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A Creative Way to Practical Knowledge: Optimal ratio determination of binders, fillers and pigments in oil paint production

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1. Introduction

Owing to its unique characteristics, oil paint still remains an indispensable paint material. There are plenty of ready-made products on the market and they vary both in price and quality. Painters usually use more affordable oil paints that are consequently of lower quality. This results in a faster deterioration of paintings and a more difficult conservation-restoration work.

These were the main reasons behind our wish to create oil paints of high quality that would still remain accessible to a wide range of users.

Projects titled A Creative Way to Practical Knowledge were meant to connect the University with the economy. Our project, Optimal Ratio Determination of Binders, Fillers and Pigments in Oil Paint Production, was meant to create oil paints of high quality that would still remain accessible to a wide range of users. It was financed by the European Social Fund, the Slovene Human Resources Development and Scholarship Fund and by the Ministry of Education, Science and Sport of the Republic of Slovenia.

There were two members of the University of Ljubljana, Slovenia involved in this project: the Academy of Fine Arts and Design (UL ALUO thereafter) and the Faculty of Chemistry and Chemical Technology (UL FKKT thereafter) together with the company Samson Kamnik d.o.o.

The project took place over a period of five months in 2014. It was carried out on the premises of the Conservation-Restoration department of the UL ALUO, on the premises of the company Samson Kamnik d.o.o, in the laboratories of the UL FKKT, Centre of Preservation of Library Materials of National and University Library of Ljubljana and in the Restoration centre of Institute for the Protection of Cultural Heritage of Slovenia.

Students of the Academy of Fine Arts and Design: Čila Berden, Barbara Dragan, Boj Nuvak, Martina Perković, Barbara Slapnik, Barbara Š kander, Petra

Zaviršek and students of the Faculty of Chemistry and Chemical Technology: Andrej Iskra, Andraž Mavrič and Ida Kraševec were working under the supervision of the following mentors and coordinators: Tamara Trček Pečak, MA, Associate Professor, Irena Kralj Cigić, PhD, Associate Professor, Drago Kočar, PhD, Associate Professor, Aleksander Mikuš, Gregor Kokalj, MA, Teaching Assistant, Nina Dorič Majdič, MA, Teaching Assistant.

2. About the project

Last years' project was merely a first step on the way of achieving our goal. In this phase, our task was to intertwine professional, artistic, scientific and economic interests and to find our common ground. That was possible only by linking the chemical knowledge with the knowledge of conservation and restoration.

Despite the exacting preparation technique of oil paints, they are still indispensable paint material. As restorers, we are constantly endeavouring for a better quality of materials in the original works as well as in those used during restoration procedure. Because of our education we have a better technological knowledge and we know what caused degradation of materials of artworks in the past: the painters' choice was mostly influenced by price and not by quality. It is in our interest to conserve our cultural heritage, therefore we strive to produce an oil paint with both quality characteristic and a reasonable price.

Oil paint is made of a pigment, a binder (in our case linseed oil) and filling. If those components are not balanced there will soon be difficulties. We were trying to highlight the problem from three points of view: fine art-conservation-restorational, natural science and economical.

The questions we asked ourselves were the following:[1]

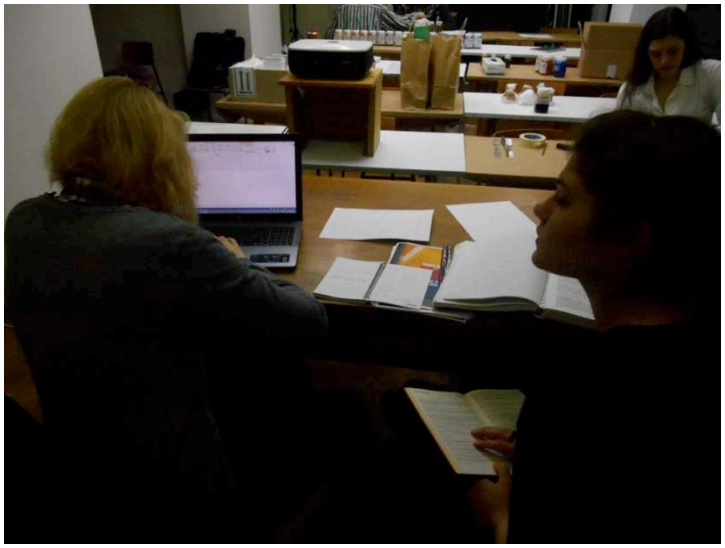
- What should be a criterion for the choice of pigments?
- How will the chemical structure influence the behaviour of pigments when a binder is added?
- How to prepare the samples for analysis and research?
- How does type of a pigment affect the ratio of pigments' quantity to binders'?
- And finally: How to recognise the ideal blend, which would allow smooth strokes, easy manipulation of opacity and would be durable at the same time?

