Discoloration in Renaissance and Baroque Oil Paintings. Instructions for Painters, theoretical Concepts, and Scientific Data
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Appendix
Indigo as a Pigment in Oil Painting and the Problem of its Fading

Materials and preparation of paint reconstructions

Pigments
- Synthetic indigo (BASF Germany).
- Indigo powder echt indisch, 3600-A from India (Kremer Pigmente).
- Indigo powder from India (Verfbrunnen de Kat).
- Lead-white (Scheveningen in Driebergen), available in powder form and as ready-made paint (88% lead-white to 12% cold pressed linseed oil (w/w)).

Media
- Cold pressed linseed oil (Winsor Newton), purified by washing in water over a period of weeks by Hayo de Boer (ICN).
- Egg yolk tempera made of 1 part chicken egg yolk and 1 part distilled water.
- Egg white tempera made of 1 part chicken egg white and 1 part distilled water.
- Glue tempera made of 7 grams hare glue (nr. 63020, Kremer pigmente) in 100 cl of distilled water.
- Gum arabic medium made of 1 part gum arabic (nr. 63300, Kremer pigmente) and 1 part of distilled water.
- Paraloid B67 dissolved in white spirit. We did no work with Paraloid B73, since this type of paraloid needs to be dissolved in the poisonous xylene and for the reconstructions the extra of stability of Paraloid B73 was not necessary.

Paint application
The paints were applied on test cards (BYK Gardene) made of cardboad with a coating of polypolyne thus providing an inert ground for the indigo paints. Some of the water-based paints did not sufficiently bond at the polypolyne surface.
These paints were applied on an oak panel of c. 1cm thickness, with a chalk/glue ground, and an isolation layer of lead-white and linseed oil.
Since indigo provides a very dark, blackish blue colour it is not possible to measure the colour when the paint has been applied at complete hiding. Further, such paint-layers will discoulour very slowly. In order to measure the discoloration, the indigo was applied in the following ways:
1. Indigo was mixed with lead-white in the proportion 1:16 (w/w) and applied as a c. 30 µm thick paint layer at complete hiding.
2. The pure indigo paint was very thinly applied. Since it was not possible to achieve an even paint layer with the brush alone, the indigo was blotted afterwards. This provided a translucent paint layer. This means that the thickness of the paint layer and the pigment volume concentration must be taken into account during colour measurements.

Light ageing conditions
Before artificial light ageing, the paint samples were allowed to dry for five months in the dark while air was still able to circulate freely. Relative humidity and temperature were kept constant.

Paint samples were subjected to three types of artificial light ageing:
I. Artificial daylight at the Stichting Restauratie Atelier Limburg (SRAI.)
- Daylight fluorescent tubes Philips TLD 96.5 (36 W, daylight 6500 °K).
- Average light level is 10,000 lux an hour. The light distribution on the sample surface cannot be homogeneous because on the four sides of the light ageing unit the light levels decrease compared to the centre. To guarantee that all samples got equivalent light, they were rotated at regular intervals.
- UV light was filtered by means of lexan filters (polycarbonate), which cut out UV under 370 nm completely. Radiation above 400nm was being transmitted.
- Surface temperature of the samples varied between 20 and 24°C.
- Relative humidity in the light ageing unit varied between 40 and 44%.
- In total samples were exposed to 18,560,000 lux. This may be compared to c. 36 years (13,257,142 days) of lighting of 1400 lux a day (7 hours of 200 lux an hour is considered 'normal' museum lighting).
II. *Ultra violet light at the Stichting Restauratie Atelier Limburg (SRAL)*
- Philips TLD 36W 8, UV-A black lights, 340-410 nm (365 nm peak).
- The light distribution on the sample surface cannot be homogeneous because on the four sides of the light ageing unit the light levels decrease compared to the centre. To guarantee that all samples got equivalent light, they were rotated at regular intervals.
- Surface temperature of the samples varied between 20 and 24°C.
- Relative humidity in the light ageing unit varied between 40 and 44%.
- Light ageing over a period of 238 days. Blue wool standard fading till 8.

III. *Atlas Xenostest 150 at the Netherlands Institute for Cultural Heritage (ICN), Amsterdam.*
- Xenon lamp, colour temperature between 5500 and 6500 K.
- UV light was filtered. The glass used for the filter has a transmission of at least 90% between 380 and 320 nm.
- Temperature c. 40°C.
- Relative humidity 40-60%.
- Light ageing for 72 hours.

**Colour measurements of samples subjected to light ageing no. I.**

On the samples subjected to light ageing no. 1, colour measurements were performed with a spectrophotometer (Minolta CM 508-d). Since the samples had been preserved in the dark for two years, the oil medium had yellowed considerably. The yellow tinge of the oil disappeared after the first 48 hours of light exposure. This moment became the starting point for colour measurements. During the first 14 days of light ageing samples were measured every 24 hours. Then measurement were carried out after intervals of 8 days, 8 days, 6 days, 16 days, 7 days and 16 days. A publication of the results obtained by colour measurements is in preparation by René Hoppenbrouwers, SRAL.

**Experiments for paragraph *Light ageing tests with synthetic and natural types of indigo***

Paint reconstructions with various indigo types. Samples were subjected to light ageing I and II.

The following samples were subjected to light ageing I and II.

| Synthetic indigo (BASF) | Linseed oil (1 gr. : 1500 µl) | mixed with lead-white 1 : 16 (w/w) |
| Natural indigo (Kremer) | Linseed oil (1 gr. : 400 µl) | mixed with lead-white 1 : 16 (w/w) |
| Natural indigo (De Kat) | Linseed oil (1 gr. : 500 µl) | mixed with lead-white 1 : 16 (w/w) |

**Experiments for paragraph *Recipes for purification of tropical indigo***

*Boiling indigo*
Natural indigo (Kremer) was boiled in two ways.
- 10 grams of indigo were boiled for one hour in two liters of distilled water. The water obtained a dark brown colour. The water with the finely dispersed indigo was filtered and the indigo residue was dried.
- 10 grams of indigo were mixed into a paint with 4ml of purified cold pressed linseed oil. The paint was boiled for one hour in two liters of distilled water. During the first 10 minutes the indigo paint secreted a red tincture. Then the water obtained a yellow and at a later stage a brown colour. A thin layer of oil floated on the water and the mixture smelled like a dyers indigo vat. Then the water was poured off and the indigo was dried on absorbing paper in an oven on 50 degrees.
Experiments for paragraph *Influence of binding medium*

*Paint reconstructions with natural indigo (Kremer) mixed with various media.* Samples were subjected to light ageing I and II.

- linseed oil (1 gr : 400μl)
- linseed oil (1 gr : 400μl)
- glue water
- glue water
- egg yolk
- egg yolk
- egg white
- egg white
- paraloid B67
- paraloid B67

Mixed with lead-white 1:16 (w:w)

*Paint reconstructions with natural indigo (Kremer) pre-treated with various media (note 276).* Samples were subjected to light ageing III.

- un-treated indigo
- indigo pre-treated with glue water
- indigo pre-treated with egg yolk
- indigo pre-treated with egg white

Mixed with oil, and lead-white oil paint