and b*) in rapport with its initial value, on each sample and on the same place. Finally, the total change of colors was calculated in each point, using the following equation [11-12] in which:

- ΔL^* is the change of the light in the point, on different time intervals, compare with the initial value: $\Delta L^* = L_1^* - L_{initial}^*$;

-Δa^* is the chromatic deviation of the a* coordinates (red and green color) of the same point, on different time intervals, compare to the initial value: $\Delta a^* = \Delta L^* = a_1^* - a_{initial}^*$;

-Δb^* is the chromatic deviation of the b* coordinates (yellow and blue color), respecting the same mathematic formula: $\Delta b^* = b_1^* - b_{initial}^*$.

The weighting of the sample was also done before and six times after the treatment using a KERN electronic scale, with an accuracy of 0,001 g, at different time intervals (0, 4, 8, 24, 48, 72h).

Results and discussion

The choice and elaboration of the six pieces followed a pre-establish protocol. First the wooden panels from where the pieces were taken had to be severally affected by strong xilophagous attacks. The pieces were taken from two different wooden panels, made one from lime-tree and the other from oak-tree. The two wood species were selected because these are two of the most often used in making the old icons in Romania.

Three lime and three oak wooden pieces were taken, with the following dimensions: 20mm x 20mm x 10 mm. The samples were labeled from P1 to P6, as follow:

- P1, P2 and P3 lime-tree pieces
- P4, P5 and P6 oak-treepieces

The pieces and samples taken from them were first analyzed through optical microscopy, at different magnifications (5X-20X).

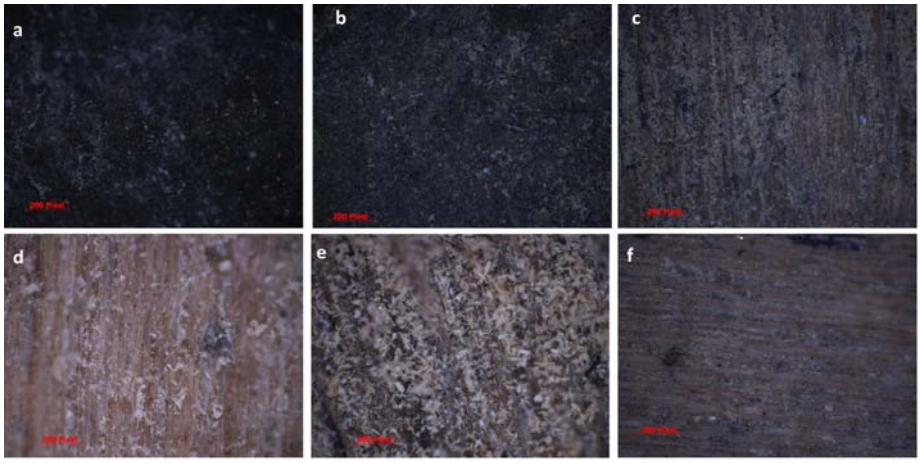

Fig. 1. Optical microscopy of the surfaces of the six wooden pieces, before consolidation treatment:
a, b and c – oak-tree pieces 200X (P1-P3);
d, e and f – lime-tree pieces 200X (P4-P6);

The OM technique done on the surface of the six pieces allowed us to observe the differences between them. The first three lime-tree pieces are covered with a thinner layer of dirt (Fig. 1).

OM analysis was also performed on samples taken from the inner part of the samples in order to determine the structural resistance of the collected pieces. As shown in figure 2, both types of wood, lime and oak-tree, are affected by xylophagous attacks, which lead to a low structural resistance of the wood.

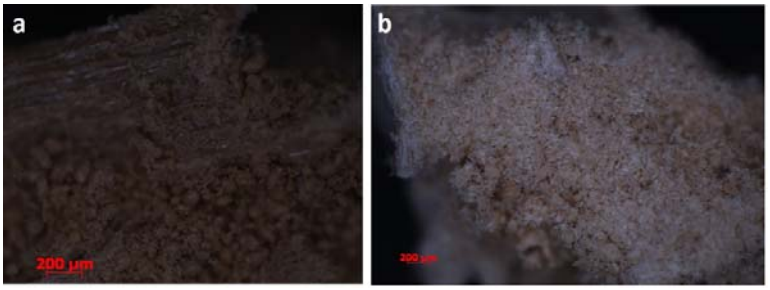

Fig. 2. Optical microscopy done on samples taken from the wood pieces,
before consolidation treatments: OM for P3 (5X); b) OM for P4 (5X);

SEM-EDX analysis was done afterwards on the six samples taken from each wooden piece selected for the experiment.