[1] TRČEK PEČAK, Tamara, *Brochure: A Creative Way to Practical Knowledge: Optimal ratio determination of binders, fillers and pigments in oil paint production,* Ljubljana: UL ALUO, 2014

3. First steps

Aleksander Mikuš, who has been our work mentor, chose pigments for testing in collaboration with students of the UL FKKT (Picture 1) [2]. Fifteen pigments of different types were selected based on their origin, chemical structure and physical characteristics. Fundamentally they are divided in two groups: natural and artificial. The latter are divided based on their chemical structure, namely inorganic and organic azo compounds with organic polycyclic pigments. We collected information about the pigments' properties and origin from variety of sources (Picture 2).

Picture 1. Fifteen selected pigments (Photo: Barbara Škander, February 2014)



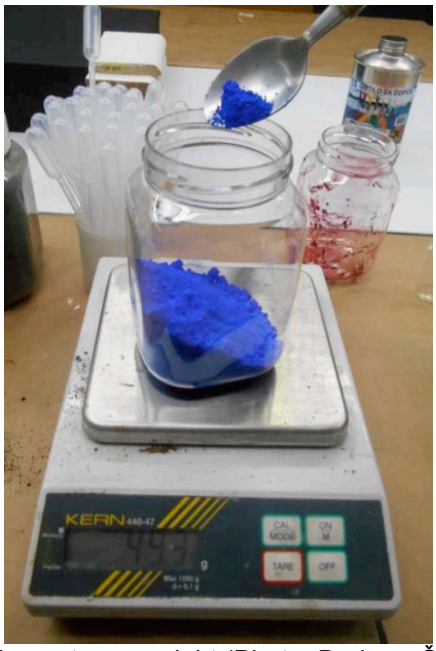
Picture 2. Learning about pigments' characteristics (Photo: Nina Dorič Majdič, February 2014)

A quantity of linseed oil content differs from pigment to pigment. The accurate mass of pigment mixed with oil (Pictures 3, 4 and 5), was ground with a glass grinder on a sanded glass board (Picture 6). Pigments vary in their structure and size of particles, so we had some problems during grinding. It became clear there should be given some additions in order to improve the paints.

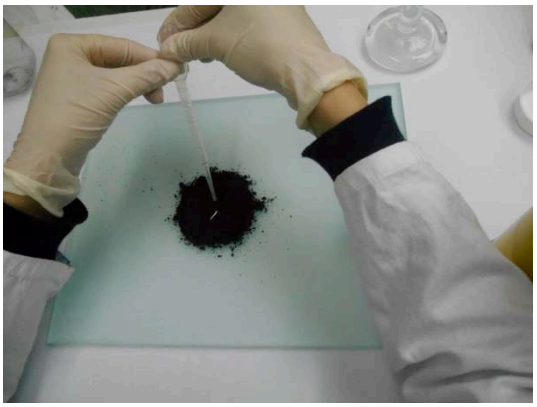
[2] TRČEK PEČAK, Tamara, DORIČ MAJDIČ, Nina, KOKALJ, Gregor, BERDEN, Čila, DRAGAN, Barbara, NUVAK, Boj, PERKOVIĆ, Martina, SLAPNIK, Barbara, ŠKANDER, Barbara, ZAVIRŠEK, Petra, *FINAL REPORT ON EXECUTED PROJECTS' ACTIVITIES, A Creative Way to Practical Knowledge: Optimal ratio determination of binders, fillers and pigments in oil paint production, PUBLIC TENDER TO CO-FINANCE PROJECTS NAMED A CREATIVE WAY TO PRACTICAL KNOWLEDGE, within: "Human Resources Development" Operational Programme 2007 – 2013, 1st priority axis "Promoting entrepreneurship and adaptability" and preferred orientation 1.3: "Scholarship Scheme", partially funded by the European Union through the European Social Fund. Project manager Tamara Trček Pečak.* Ljubljana: Department of restoration, UL ALUO, 2014, p. 2.

After grinding all the pigments, we started to prepare samples for analysis. First we made a plan of things to research: accelerated aging of paint, the effect of ultraviolet light, elasticity of film, gloss, how quickly does the paint dry, viscosity and also the paints' stability in tube or rather how much does pigment settle in oil.

