Discoloration in Renaissance and Baroque Oil Paintings. Instructions for Painters, theoretical Concepts, and Scientific Data
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Link to publication

Citation for published version (APA):

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Indigo as a Pigment in Oil Painting and the Problem of its Fading*

'Some specimens fade with great rapidity, while others seem to be permanent. As yet we have been unable to find out the reason for either fact.'

Tristram James Ellis *Sketching from nature...*, London 1887.

Fading and discoloration of indigo paint is quite common in 17th-century Netherlandish oil paintings. In the *St. Adrian militia portrait* (c. 1630) by a master of the Haarlem school (formerly attributed to Hendrik Pot (c.1585-1637)), in the Frans Halsmuseum, the sashes and standards painted with indigo have a pale greyish appearance (Fig. 1a, b). Their once vivid blue colour has been preserved only at the top of a standard and a strip of a sash at the right edge of the painting, where they were covered by the frame (Fig. 1c, d). Due to the fading of indigo, it is no longer obvious that the officers display the colours of the state flag: orange (red), white and blue. The degenerative colour changes in the sashes and standards are not only of aesthetic importance, but also result in significant loss of the painting's meaning. *The regentesses of the St. Elisabeth's hospital* painted in 1641 by Johannes Verspronck (1597-1662), in the same collection, provides another example of profound changes in a painting's appearance caused by fading indigo (Fig. 2a, b). Today, the tablecloth has a pale greenish and remarkably flat appearance with only a few brushstrokes of more intense blue. The indigo paint has become so transparent that it no longer covers the colour of the ground and paint strokes from earlier stages in the painting process. The right edge of the painting, shielded by the frame, gives an idea of the tablecloth's original intense dark colour through which the colour of the ground is only partially visible (Fig. 2c, d). Originally, a convincingly modelled tablecloth contributed to the spatial illusion in the portrait, while its dark colour connected the four personages dressed in black. Today, the Regentesses appear to be placed around a strange flat pattern that stands out between their dresses.

Since A.M. de Wild's 1928 publication on the use of indigo in Netherlandish 17th century oil paintings (Fig. 3),4 conservation literature has paid only limited attention to indigo as an artist's pigment. The most important studies on indigo fading were undertaken by Padfield & Landi (1966) and Crews (1987) but these address indigo used as a textile dye. Saunders & Kirby (1994)2, reported indigo's fading as a pigment in water-based media. Little attention has been given to the deterioration of indigo in oil media. This may be explained by the fact that until recently it was assumed that old master

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* This research was carried out in collaboration with Ellis Hendriks (head of conservation at the Van Gogh museum Amsterdam) at the time head conservator at the Frans Halsmuseum in Haarlem. I gratefully used her observations on various paintings in the Frans Hals museum and from other collections. In addition, I made use of an unpublished (more extensive) version of our article for the 1998 IIC Dublin congress.


2. Indigo was identified by De Wild (1928), using light microscopy and wet chemical analysis.


4. Wild (1928).
painters rarely used indigo in oil. However, there is a growing body of published and unpublished evidence to suggest that indigo was quite commonly used in oil painting, especially in the 17th century. The relative absence of literature on the fading of indigo oil paint may further be related to the fact that when used as a textile dye, fading due to light exposure is not considered problematic. Indeed, indigo dyes are generally noted for their good light fastness properties. As Schwepp (1997) reports in his monograph on indigo in the Artists' Pigments series: ‘used as a textile dye, indigo has an excellent light fastness of grade 8 on wool, but only a moderate four on cotton’ (grades in relation to BS1006 Blue Wool Standards, Colour Index 1971).

The generally good light fastness of indigo on textiles seems in sharp contrast to severe fading visible in so many oil paintings. The visual evidence displayed by these paint areas is varied. There are different degrees and types of discoloration in various paintings and even within one and the same painting. Paintings by the same artist and of approximate the same date or paintings that have been kept under striking similar conditions, show marked differences in the color preservation of indigo. Examples of these phenomena will be described in the course of this chapter.

The fading of indigo paint is caused by the chemical breakdown of the component: indigotin. The extent to which this process takes place depends on a variety of factors. In the literature several external factors have been identified, including light intensity, and wavelength distribution, and air pollution. Studies of red and yellow organic pigments have demonstrated that the fading process of these organic colours is also due to a number of internal factors. These include the preparation of pigments and the type of binding medium, paint layer thickness, pigment volume concentration and mixture with other pigments. One might therefore expect that the degradation of an indigotin-containing paint matrix would also depend on various internal factors, but to what extent is not known. Because of the fundamental changes in many Netherlandish paintings caused by the use of indigo, special attention has been given to the ageing behaviour of indigo in paint media, especially oil, within the MOLART project. Several studies have been and are still being carried out to establish 1. The physical and chemical changes that take place when oil based indigo paint discolours and 2. Which factors cause this discoloration.

The goal of the present study is twofold. It is the first comprehensive survey of the use of indigo in oil painting technique, tracing the use of the pigment from the 15th through to the 19th century. This

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5. For example, Schramm & Hering (1988), p. 59, state that indigo was only seldom used in oil media.

6. The recently published monograph on indigo by Schwepp (1997) includes only one short paragraph on indigo’s permanence. Alan Phenix (1997) has made a more comprehensive overview of the literature on the fading behaviour of indigo and factors involved in this process.


8. The MOLART indigo project was set up at the initiative of Ella Hendriks in 1996. Co-ordinators of the project were Ella Hendriks and Margret van Eikema Hommes. Study of painting technique was carried out in collaboration with Karijn Groen, Netherlands Institute for Cultural Heritage (ICN), Amsterdam, and Prof. Dr. J.R. van Asperen de Boer, Rijksuniversiteit Groningen. Kees Levy-van Halm contributed to the historical research. Ageing tests were carried out in collaboration with René Hoppenbrouwers, Alan Phenix, Jaap Boon (MOLART) Judith Heunen de Graaff, Wilma Rocks and Haye de Boer (ICN). Chemical analyses of indigo pigments, paint samples and paint reconstructions were carried out by my MOLART colleagues Oscar van den Brink, Jaap Boon and Jerre van der Hoest (DTMS) and Jaap van der Weert (FTIR). Kees Mensch (Shell Research) analysed samples using SEM-EDX. Maarten van Bommel (ICN) analysed samples using HPLC. See Eikema Hommes & Hendriks (1997), Hendriks et al. (1998), Benk et al. (1999), Novotna (in preparation), and report nr.11 in the various volumes of the MOLART year reports.