The SEM results of the analysis done on the samples taken from the six wooden pieces before the consolidation treatment confirmed the OM results regarding the poor structural resistance of the wood, due to the xilophagous attack (Fig. 3).

Each of the six pieces of wood were also submitted to CIE L*a*b* measurements and weighting. The initial measurements data are given in Table 1.

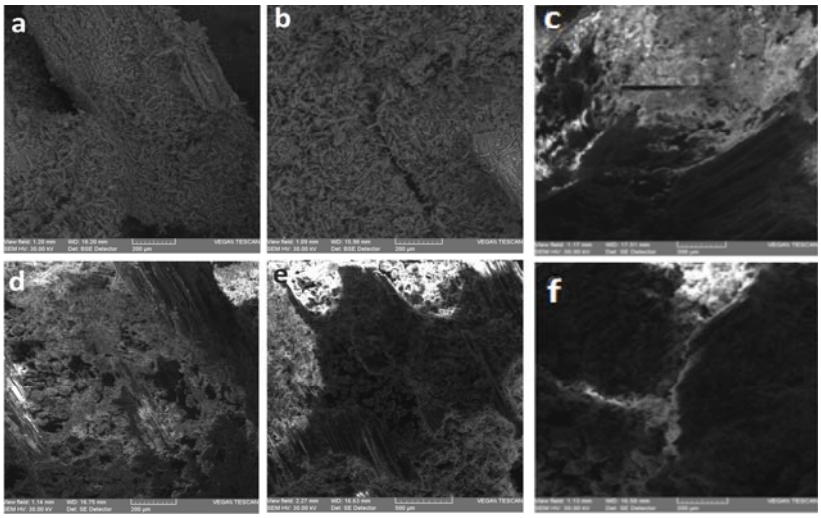

Fig. 3. SEM microscopy of the six samples before the consolidation treatment:
a - Sample taken from P1 (200X, BSE); b - Sample taken from P2 (200X, BSE);
c - Sample taken from P3 (200X, SE); d - Sample taken from P4 (200X, SE);
e - Sample taken from P5 (100X, SE); f - Sample taken from P6 (200X, SE);

Table 1. Initial ΔE* of the surfaces and weight of the six samples of wood, before the consolidation treatment.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**
ΔE*	55,5009	55,4835	50,8917	19,1394	19,9428	20,3481
Weight	1,0964	1,1452	1,1071	1,1653	1,1674	1,0973

After implementing the OM, SEM and CIE L*a*b* techniques on the six samples taken from the six pieces of wood selected for this experiment, the pieces underwent the consolidation treatment. The polymeric consolidation solutions were obtained by dissolving the two synthetic polymers, Paraloid B67 and Paraloid B72 each in three different solvents with different degrees of toxicity and evaporation: xylene, acetone and turpentine.

The concentration of the six solutions was set to 10%. In order to obtain the solutions, 10mg of Paraloid B67 and 10mg of Paraloid B72 were mixed with 100mL of each of the three mentioned solvents. The obtained solutions were named as follows:

- S1: Paraloid B67, dissolved in xylene 10%
- S2: Paraloid B67, dissolved in acetone10%
- S3: Paraloid B67, dissolved in turpentine 10%
- S4: Paraloid B72, dissolved in turpentine 10%
- S5: Paraloid B72, dissolved in xylene 10%
- S6: Paraloid B67, dissolved in acetone 10%

After the six solutions were obtained, the six pieces of wood were treated, as follows: S1-P1, S2-P2, S3-P3, S4-P4, S5-P5 and S6-P6. Each sample was treated with the solution through cold immersion, for 4 hours [19].