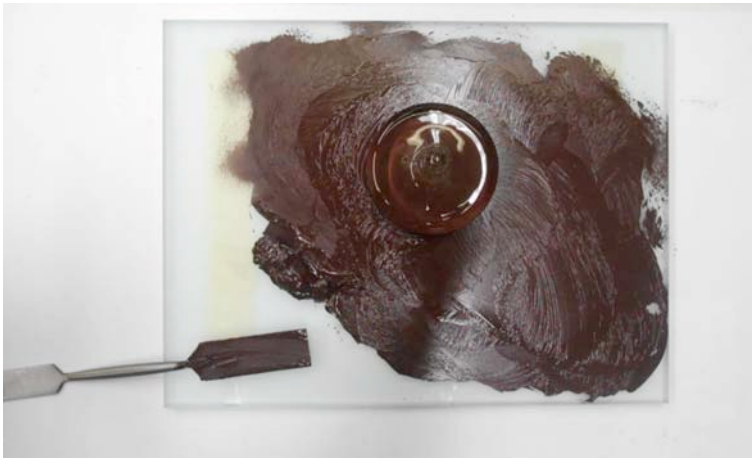
Samples that were used to measure aging, UV light effect and elasticity of film, were compared to brands that are already on the market, such as *Rembrandt, Aero, Schmincke, Windsor & Newton*, etc. Pigments of the latter are the same of those we used in our research.



*Picture 3.*The mass of pigment was weight (Photo: Barbara Škander, March 2014)



Picture 4 (left) and 5 (right): Linseed oil was added to pigment and then mixed together (Photo: Barbara Škander, March 2014)



Picture 6. Grinding the pigment (Photo: Barbara Škander, March 2014)

4. Measurments and results

4.1. Effects of accelerated aging and UV light exposure

One of the project's goals was to produce a paint that would remain of high quality even after a long period of time. Therefore, we prepared samples of paint (Picture 7) and put them in accelerating age chamber for 63 days (Picture 8). The chamber has very high temperature and high humidity. Samples were applied on machine-gessoed linen canvases.

The same type of samples was prepared for measuring effects of UV light exposure. Samples were exposed to sunlight for 443,9 hours in 61 days.

When we compared the results with the quantity of added binder, we found out that changes occurred due to the different type of the binder, rather than to its higher quality.

There was no major noticeable change in most of the paint coatings and in some cases it was barely noticeable. However, a few paint coatings made drastic changes to the colour. The Phthalo Blue Dark pigment was the one that changed the most; it changed to greener colour, whereas the Burnt Sienna pigment (commercially available) was the most stable one (Table 1)[3].

[3] KRALJ CIGIĆ, Irena, KOČAR Drago, KRAŠEVEC, Ida, MAVRIČ, Andraž, ISKRA, Andrej, *FINAL REPORT ON EXECUTED PROJECTS' ACTIVITIES, A Creative Way to Practical Knowledge: Optimal ratio determination of binders, fillers and pigments in oil paint production, PUBLIC TENDER TO CO-FINANCE PROJECTS NAMED A CREATIVE WAY TO PRACTICAL KNOWLEDGE, within: "Human Resources Development" Operational Programme 2007 – 2013, 1st priority axis "Promoting entrepreneurship and adaptability" and preferred orientation 1.3: "Scholarship Scheme", partially funded by the European Union through the European Social Fund. Project manager Tamara Trček Pečak*. Ljubljana: UL FKKT, 2014, p. 20

Table 1. Changes in paint coatings after accelerated aging and UV light exposure

No change of colour	**Barely noticeable change of colour**	**Change of colour**
Brilliant yellow Extra red Light red Oxide Yellow Oxide French Ochre Golden yellow Caput Mortuum Permanent Purple-Red Lamp Black	Zink White Cobalt Blue Lead White	Phthalo Blue Dark Ultramarine

Picture 7. Preparation of samples for measuring effects of *accelerated aging and* UV light exposure (Photo: Nina Dorič Majdič, April 2014)

Picture 8. Results of samples after 63 days in accelerating age chamber (Photo: Nina Dorič Majdič, June 2014)

4.2. Measurements of elasticity of coating

Because paint is most commonly applied to a flexible carrier, the elasticity of paint coating is very important. Samples for measuring elasticity were applied to aluminium foil (Picture 9), which we repeatedly folded. Results were probably incorrect, because the coating did not break even after multiple foldings. We assumed that the short amount of time of drying was the one to blame[4].