9. Harley (1970, 1992) has given only a short overview of English written sources on the use of indigo as an artists' pigment. The recent study by Schwepp (1997) focuses on the chemical composition of indigo and the identification of indigo in paint-layers. To date, historical research has focused on the utilisation of indigo as a textile dye. The literature in this field is comprehensive. See the bibliography in Balfour Paul (1998) and Schwepp (1997) for an overview of the most important studies.
study will involve the analysis of a broad range of historical texts regarding the preparation of indigo pigment and its use in oil media. A group of approximately thirty oil paintings will be visually and technically examined in light of these texts. The paintings date from the 15th to the 19th century and were painted in various European countries, although most are of 17th century Netherlandish origin. This study's second objective is to obtain insight into the extent to which internal factors such as type and quality of indigo, and different painting techniques (e.g. type of binding medium, admixture of other pigments, paint layer build-up etc.), influence the colour-fastness of indigo paint. To this end, based on results obtained from examination of written sources and paintings, reconstructions were prepared of historical indigo paints. These were subjected to artificial light ageing in order to investigate optical and chemical changes. Insight into the composition of the starting materials and the intentions of the painters obtained by this integrated approach contributes to a better understanding of changes of indigo paint areas in old master paintings.

Due to the intense, bright blue colours of textiles dyed with indigo, from the earliest civilisations onwards, the colorant has been greatly valued. In many cultures indigo blue has been given symbolic meaning like the infinite midnight sky, the shadowy dusk or early dawn. Bearing in mind these poetic descriptions, one may be surprised by the subdued, greyish blue colour obtained when indigo is used in an oil medium. Indeed, with all other historical blue pigments; smalt, azurite, blue verditer and especially ultramarine, more intense blue oil colours could be achieved. Indigo was not particularly cheap, and painters were well aware that its blue oil colour could fade rapidly. One may well wonder why the blue was used at all. Yet, there was one enormous advantage of the material for painters; its advantageous working properties enabled them to depict blue (and when mixed with yellow also green) objects more convincingly than could be achieved with any of the other blue pigments available. The history of the use of indigo in oil painting is thus a story of painters' continuous efforts to make a material, that is not suited well to oil media, nevertheless compatible with them.

I. Indigo as a textile dye: production and history

Indigo was mainly used in oil paintings from the 15th to 17th centuries. During this period, indigo's application as a pigment was closely associated with its use as a textile dye. Reviewing the use of indigo in the textile industry is therefore necessary to understand its application in oil paintings.

Preparation of natural indigo from indigo plants

Indigo colorant is obtained from a great number of plant varieties. The main sources are plants of the tropical genus *Indigofera*, from which almost 800 species are known (Fig. 4). Dozens of species were, and some still are, cultivated in India, Indonesia, China, Japan, South Africa and South and Central America. In addition to the *Indigofera* species, other plants were used for the preparation of indigo. Until the 17th century, for example, in Europe, the native woad plant, *Isatis tinctoria* L., was the most important source for indigo (Fig. 5).

10. A publication on the preparation of the paint reconstructions and the results obtained by their artificial light ageing is in preparation by the author, René Hoppenbrouwers, Oscar van den Brink and Jaap Boon.


All indigo dye plants contain water-soluble indican as the main precursor of the colorant indigotin.† If indigo is intended for long distance transport, as was formerly the case with tropical indigo for the European market, the colorant is usually extracted from the plants to obtain a concentrated form of dye. Indigo plants are placed in shallow basins with water so that a fermentation process can start that breaks down the cell walls of the plants so that water-soluble indican comes into solution (Fig. 6).† The glucosidic bonds in indican are broken by enzymatic hydrolysis leading to the formation of indoxyl and glucose. The liquid is then drained off into deeper basins and is brought into contact with atmospheric oxygen by vigorous stirring. As a result, the indoxyl is oxidised, first to yellowish, water-soluble leuco-indigo or 'indigo white,' and subsequently to insoluble indigotin or 'indigo blue.' The indigo precipitate settles to the bottom of the basin. Often chalk or (slaked) lime is added. Apparently this addition induces the precipitation process more readily. The water is carefully drawn off, leaving behind a clay-like indigo paste. This is filtered and pressed into small bricks that can be dried in the air or in ovens (Fig. 7).

If the indigo is not intended for long distance transport, textile fibres are sometimes dyed with fresh indigo leaves but more often with dried, composted plant pulp. Woad plants used to be traded in this last form, probably because it was unrewarding to extract the colorant first from the plants due to their low dye content (approximately 1/30 of the amount of dye in Indigofera species).† Fresh woad leaves were crushed in grinding mills and the resulting pulp was drained and moulded into balls that were dried for several weeks. This product, known as 'green woad,' or in France coques / cocaignes, was transported to the various dyeing centres. Here the product was often subjected to a fermentation or 'couching' process, which resulted in a more concentrated product and the indican in the plant cells was partially converted into indigo blue. After six to nine weeks the mass was dry and appeared as dark, crumbly clay known as pastel in many countries.

Indigo dye

In the process of dyeing textiles blue, the insoluble indigo dyestuff is first reduced in a warm alkaline solution in a dyer's 'vat.' As a water-soluble 'indigo white' solution it can adhere to the textile fibres which turn blue after exposure to air, when oxygen converts the leuco-indigo into the insoluble blue form again.† Until the end of the 16th century in Europe, the reduction process in the vat depended on the presence of micro-organisms. Thus, the vat had to be 'nourished' with sweet, mealy or fermenting materials. In the Middle Ages one generally used madder, wheat bran or dough and in the 17th. and 18th centuries woad pulp itself was used as a fermenting agent in the woad-indigo dyeing vat. An excess of lactic acid formed in the fermentation process was neutralised by adding alkali in the form of lime or natural soda, wood ash, potash or stale urine.†

13. Schwepp (1997), pp. 88, 91. for formulas for indigo and related compounds. Until recently, it was assumed that the precursor of woad was isatan B. However, new studies have revealed that much of the precursor in woad is indican and that only some isatan B is present. Tropical and subtropical plants appear to contain some isatan B themselves in addition to indican: Balfour-Paul (1998), pp. 100-02, 234.


17. Dyers made numerous attempts to simplify the laborious fermentation process. By the end of the 16th century, European dyers began to experiment with the Indian method of using arsenic sulphide as a reduction agent. Later, other inorganic reduction agents were used that provided an easier control of the fermentation process. By the middle of the 18th century, for example, a ferrous sulphate was used in combination with slaked lime or potash, and a century later the zinc-lime vat was developed; ibid.
Import of tropical indigo in Europe.