At the end of the consolidation treatment, the six pieces underwent a new set of the same analyses (OM, SEM-EDX, CIE L*a*b* and weighting) in order to determine the exact modifications that have appeared after the treatment.

Again, the first technique implemented was the optical microscopy.

The OM analysis shows the fact that while the solid surface of the samples is well covered (Fig. 4a, b and d), the inner part of the pieces, where the cellular structure of the wood

has collapsed, is not completely consolidated, free spaces still being observed in both lime (Fig. 4e and f) and oak-tree (Fig. 4c) samples.

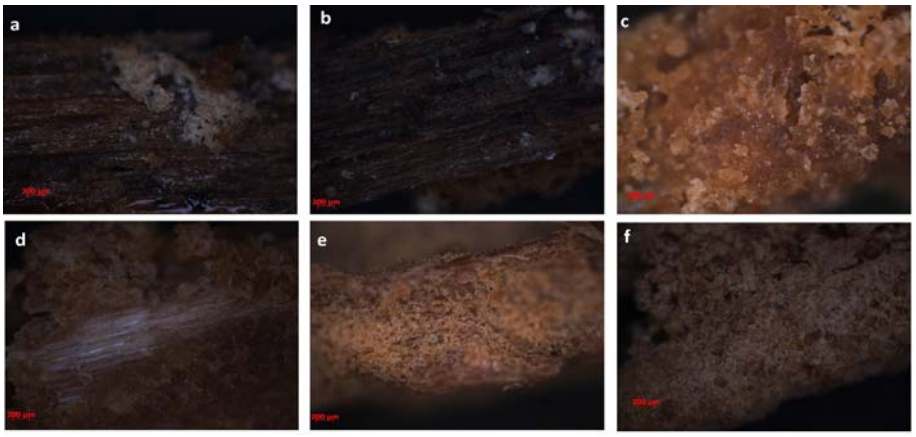

Fig. 4. Optical microscopy of the samples taken from the pieces, after the consolidation treatment: a - Sample taken from P1, treated with S1; b - Sample taken from P2 treated with S2; c - Sample taken from P3, treated with S3; d - Sample taken from P4, treated with S4; e - Sample taken from P5, treated with S5; f - Sample taken from P6, treated with S6;

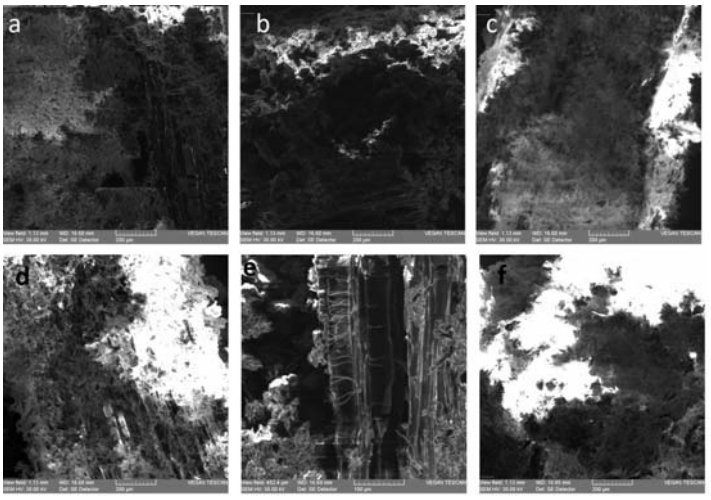

Fig. 5. SEM microscopy of the six samples after the consolidation treatment: a - Sample taken from P1 (200X, SE); b - Sample taken from P2 (100X, SE); c - Sample taken from P3 (200X, SE); d - Sample taken from P4 (200X, BSE); e - Sample taken from P5 (500X, BSE); f - Sample taken from P6 (200X, SE);

This is one of the disadvantages of using synthetic polymers. When the wood cellular structure is totally collapsed, the polymer does not have a solid cellular wall to attach to and cannot completely consolidate the sawdust like wood.

These OM obtained information were confirmed through SEM. The “sawdust” like aspect of the samples can also be observed through SEM (Fig. 5).