Picture 9. Samples for measuring elasticity (Photo: Barbara Škander, May 2014)

4.3. Measurements of opacity, shine and drying rate

Opacity, shine and drying rate are important information for anyone who will use the paints: Information on opacity tells one whether the paint is opaque or translucent; information about shine tells one what kind of shine the paint has; and information of drying rate tells users how long it will take for the paint to dry.

Special test papers were made to measure these three pieces of information. They were black and white and their absorption was minimized and equalized with a thin coat of varnish. When we prepared the test samples (Picture 10), we noticed that the layer of varnish was not evenly applied which led to false results; paint did not have the same shine or drying rate on the black and the white part of the test paper.

[4] KRALJ CIGIĆ, Irena, KOČAR Drago, KRAŠEVEC, Ida, MAVRIČ, Andraž, ISKRA, Andrej, *FINAL REPORT ON EXECUTED PROJECTS' ACTIVITIES, A Creative Way…, p. 29*

Picture 10. Prepared test papers (Photo: Barbara Škander, May 2014)

In the project's continuation, it would be necessary to redo these measurements on adapted test papers and with different thickness of coating, since the used thickness of paint (100, 80 and 50 µm) did not give satisfactory results.

The measurements of opacity were successful. We compared opacity on a white and on a black field and calculated the medial value. Zinc white and French Ochre Golden Yellow were the most translucent, but the others were quite opaque[5].

4.4. Measurements of viscosity

Viscosity is of main importance when applying paint. Paint must not be too thin nor too thick because it must be suitable for application with a spatula and a brush. Prepared paint was put in bottles of 10ml (Picture 11).

[5] KRALJ CIGIĆ, Irena, KOČAR Drago, KRAŠEVEC, Ida, MAVRIČ, Andraž, ISKRA, Andrej, *FINAL REPORT ON EXECUTED PROJECTS' ACTIVITIES, A Creative Way…, pp. 25-28*

Picture 11. Prepared samples of oil paint (Photo: Barbara Škander, June 2014)

Samples were compared and divided in groups from the most to the least viscose. The least viscose colours were Brilliant yellow, Cobalt Blue and Permanent Purple-Red (Table 2)[6].

Table 2. Oil paints categorised according to their viscosity

Low viscosity	**Medium low viscosity**	**Medium high viscosity**	**High viscosity**
Zinc white Light Red Oxide Lead White Ultramarine blue Dark Burnt Umbra	Extra Red French Ochre Golden Yellow Yellow Oxide Lamp Black	Caput mortuum Phthalo Blue Dark	Brilliant Yellow Cobalt Blue Permanent Purple-Red

4.5. Measurement of paints' stability

Measurement of paints' stability in tube was executed by observing prepared paints in transparent test tubes (Picture 12). It was observed how much did the pigment settle and the quantity of excessive oil on pigments' surface was measured as well[7]. Colours with lots of pigment sediment need to be prepared again with fillings, additives or perhaps with a different quantity of linseed oil.

[6] KRALJ CIGIĆ, Irena, KOČAR Drago, KRAŠEVEC, Ida, MAVRIČ, Andraž, ISKRA, Andrej, *FINAL REPORT ON EXECUTED PROJECTS' ACTIVITIES, A Creative Way…, pp. 28-29*

[7] TRČEK PEČAK, Tamara, DORIČ MAJDIČ, Nina, KOKALJ, Gregor, BERDEN, Čila, DRAGAN, Barbara, NUVAK, Boj, PERKOVIĆ, Martina, SLAPNIK, Barbara, ŠKANDER, Barbara, ZAVIRŠEK, Petra, *FINAL REPORT ON EXECUTED PROJECTS' ACTIVITIES, A Creative Way…, p. 22*

Picture 12. Samples for measuring paints' stability (Photo: Nina Dorič Majdič, August 2014)

5. Conclusion

To conclude we would like to say that this project taught us a lot. We learned to improvise, work as a part of a team, the importance of interdisciplinarity and, of course, the technological properties of oil paints. It was only after thorough research and analysis we were really able to understand why the paint acts the way it does. As students of conservation-restoration, we found it interesting to look at the oil paints through the eyes of chemists.

During the project and especially toward the end of it, some deviation from estimated tasks turned out. The biggest issue was to keep up with the timeline. There have been some pigments that were hard to grind, so their preparation was quite time-consuming. Slow drying of paint has also taken quite some time. However, despite all the problems, we can proudly say, that this project shows promise. It laid foundations for continuation of the research, which we are currently doing in this years' project, called "The definition of the ratio between oil binders, fillers and pigments in oil paintings by Marij Pregelj".

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