The word 'indigo' derives from the trade name 'indicon' (Greek) or 'indicum' (Latin) meaning 'Indian' or 'coming from India.' Beginning a few centuries before Christ, indigo extracted from the tropical Indigofera species was exported, along with other luxury goods, to the Greeks and Romans. At the time, it was extremely expensive and the amount sent to Europe must have been rather small. The product was used for medical and cosmetic purposes. Both Pliny the Elder and Vitruvius refer to its use as a painter's pigment. Presumably, in antiquity indigo was seldom used as a textile dye, since the native woad plant was more readily available. Likewise, in the medieval European textile industry woad plants were used almost exclusively. In the Languedoc and in Thuringen around Erfurt, woad culture was extensively developed. Tropical indigo came from the district Gujarat in North-western India and was brought by Arabian tradesmen to Baghdad. From this main trading centre of Indian and Persian goods, Genoese and Venetian merchants brought the product to Italy from where it was distributed throughout Europe. However, there was no widespread use of the tropical product for dyeing textile in Europe other than in Italy. Until 1550, only Italian texts containing formulas for dyeing, such as the Venetian Pūchto de l'arte de tentori (1548), mention the use of tropical indigo as a textile dye. After Vasco da Gama discovered the sea route to East India via the Cape of Good Hope in 1498, Portuguese tradesmen supplied indigo directly from India. Their dominance on the Cape route stimulated other European countries to concentrate on the Levant trade instead. Due to these developments, the Venetians lost their trade monopoly of indigo by the 1560s. By the second half of the 16th century the Spanish had started to produce indigo on a commercial scale in Guatemala. At first, this indigo was reserved for the Spanish textile industry. Before 1586 there is no demonstrable export from Spain to other European countries.

Portuguese traders initially used Antwerp as the first port of entry for shipment of indigo to the Netherlands. In his Descrittione di tutti Paesi Bassi (1567), Ludovico Guicciardini mentioned, in an overview of East-Indian goods that Antwerp imported 'the colour indigo, called by the Portuguese anil' from Portugal. According to Guicciardini, indigo was also imported from Venice, Ancona and France. When at the end of the 16th century, the Northern Netherlands textile industry had come well into its stride, the Portuguese tried to find a new outlet there. In 1578 the mayors of Leiden allowed an envoy of the king of Portugal to teach the Leiden textile dyers to dye with 'anil de indigo.' In many textile

19. For Pliny the Elder, see Rackham (1961), vol. 9, p. 121; For Vitruvius' De architectura (1st century BC), see Mungan & Warren (1914; 1960), p. 220. Indigo has been identified in Roman wall paintings dated 1st century A.D.: Schwepppe (1993), p. 302.
22. Pūchto de l'arte de tentori mentions six recipes for dyeing blue. In four recipes the use of indigo (endego, endego de Baghdad) is described. The importance of woad (guado, fior de guado, brasilio de tentori) is emphasised as well. Edelstein & Borghezio (1960). Northern manuscripts of the period, such as Thaukt van woadre, Brussels (1513), and Allerby machel, Mainz (1532), only refer to the use of woad: Hofenk de Graaff (1985), p. 27.
centres the use of indigo remained under discussion for several decades. In some towns, like Rotterdam where the industry was not regulated, everyone was free to use indigo. In Amsterdam and Haarlem there were more restrictions and the product was only released in 1592. Shortly thereafter, the use of indigo was allowed in Leiden on a limited scale although it was not until 1615 that it was completely permitted. The 1602 formation of the Dutch East Indian Company (VOC) resulted in an increased import of indigo from India into Europe and played an important part in the unlimited use of the tropical product. The increasing supply had enormous consequences for the native woad production. Merchants from North-European textile centres saw their interests in woad cultivation threatened. In the cities, this resulted in strong resistance to the use of indigo as a textile dye. At the end of the 16th century, in many French and German areas, its use was forbidden (sometimes even under threat of death!). In some regions, these restrictions lasted well into the 18th century. Indigo, however, was used by the dyers long before their governments gave them official permission to do so. The percentage of indigotin in tropical indigo is much higher (more than 175 times) than in products made from woad plants, so using it one could dye more quickly at a lower cost. Dyers, therefore, requested their governments to revoke the restrictions on indigo with increasing insistence, especially after they were lifted in neighbouring districts. In addition, the VOC put a lot of effort to sell the product not only in the Northern Netherlands but also in surrounding countries. This resulted, along with the destructive influence of the 30-year war (1618-48) on the woad industry in the almost universal preference for tropical indigo.

II. Types of indigo pigment used in oil media

Although indigo found its main use in the textile industry, from antiquity onwards, the product was also regularly used in Europe for making paint and ink and to colour leather and paper. Instructions for the application of indigo in oil media date from the 14th century. These formulas indicate that, in addition to the material extracted from tropical plants, a variety of local indigo pigments were used in easel painting. Regularly painters seem to have used a pigment made from the blue froth skimmed off the dyer’s woad vat. In 15th and 16th-century sources the term indigo is occasionally used for a pigment extracted from woad leaves or made from fermented blue wool. Today we know that in all these materials the colouring component (indigotin) is identical. However, the old masters may not have been aware that these products were in fact the same pigment. At the time, there was much uncertainty about the composition of indigo brought from Bagdad. The material was often mistaken for a mineral. The old recipes for making indigo from woad leaves or blue wool should


28. Despite the fact that the extraction of indigo from plants in India had been described in contemporary travel reports; Vetterli (1950), p. 3418.
presumably be understood as instructions for making a pigment with a colour resembling that of Indian indigo.\textsuperscript{29}

In this study, modern and, when available, historical samples of indigo pigments were studied under the light microscope and their chemical composition was analysed using high performance liquid chromatography (HPLC) and direct temperature mass spectrometry (DTMS). Both techniques can be used to identify indigo (Fig. 8).\textsuperscript{30} HPLC is most suitable for the identification of the secondary organic colouring components in the indigo pigment, including isatin, kaempferol and indirubin.\textsuperscript{31} HPLC, however, is only able to detect soluble compounds. Plant remains and other impurities were investigated by DTMS, since this technique can identify small quantities of sugars, fats and proteins. Scanning electron microscopy, combined with energy-dispersive X-ray microanalysis (SEM-EDX) was used to obtain insight into the inorganic components in the various indigo pigments, such as residual salts from the plants or impurities resulting from the production and trading process.