Another disadvantage of using the two synthetic polymers is the chromatic modification that the treated wooden panel suffers [20, 21], as seen by comparing figure 1 and 2 with figure 4. In order to determine the chromatic changes the samples were analyzed again with CIE

L*a*b* after the consolidation treatment. The first measurement was done right after the consolidation treatment, and then after 4h, 8h, 24h, 48h and 72h respectively.

After analyzing the results of these six colorimetric measurements done on the treated pieces, it was determined that the pieces reacted differently, due to the different solvent in which the two synthetic polymers were dissolved.

None of the three pieces of oak-tree consolidated with the Paraloid B67 regained its original color after the evaporation of the solvents, all three remaining about 10% darker. The biggest chromatic change was observed at the piece treated with Paraloid B67 dissolved in turpentine (P3). The same oak-treepiece had the lowest rate in turning back as close as possible to its original color, compared to the other two oak-tree pieces treated with the same polymer (P1 and P2), but dissolved in xylene and acetone (Fig. 6a). This difference is due to the fact that turpentine has a lower evaporation point then acetone and xylene.

The initial chromatic change was higher in the case of the three lime samples treated with Paraloid B72 dissolved in the three solvents. Again the piece treated with turpentine (P4) had the lowest rate in turning back to its original color, for the same reason mentioned above (fig. 6b).

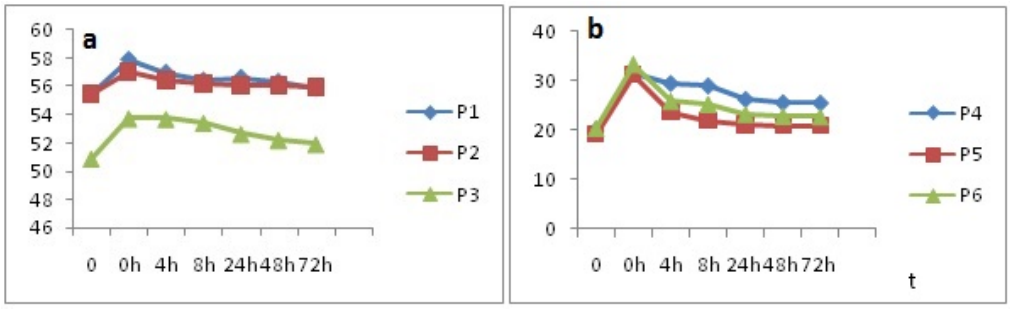

Fig. 6. CIE L*a*b* colorimetric analysis of the six wood samples:
a - CIE L*a*b* analysis on the oak-tree samples P1, P2 and P3;
b - CIE L*a*b* analysis on the lime-tree samples P4, P5 and P6;

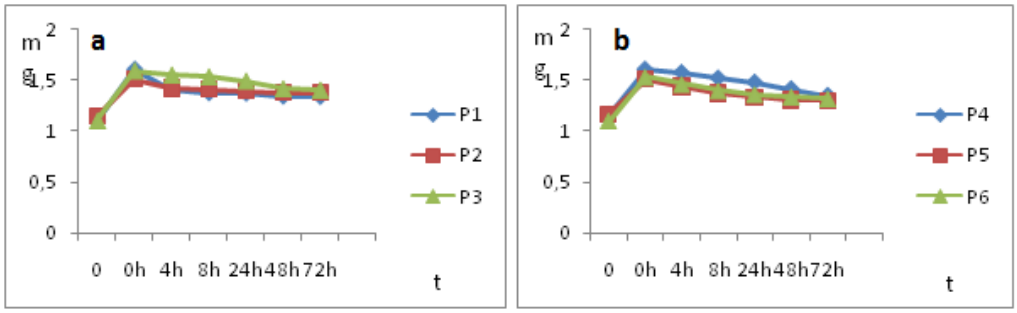

Fig. 7. Weight measurements of the six wood samples:
a - Weight measurements on the oak-tree samples P1, P2 and P3;
b - Weight measurements on the lime-tree samples P4, P5 and P6;

The weight of the samples also changes after the consolidation treatment. The weight evolution curve of the six samples can be observed in figure 7. Again the samples consolidated with the polymers dissolved in turpentine are the most affected, their weight being approximately 15% higher (P3 and P4) then the original weight.