It is not yet possible to determine in ancient textile or paint samples whether the indigo that was used derived from wood or from tropical indigo plants. When indigo is used as a textile dye, inorganic components remain in the dyer’s vat or are washed out of the fabric. Some organic components, however, attach themselves to the fibre in addition to the indigo dyestuff. At present, it is being investigated whether the presence or absence of these materials in a textile sample may indicate the origin of the indigo used.\textsuperscript{32} When indigo is used as a pigment it will often not be possible to determine the product’s origin based on the presence of organic secondary components. The small amount of sample available does not allow the characterisation of these components. In addition, as will be explained below, painters subjected their indigo pigments to purification processes. Reconstructions indicate that these procedures remove the majority of organic ‘impurities.’ However, inorganic compounds can end up in a paint layer. Thus, their presence may sometimes be indicative of the origin and the purity of the indigo product.

\textit{Lumps of tropical indigo}

Until the 17\textsuperscript{th} century, the dark blue lumps of indigo (\textit{inda}, \textit{ynde}, \textit{endich}, \textit{endicho} in sources) imported from India were often denoted as \textit{indigo from Baghdad}.\textsuperscript{33} In German sources, tropical indigo is also referred to as Lombardian Indigo.\textsuperscript{34} From the northern Italian district Lombardia, ‘Indian indigo that had been

\textsuperscript{29} This explains the occurrence of recipes for making \textit{indigo}, which are in fact instructions for making blue colours of a completely other composition. For Example, Bredell (1601), p. 361, advises making ‘\textit{Indio sano}’ from ‘\textit{huan di morinda}’ (probably berries of myrtle).

\textsuperscript{30} For HPLC analysis Wouterse (1991). In the mass spectrum 205, 234 and 262 are marker peaks for the presence of indigotin or indirubin: Schweppie (1997).

\textsuperscript{31} Wouterse (1991). For the present analysis, 1.2 to 1.4 milligrams of indigo was dissolved into 4 ml DMF. The solution was heated for ten minutes to 140\degree (just under the boiling point (150\degree) of DMF). This method is generally used for dissolving indigo from indigo dyed textile.

\textsuperscript{32} Verbal communication Maarten van Bommel (ICN) who is currently investigating the possibilities of distinguishing textile dyed with tropical indigo and wood indigo.

\textsuperscript{33} Sources mention for example ‘\textit{indigo bagadoli},’ ‘\textit{indigo basado},’ ‘\textit{inda Baudia},’ ‘\textit{bandas induh}’ and ‘\textit{indigo del golfo}’ to denote the product’s Indian origin: Merslefield (1849; 1967), vol 1, p. cxxv.

\textsuperscript{34} Boltz von Ruffach (1549); see Benziger (1913; 1988), p. 81: ‘\textit{Vom Endich: ob ich synderley arten identiben aber ich wil mich allein zu dem gesetzten halten, den man neuen Lampschten endich, den findet man in den wurtzlanden.}’ Carel Baten in his Secret Boek (1600) paraphrased Boltz von Ruffach’s recipes on indigo and recommended thus the use of ‘\textit{Lamboardische indie}.’ Recipes in the Strassburg MS (15\textsuperscript{th} C.) recommend the use of ‘\textit{Lampuchten endich},’ see Borradaille (1967), p. 44. According to Borradaille (1967), p. 102, the specification ‘\textit{lampuchten}’ probably indicated that this indigo pigment came from London and would have been made of the native wood plant. However, in light of the reference by Boltz von Ruffach
brought to Venice and Genoa, would have been exported to other (mid) European countries. Tropical indigo was assessed as being superior to other indigo pigments. Boltz von Ruffach maintained in his *Illuminierbuch* (1549) that among the many types of indigo the surest was the *Lampartischen endich*. At the time, Indian indigo seems to have been ranked among the mid-price pigments. It was a lot cheaper than ultramarine and good quality azurite and about the same price as small, lower quality azurite or synthetic copper carbonate blue. In 15th and 16th century account books for decorative projects, Indian indigo is sometimes mentioned. Its price was considerable but still such that it could be used for temporary schemes. Giovanni da Udine recorded the prices of some of the pigments he bought in 1531 for his work in St Peter’s in Rome. *Endicho* was one of dearer pigments. Two purchases cost each 75 and 48 *baischi* a pound, compared with 60 *baischi* a pound for small, 50 *baischi* and 1 *scudo* 20 *baischi* for *biadetto* (not identified further), and 3 or 6 *baischi* a pound for lead-white.

It is well known that tropical indigo, in addition to indigotin, always contains a lesser or greater amount of indigotin's isomer indirubin (indigo red) as well as the yellow colorant kaempferol. The percentage of these components depends on the plant species, the age of the plant and the process used for the making of indigo. Natural indigo also contains plant material. This includes organic components of indefinable composition, which are referred to in the literature as indigo gluten and a brown amorphous substance indicated as indigo brown. Indigo may also contain a varying amount of residual salts from the plants primarily calcium and magnesium carbonate and, to a lesser degree, aluminium and iron oxide. In the period examined, the quality of the indigo was affected by a variety of factors. The plants were cut three times a year and the moment of the harvest influenced the quality of the indigo to a great extent. The degree of sophistication in the manufacturing process influenced the quality as well. Indigo was frequently adulterated with substances such as ashes, washed earth, sand and slate or brick dust. In Europe, indigo was also adulterated. Finely crushed blue wool, silk rags, soot, starch, resin, rust and, from the 18th century on, Prussian blue, were often mixed with the product. Depending on the amount of secondary compounds, the quality of indigo lumps can vary enormously.

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and Van Baten, it is more likely that *lampascudo* referred to the Lombardian district. In the 15th century, indigo pigment made from wood leaves would presumably not have been exported from England, as it is only at the end of the 16th century that wood became an established crop in its southern provinces.

35. See reference in the previous note.

36. For example, the account for the decoration paintings made by Holbein and others for king Henry VIII at Greenwich in 1527, mentions: ‘For for 1½ h of fine red *baischi*’; see Forster (2001), p. 122.

37. Cargnelotti (1987), vol. 1, pp. 35-36. There were 100 *baischi* to the *mado*.


39. Ibid.

40. Tavener (1676-77; 1679), vol. 2, p. 295 recorded in his travel account about the indigo from Gujarat: ‘La premiere herbe est sans comparaison meilleure que les deux autres, la seconde est moins de dix ou douze pour cent que la premiere, & la trentième de la seconde de singe pour cent.’