The consolidation with the presented synthetic polymers does not affect only the wooden panels consolidated, but also the restorer and the environment due to the fact that the most

commonly used solvents are toxic [22-25]. Despite the fact that the use of xylene was abandoned in countries around Europe, in Romania is still one of the most used solvent for obtaining consolidation solutions.

Conclusions

The consolidation of six different pieces made of lime and oak-tree respectively with polymeric solutions of Paraloid B72 and Paraloid B67 dissolved in 3 different solvent (acetone, turpentine and xylene) was evaluated and led to following conclusions:

- The inner part of the pieces, where the cellular structure of the wood had collapsed, is a not completely consolidated, free space still being observed in both lime and oak samples.
- After analyzing the results of these six colorimetric and weight measurements done on the treated pieces, it was determined that the pieces reacted differently, due to the different solvent in which the two synthetic polymers were dissolved, the samples consolidated with turpentine dissolved polymers being the most affected ones (P3 and P4).
- None of pieces return to their original color and weight.

Acknowledgements

This work was co-funded by the European Social Fund through Sectoral Operational Programme Human Resources Development 2007 – 2013, project number POSDRU/187/1.5/S/155397, project title "Towards a New Generation of Elite Researchers through Doctoral Scolarships."

References

[1] L. Ellis, A. Heginbotham, *An Evaluation Of Four Barrier-Coating and Epoxy Combinations in the Structural Repair of Wooden Objects*, **Journal of the American Institute for Conservation, 43(**1), 2004, pp. 23-37.

[2] S. Chapman, D. Mason, *Literature Review: The use of Paraloid B-72 as a Surface Consolidant for Stained Glass*, **Journal of the American Institute for Conservation, 42**(2), 2003, pp. 381-392.

[3] M. Favaro, R. Mendichi, F. Ossola, U. Russo, S. Simon, P. Tomasin, P. A. Vigato, *Evaluation of polymers for conservation treatments of outdoor exposed stone monuments. Part I: Photo-oxidative weathering*, **Polymer Degradation and Stability**, **91**(12), 2013, pp. 3083-3096.

[4] A. Cataldi, F. Deflorian, A. Pegoretti, *Microcrystalline cellulose filled composites for wooden artwork consolidation: Application and physic-mechanical characterization*, **Materials and Design, 83**, pp. 611–619.

[5] A.A.T. Traistaru, M.C. Timar, M. Campeanu, C. Croitoru, I. Sandu, *Paraloid B72 versus Paraloid B72 with Nano-ZnO additive as consolidants for wooden artifacts,* **Materiale Plastice, 49**(4), 2012, pp. 293-300.

[6] M.C. Timar, I.C.A. Sandu, E. Beldean, I. Sandu, *FTIR investigation of Paraloid B72 as consolidant for old wooden artefacts - principle and case studies,* **Materiale Plastice, 51**(4), 2014, pp. 382-387,

[7] A.-A. Tuduce Traistaru, I. C. A. Sandu, M. C. Timar, G. L. Dumitrescu, I. Sandu, *SEM-EDX, water absorption, and wetting capability studies on evaluation of the influence of nano-zinc oxide as additive to paraloid B72 solutions used for wooden artifacts consolidation*, **Microscopy Research and Technique**, **76**(2), 2013, pp. 209-218.

[8] V. Vasilache, C. Luca, I. Sandu**,** I.C.A. Sandu**, A new approach to the scientific conservation of old polychrome wood,** Ed. Universitatii "Al. I.Cuza" (ISBN 978 - 973 - 703 - 477 – 9), Iasi, 2009.