41. Plants had to be free from dirt and for their fermentation exact timing was critical to avoid the extraction of impurities. Furthermore, clean water had to be used in the heating tank, and determining the exact moment to stop the oxidation process demanded great experience. The indigo paste had to dry slowly with sufficient ventilation as the paste could otherwise be scorched in the blazing tropical sun, and result in the inferior *burnt indigo*. Balfour Paul (1998), pp. 108-12, Schwepppe (1997), pp. 91-93. Examples of historical descriptions of the making of indigo include those by Tavener (1676-77; 1679), vol. 2, pp. 294-96, Vuurst (1819), and Georgievics (1892).
The best types contain 90% indigotin, more inferior types 40% to 50%, while the most inferior lumps contain only 20% indigotin.42

For the present study, two modern types of indigo pigment and three samples from the collection of the early 19th century Amsterdam painting material supplier Hafkenscheid, were analysed.43 This determined the presence of a great variety of organic and inorganic components in addition to indigotin. HPLC identified isatin, indirubin, several orange red components and a range of yellow components in all samples although in different percentages. A series of materials closely related to indigotin and indirubin were also consistently present (Fig. 9).44 SEM-EDX analysis of indigo leaves identified a small relative amount of silicon, iron, magnesium, phosphorus, sulphur, chlorine, potassium and calcium. These elements were also detected in the pigment samples. In all pigment samples, but especially in the two modern types, silicon and iron were present in much higher percentage. In addition, a high relative amount of aluminium was identified (Fig. 10). Under the microscope, mineral matter in indigo pigments is clearly visible as birefringent material (Fig. 11). Possibly, clay, sand or rust had been added during the production process or trade.

Indigo from the flower of the dyer’s vat.

15th and 16th-century texts regularly mention recipes for the preparation of flower (English: flouery, flory; French: fl pictre, Italian: fiorata, fiore, Dutch: bloem, bloemen; German: plumen) from the dyer’s vat. During the reduction process in the vat, leuco-indigo oxidises at the surface of the vat into indigo blue (Fig. 12). This finely dispersed indigo floats on the liquid of the vat as an iridescent purple blue froth. When the froth or flower is skimmed off, it can be used as a pigment. Recipes in Northern European texts will most likely have referred to the product of the woad vat. Italian recipes also explicitly name the froth from a woad (denoted in Italian sources as guasto, guado or guastum) dyers vat.46 However, we have to bear in mind that during the 16th century, when the use of imported indigo was increasing, this product was regularly added to the woad vat.46 Then, the flower would have been a mixture of both imported indigo and woad. Painters seem to have greatly valued this secondary product of the local textile industry. The substance was, according to Boltz von Ruffach (1549), abundantly and frequently used for [paint] mixtures.47 The Italian author Alessio Piemontese mentions in the second part of his influential De’secreti (1558) the use of Palma Christi, brought from Germany, which is like the flower of woad.48 Apparently,
flower was even exported from Germany into Italy by the 16th century. Notably, in 15th and 16th-century account books for decorative projects, flower is more regularly mentioned than Indian indigo. Possibly, at that time, the local product was cheaper and thus an alternative for the pigment imported from outside Europe. In 16th-century accounts, Indian indigo is mentioned more frequently. These records indicate that at that time prices for both pigments were comparable.\[^{54}\]

In order to remove the remaining vat liquid from the 'blue flower', a 16th-century Flemish recipebook named *Diverse verwen te maken* advised putting the substance in an earthenware vessel with tiny holes, or evaporating the liquid in a pan above the fire.\[^{31}\] Subsequently, the substance was ground into a paste with fresh water and lead-white, or white earth. Some painters preferred a more sophisticated preparation. It is quite conceivable that the froth from an historical dyeing vat contained remnants of the fermenting products that were added to the vat (such as dough and plant pulp) that may have had a detrimental influence on the brightness of the blue colour. An English manuscript containing 16th-century recipes, suggested grinding a mixture of *flower* and chalk at least three times with fresh water: 'for the more it is done the better will be the colour.' After the paste had dried in a vessel (of presumably porous material) the 'blue indel' could be mixed into paint with glue-tempera or an oil medium.\[^{52}\] The 15th-century manuscript, *Segreti per colori*, described how a mixture of *flower*, urine and starch is filtered.\[^{53}\] Soaking in urine may work to dissolve both organic and inorganic impurities from the dyer's vat. These impurities would have combined with the starch so that these were sufficiently removed. In order to use *flower* in oil media, an early 16th-century Italian manuscript advised boiling the substance in alum water and straining it through a cloth.\[^{34}\] Water-soluble contaminants would form a compound with the alum and would thus be removed.

SEM-EDX analysis of the froth from a modern dyeing vat made with natural indigo indicated that the substance contained little inorganic material.\[^{55}\] Indeed, the main contaminants of indigo lumps: sand, clay and rust, would have sunk to the bottom of the vat. Only small quantities of calcium and potassium salts were detected, probably deriving from water-soluble calcium salts and potassium carbonate used for the reduction process. Both HPLC and DTMS analysis indicated that the modern pigment was also remarkably free of organic secondary products.\[^{56}\] Accordingly, there appear to be no

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49. Examples mentioned by Kirby (2000); Forster (2001); personal communication Jo Kirby, National Gallery London.

50. From the accounts for the Greenwich festivities of 1527 it is evident that flower indigo (26d a pound) was even somewhat more expensive than Indian indigo (26d4 a pound).Forster (2001), p. 122.


53. *Segreti per Colori* (15th C); see Merrifield (1849; 1967), vol. 2, p. 417. Alessio (see note 48) advised soaking the wood flower in urine overnight and grinding it afterwards while adding a little slaked lime.

54. *Trecenttre Diversi* (16th C); see Merrifield (1849; 1967), vol. 2, p. 613. Recipes in the *Segreti per Colori* (15th C); see Merrifield (1849; 1967), vol. 2, pp. 413-15, recommended mixing flower with alum water or urine but without subsequent filtering. Although impurities remained, it is conceivable that if these substances were bound to alum or urine they would no longer have a detrimental influence on the quality of the colour.

55. Froth from an indigo dyeing vat in Mexico made of *Indigofera suffrutescens* Mill.; see Fig. 12. Sample provided by Dr Arie Walbert, Rijksmuseum Amsterdam.

56. In addition to indigotin and indirubin, HPLC analysis of the flower identified a range of blue, orange-red and yellow secondary components that were also present in the indigo lumps (see above). However, in the flower these components were only present in very small quantities.
possibilities for analytically distinguishing the flower in the paint layer from a pure indigo pigment imported from outside Europe.

**Indigo pigment from woad leaves**

The *Segreti per colori* also describes how indigo pigment is extracted from fresh woad leaves. Pounded leaves were sprinkled with urine and placed in the hot sun. The heated mixture would then ferment and decompose the plant cells, while sunlight induced the oxidation of *leuco*-indigo into indigo blue. The recipe describes how indigo is secreted from the heated mass as *large worms of a blue colour*. These 'worms' were collected, remaining moisture was squeezed out in a linen cloth and the substance was ground and dried. This method resulted in extremely low yields. Reconstructions by Malla-Stina Tallgren using a comparable method have shown that 1-kilogram of woad leaves produces less than 1 gram of indigo pigment. Nevertheless, the pigment seems to have been used in easel painting. The 16th-century manuscript *The art of limning* recommended, in addition to *'Inde Baudias,'* the pigment *'English Inde'* which Henry Peacham later described in his treatise *The art of drawing with the pen* (1606), as *'English Indebaudias.'* Peacham considered this as giving *'not fully so good a colour as your Indebaudias'* from Baghdad. In the southern provinces of England, at the end of the 16th century, when the English textile industry was going strong, woad had rapidly become an established crop. English painters may have used woad leaves to make their *'English indigo'* pigment, as at that time the tropical product was still expensive.

In modern pigments made of woad leaves, an orange red colorant that was not present in the pigments examined from the *Indigofera* species was identified using HPLC. Remarkably high relative amounts of calcium and phosphorus were found by SEM-EDX in pigments derived from woad (*Fig. 13*). These compounds were also present in relatively high quantities in woad leaves. In leaves and pigments made of the *Indigofera* species, the inorganic compounds, especially the latter, were only present in relatively small quantities. Thus, when indigo agglomerates in paint samples from historical paintings contain a high relative amount of both calcium and phosphorus, this could imply that woad-indigo was used.

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57. *Segreti per colori* (15th C); see Merrifield (1849; 1967), vol. 2, p. 417. In the same manuscript, p. 413, another recipe for making indigo describes how pounded woad leaves are ground with a mixture of salt, sulphur and rock salt. The mass is mixed with water and evaporated above fire into a dough-like substance. After drying, this product is ready for use. The functioning of the recipe is unclear and will presumably not have resulted in a blue pigment.

58. I am grateful to Malla-Stina Tallgren, Helsinki for kindly providing me with four samples of her homemade woad indigo. With her method, fresh woad leaves were soaked in an urea solution (20 grams of urea in 1 liter water). Then ammonia was added. The solution was brought into contact with oxygen by repeated pourings so that indigo blue was precipitated. This indigo was washed several times with fresh water.

59. *Art of limning* (16th C., f. 133v, Peacham (1606; 1730), p. 57.


61. Four samples of woad pigment homemade by Malla-Stina Tallgren (see note 58) were analysed as well as several reference samples in the collection of the ICN. Maarten van Bommel from the Netherlands Institute for Cultural Heritage, Amsterdam is currently investigating whether the presence or absence of this component in historical paint and textile samples may provide a criterion for the identification of the type of plant used for the making of the indigo.

62. However, we may not rule out that bone white (Ca3(PO4)2), had been added to the indigo paint. Harley (1970; 1982), pp. 153, however, states that although the pigment was mentioned occasionally in 17th-century sources, it is obvious that it was never used extensively.
Indigo made from blue wool.

From the 14th to the 16th century, a number of recipes have come down to us for the preparation of indigo pigment from blue wool. At the time, red colorants were regularly extracted from clippings of dyed textile using lye of ash or similar alkaline solutions. The red colorant that had come into solution was precipitated by the addition of alum. Recipes for making indigo from textile, as described in two 15th-century German recipe books, similarly advise to drench deep blue wool in a strong alkaline solution. However, contrary to red dyes, indigo is not alkali-soluble, so that the caustic bath must have another purpose. Reconstructions by the author indicated that the alkaline solution served to break down the protein bonds of the wool fibres so that the wool could be completely converted into a blue jelly-like substance that could be dried and pulverised. In order to remove superfluous liquid, recipes advise pressing the pulp carefully through a cloth. The substance was then dried and rolled into little balls with the help of a little bit of fine quartz sand. A recipe in the 16th-century Diversc verven te maken, simply recommended making indigo pigment by leaving wet blue wool to rot for a couple of weeks in a warm place. The substance was then ground with lead-white and used with gum water or linseed oil. The reconstructions indicate that when indigo/wool pulp is mixed with oil a smooth paint is obtained without any threads remaining from the wool. However, very careful washing is needed to remove all traces of alkalinity.

When wool indigo pigment is examined under the microscope, remaining wool fibres are clearly visible using crossed polarizers although they are more difficult to recognize in normal light. Likewise, in samples from historical indigo paints, traces of threads may be distinguished. When fine quartz sand was added to the product, this is visible as well. DTMS analysis of the wool pigment identified marker peaks for proteinaceous material and marker peaks for sterols of which some are typical of wool. These components may be detectable in oil paint layers too; certainly in young paint films, although with more difficulty in aged systems. To date, in conservation literature no reference has been made to traces of threads indetified in indigo paints. The sporadic recipes suggest that indigo/wool pulp was not commonly used in easel painting. The substance could have been used for decorative arts, such as printing designs on fabrics.

III. Increasing import of tropical indigo and its growing importance as an artists' pigment

Just as in the textile industry, increasing quantities of tropical indigo imported from the late 16th century on into Europe had consequences for the art of painting. Since the 17th century, painting instructions almost exclusively refer to the use of tropical indigo. Until the middle of the 16th century, vat flower


64. Nürnberg Kunsthuch (15th C), f. 20v; and Anonymous MS (15th C) 12, f. 181v: Ploss (1962; 1989), p. 140.

65. Indigo dyed blue wool was cut into very small pieces. These were soaked for 16 hours in a solution of 4M NaOH. In the first hour the wool disintegrated although wool fibres remained visible by the naked eye. Later on, the wool completely converted into a jelly-like substance.


67. In the DTMS spectra we observe preserved cholesterol and oxidized cholesterol. In the mass spectrum peak 386 is a marker for cholesterol and peak 382, 384, 400, 402 are markers for oxidised sterols: Brink (2001), chapter V. A peak observed at m/z 426 is tentatively assigned to lanosterol; peak m/z 98, 117 and 194, observed at relatively high temperatures in the DTMS run, are known markers for proteinaceous materials.

68. The sporadic occurrence of recipes recommending other types of indigo pigment are paraphrases of authoritative older texts, which only...
was still a useful alternative for tropical indigo, and pigment extracted from woad leaves or made of blue wool may occasionally have been used. In paintings of this early period it is uncertain whether the indigo pigment used was imported from outside Europe or was obtained locally. As indicated above, in a paint layer only pigments made from wool can be securely identified, but this product seems to have been rarely used in easel painting. In the 17th century, however, there was hardly any necessity left for the use of local indigo products. Presumably, in this respect, there was little difference between those regions in Europe where tropical indigo had been released as a textile dye (as of the early 17th century) and those regions where its use was still forbidden since there is no indication that the tropical product was also forbidden in painting.