[9] G. M. Crisci, M. F. La Russa, M. Malagodi , S. A. Ruffolo, *Consolidating properties of Regalrez 1126 and Paraloid B72 applied to wood*, **Journal of Cultural Heritage, 11**(3), 2010, pp. 304-308.
[10] F. Lionetto, M. Frigione, *Effect of novel consolidants on mechanical and absorption properties of deteriorated wood by insect attack*, **Journal of Cultural Heritage, 13**(2), pp. 195-203.
[11] J. Schanda, **Colorimetry. Understanding the CIE System**, New Jersey, Wiley-Interscience, John Wiley & Sons, Inc, Hoboken, 2007.
[12] G. Sharma, **Digital Color Imaging Handbook**, CRC Press LLC, New York, 2003.
[13] G.V. Atodiresei, I.G. Sandu, E.A. Tulbure, V. Vasilache, R. Butnaru, *Chromatic characterization in CieLab system for natural dyed materials, prior activation in atmospheric plasma type DBD*, **Revista de Chimie**, **64**(2), 2013, pp. 165-169.
[14] S. Pruteanu, V. Vasilache, I.C.A. Sandu, A.-M. Budu, I. Sandu, *Assessment of cleaning effectiveness for new ecological systems on ancient tempera icon by complementary microscopy techniques*, **Microscopy Research and Technique**, **77**(12), 2014, pp. 1060-1070.
[15] V. Vasilache, I.C.A. Sandu, S. Pruteanu, A.T. Caldeira, A.E. Simionescu, I. Sandu, *Testing the cleaning effectiveness of new ecological aqueous dispersions applied on old icons*, **Applied Surface Science**, **367**, 2016, pp. 70-79.
[16] S. Hrdlickova Kuckova, M. Crhova Krizkova, C.L.C. Pereira, R. Hynek, O. Lavrova, T. Busani, L.C. Branco, I.C.A. Sandu, *Assessment of green cleaning effectiveness on polychrome surfaces by MALDI-TOF mass spectrometry and microscopic imaging*, **Microscopy Research and Technique**, **77**(8), 2014, pp. 574-585.
[17] C. Pereira, T. Busani, L.C. Branco, I. Joosten, I.C.A. Sandu, *Nondestructive characterization and enzyme cleaning of painted surfaces: Assessment from the macro to nano level*, **Microscopy and Microanalysis**, **19**(6), 2013, pp. 1632-1644.
[18] S. Pruteanu, I. Sandu, M.C. Timar, M. Munteanu, V. Vasilache, I.C.A. Sandu, *Ecological systems applied for cleaning gilding in old icons*, **Revista de Chimie**, **65**(12), 2015, pp. 1467-1472.
[19] M.C. Timar, A.T. Trăistaru, M. Porojan, L. Gurău, *An investigation of consolidants penetration in wood. Part 1: General Methodology and Microscopy*, **Proligno 6**(4), 2010, pp. 13-27.
[20] G. Genco, C. Pelosi, U. Santamaria, A. Lo Monaco, R. Picchio, *Study of colour change due to accelerated sunlight exposure in consolidated wood samples*, **Wood Research, 56**(4), 2011, pp. 511-524.
[21] A. Della Patria, S. Omarini, *Wood colour,* **Proceedings of the XXV International Congress "Preservation and Conservation of Wood". (Il colore del legno)**, Bressanone, June 23-26, 2009, pp. 629-636.
[22] R. Kandyala, S.P.C. Raghavendra, S.T. Rajasekharan, *Xylene: An overview of its health hazards and preventive measures*, **Journal of Oral and Maxillofacial Pathology, 14**(1), pp.1-5.
[23] U.I. Cieslik-Guerra, T. Rechcinski, K. Wierzbowska-Drabik, B. Uznanska-Loch, R. Winnicka, A. Krakowiak, J.D. Kasprzak, C. Frohlich, M. Kurpesa, *Cardiotoxic effect due to accidental ingestion of an organic solvent*, **International Journal of Occupational Medicine and Environmental Health, 28**(1), 2015, pp. 174-179.
[24] J.R. Baskerville, G.A. Tichenor, P.B. Rosen, *Toluene induced hypokalaemia: case report and literature review*, **Emergency Medicine Journal, 18**(6), 2001, pp. 514-516.
[25] I.C.A. Sandu, M. Hayashi, V. Vasilache, D.G. Cozma, S. Pruteanu, M. Urma, I. Sandu, *Influence of Organic Solvents and Dispersions on Wooden Supports of Paintings*, **Revista de Chimie**, **66**(4), 2015, pp. 587-595.

Received: September, 24, 2015
Accepted: February, 25, 2016