The ready availability of tropical indigo also resulted in a growing importance of indigo as an artists’ material. The number of analyses of indigo in easel paintings is still limited. On the basis of current data the following picture emerges. Indigo, either the tropical or the local product, was identified in only very few works by 15th and 16th century Northern European painters, including Stephan Lochner (active in Cologne 1442-51), Dienc Bouts (1400?-1475; Fig 14) and two contemporary anonymous followers of Holbein. In contrast, Italian painters of the period appear to have used indigo pigment more regularly, as is evident from analyses of works by Antonio Vivarini (1440?-1476-84?), Giorgio Schiavone (1436/37-1504), Francesco del Coss (c.1435-c.1477), and Jacopo Tintoretto (1518-94). The majority of these painters were active in Venice, at the time the main port of import for Indian indigo. It is therefore likely that they would have used the tropical material. Peter Paul Rubens (1577-1640) is the first painter known north of the Alps to have employed indigo on a large scale. Guicciardini's Descrizione indicated that tropical indigo was readily available in Antwerp, the city where Rubens was mainly active, by the second half of the 16th century. However, in Rubens' choice of this blue, the influence of the materials of Italian painters, with which he first became acquainted during his stay in Italy from 1600 to 1608, seems to have been decisive. In his early Antwerp works no indigo was found. His Transfiguration finished during his stay in Italy in 1607 for

seem to have been quoted for the sake of completeness. For example the recipe for making indigo from blue wool described by Bolitz von Ruffach (1549) (see note 66) was paraphrased by Van Baten (1600), pp. 316-17, and Witgeest (1679; 1967), p. 163. The recipe by Alessio (1558) for making indigo from wood flower (see note 48), was repeated by Borelli (1601), p. 361, and Lehmann (1633); see Merrifield (1849, 1967), vol. 2, p. 807, and Pictorium (1713; 1747), N.10.

69. In some cases, the froth from the dyeing vat might have been a mixture of woad and imported indigo; see note 46.

70. Moreover, the tropical pigment would not have been available for painters, not just because the product was frequently permitted in a limited scale in the dyeing industry (only as an addition to the woad vat) but also, because, despite all restrictions tropical indigo was nonetheless often imported: Vermeri (1950), p. 3418.


73. For example, no indigo was found in Rubens' The conversion of St. Paul, Sammlungen des Fürsten von Liechtenstein, Vienna; personal communication: Daniel Fabian, Conservator of the Sammlungen des Fürsten von Liechtenstein, who has recently technically examined the painting. Presumably, Rubens has made the painting in Antwerp before he went to Italy. The style is still closely related to the style of Rubens' master Otto van Veen. The fact that the support is an oak panel is another argument supporting the premise of its northern origin; verbal communication Nico van Houw who is preparing a Ph.D. thesis on the dead-colouring phase in paintings by Rubens and his workshop.
the church Sta Trinità in Mantua is the earliest known example of his use of indigo. Only then this pigment was added to his palette. Following their master, Anthony Van Dyck (1599-1641) and Jacob Jordaens (1593-1678) made use of the pigment in the early decades of the 17th century.

In the Northern Netherlands, there is a notable increase of indigo's use as a painters' pigment, since from the early 17th century large quantities were imported by the VOC. In Haarlem, around the turn of the century none of the leading painters, Hendrick Goltzius (1558-1617), Cornelis Cornelisz. van Haarlem (1562-1638) and Karel Van Mander (1548-1606) utilised indigo, whereas only a few decades later the pigment had become popular with the younger generation of painters. Of these, Frans Hals (1581/85-1666) seems to have been the pioneer, in his use of indigo in 1627 for the blue sashes and patterns of the standards in portraits of the St. George civic guard and the St. Adrian civic guard (Fig. 15, 16). Hals used indigo again in portraits of the St. Adrian (1633) and St. George (1639) companies (Fig. 17, 18). Maybe, techniques of Antwerp painters played a part in Hals' use of the unconventional painting material. We know that in 1616 Hals left for Antwerp for some months, so that it is conceivable that he received some training as a painter there. In his choice of blue, Hals was soon followed by several of his younger Haarlem colleagues including Johannes Verspronck (Fig. 2, 19, 20), Judith Leyster (1609-60; Fig. 21, 22) and Jan Miense Molenaar (c.1610-68; Fig. 23). Indigo was also identified in a painting dated 1651, by Pieter Fransz. de Grebber (1600-53; Fig. 24a).

Conspicuously, in contemporaneous easel paintings by artists from other textile centres, such as Leiden, Delft and Rotterdam, where indigo was just as readily available, the pigment has not been

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75. Indigo identified in following works by Anthony Van Dyck in the collection of the National Gallery, London: Abbé Scagnia Adoring the Virgin and child, Charity (c. 1627-28), made in Antwerp soon after returning from Italy, Lord John Stuart and his brother Lord Bernard Stuart (dated 1638-1639), The Balbi Children (painted in Genoa between 1625-1627): entries in Roy (1999).

76. Jacob Jordaens: The water and the farmer (c. 1620) and Moses drawing water from the rock, both in the State Art College Kassel: Scheppe (1997), p. 101. Triumph of Frederick Hendrick (signed and dated 1652), Koninklijk Paleis Huis ten Bosch, The Hague. The latter painting was technically examined by conservators of the Stichting Rijksbureau Litho Limburg. In this painting, indigo was identified by Jaap van der Weert using Fourier Transform Infrared Spectroscopy (FTIR). In the infrared spectrum obtained from pure indigo pigment, characteristic peaks for indigo can be distinguished on the wavelengths 1629, 1612, 1585, 1483, 1462, 1392, 1317, 1173, 1128, 1069. All these peaks are also visible in spectra obtained from oil paint reconstructions made of pure indigo that had been kept in the dark for two years. However, in oil paint reconstructions that had also been preserved in the dark, but wherein indigo had been extended with lead-white, only peaks 1629, 1612, 1585 were identified while marker peaks with a lower frequency could no longer be distinguished. Maybe, this is due to a reaction between the indigo molelules and the lead-white. That even in young and unfaded indigo lead-white paints only the 1629, 1612 and 1585 marker peaks can be identified may explain why in spectra obtained from samples from indigo lead-white paint from old paintings, usually only theses marker peaks are present. Research by Jaap van der Weert, unpublished MOLAR results.

77. Indigo was first identified by De Wild (1929) using light microscopy and micro-chemical tests. During the last restoration of the portrait series (1985 to 1987), eight more paint cross-sections were prepared from the blue sashes and studied using light microscopy by prof. dr. J.R.J. van Asperen de Boer and K. Gruen. Indigo was confirmed by means of infrared spectrophotometry. Grevenstein et al (1990). For the present study, these samples were re-examined under the microscope and additional SEM-EDX and FTIR analyses were carried out. Loose sample material preserved in the collection of J.R.J. van Asperen de Boer was studied using DITMS. One new sample was taken from the 1627 St. George portrait from dark blue indigo paint from the standard near the frame.

78. Jan Mierev Molenaar, The Town, (signed and dated: IMP1637), Panel 19.5 x 24.2 cm. Royal Cabinet of Paintings Mauritshuis, The Hague. Inv. no. 572. The Smell, see Fig. 23a. These paintings belong to a series of five panels of the five senses. Indigo was identified using light-microscopy and FTIR analysis. About the FTIR analysis; see note 76.

79. Indigo was identified using light-microscopy and FTIR analysis. About the FTIR analysis; see note 76.
identified to date. Visual examination suggests that indigo was used by some Amsterdam painters, although its use there seems to have been very limited (only three possible examples were found by the author). Notably, in two of these instances, indigo seems to have been used for the blue sashes in militia pieces that have a substantial connection with the work of Frans Hals. In 1623 Nicolaes Eliaasz (1588-1650/56) painted one such militia piece which is assumed to have been influenced directly by Hals' St. George company of 1627 in that it differs both in its theme of a civic guards meal and in its composition from then then current type of Amsterdam militia portraits. It is conceivable that the Haarlem painter may also have inspired Eliaasz in his choice of using indigo. In 1633 Frans Hals started painting a civic guard portrait, today known as the Meagre company, intended for an Amsterdam company (Fig. 25). After a long, drawn-out conflict due to the slow progress of Hals' work, the Amsterdam painter Pieter Codde (1599-1678) was requested to finish the painting in 1636. Both archival documents and examination of the paint surface suggest that at that time Hals had already underpainted the whole portrait group and finished several figures. Codde's choice of indigo will have been inspired by the technique of the Haarlem master. In the blue sashes we see Hals' underpaint layer whose greyish blue colour is typical for indigo paint that contains a lot of binding medium. On top, there are more impasted, hardly brushed-out strokes of a more intense blue. These upper paint strokes seem to have been applied by Codde since the stiff, sometimes even scratchy paint handling differs greatly from the technique evident in Hals' Haarlem portraits where opaque and transparent, blended and unblended strokes sophisticatedly alternate (Fig. 15-18).

During the first decades of the 17th century, the abundant use of indigo paint was most probably a local Haarlem tradition set forth by Frans Hals. By the second half of the 17th century, painters from other cities in the Northern Netherlands used indigo more commonly. The pigment has been identified in various works by Johannes Vermeer (1632-75) of Delft (Fig. 26), a still-life painting (c.1650) by Pieter de Ring (1615-60) of Leiden (Fig. 27), and in the portrait of Amalia and her daughters (1650) by Gerard van Honthorst (1590-1656) who worked after his return from Italy, in Utrecht, London and The Hague (Fig. 28). Cornelis Johnson (1634-after 1700), mainly working in Utrecht, used indigo in his Portrait of a Dutch gentleman (1657; Fig. 29). Indigo was regularly identified in paintings by Jan Steen

81. Eliaasz' portrait of Civic Guardsmen from the company Dutch Tradesmen's and Associates Pieter Adriaensz Raep (1639) Canvas 202 x 340.5. Amsterdam Historisch Museum. Inv. no.143 (A7314), hangs too high to ascertain whether indigo could be used for the sashes. Indigo may have been used as well for the blue drapery in two paintings from a series of five panel paintings (1626-27) attributed to Werner van den Valckert (c.1585-c.1627), that depict the different tasks of the almshouses in Amsterdam. The distribution of the bread (dated 1627). Panel 149.5 x 149 cm. Amsterdam Historisch Museum. Inv. no. 458 (A3027) and The rest is the Kemp work. Panel 148.5 x 63.5 cm, in the same collection. Inv. no. 456 (A1756).


83. Hermens et al. (1999). For the present study the samples were re-examined under the light microscope.

84. The presence of indigo was strongly suggested when the sample was studied under the light microscope. Due to the thinness of the paint-layer and because the blue pigment was used with a lot of lead-white, indigo gave not be identified using DTMX and FTIR. The limited sample material did not allow the use of additional analysis methods (see chemical analysis or HPLC, SEM-EDX analysis identified in the paint-layer lead and only very little calcium. Elements that are present in inorganic blue pigments were not found so that the presence of these pigments could be excluded. Since, no other organic blue pigment is known to have been used in oil painting in the 17th century, I currently deduce that Honthorst will have painted the blue pattern with indigo.

85. North (1996). I am grateful to the Courtauld Institute for kindly lending the paint cross-sections for re-examination under the light microscope for the present study.

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(1625/26-79) made in the 1660's (Fig. 30). 86 Notably, Steen's use of indigo coincides with his stay in Haarlem from 1660 to 1670. 87 Around the same time, indigo was utilised by Peter Lely (1618-80; Fig. 31) 88 and some decades later by Godfried Schalken (1643-1706), both Netherlandish painters working in England (Fig. 32). 89

Around the middle of the 17th century, there is also evidence of an increased use of indigo by French painters. Contacts with Italian and Netherlandish painters may have contributed to this development. Indigo has been identified in Poussin's (1594(?)-1665) Echo et Narcisse made around 1630 when the painter had been working in Italy for several years. 90 Likewise, Charles LeBrun (1619-90) who kept in close touch with Poussin, executed his Le Christ mort sur les genoux de la Vierge (1643-45) using indigo, in Italy (Fig. 33). 91 Philippe de La Champaigne (1602-74), in whose works indigo has been identified several times (Fig. 34), 92 also had contact with Poussin but may also have learned about the pigments' possibilities during his apprenticeship in Brussels under Rubens' assistant Jacques Fourquier. To date, only few examples are known of the use of indigo in 18th and 19th century oil paintings. Presumably the pigment was rarely used since Prussian blue, which was invented in 1704, had become commercially available in the early decades of the 18th century. This pigment combined all the good qualities of indigo while it faded much less than indigo. 93 The transition in technique is evident in two still life paintings by Van Huysum (1682-1749): one painted between 1702 and 1720 and the other dated 1736. In the earlier painting, green mixtures were made with indigo while in the later one Van Huysum used Prussian blue. 94 Jacob de Wit (1696-1754), used indigo in a ceiling painting (1718) for the

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86. Unpublished report ICN. Indigo was identified using DTMBS by Jaap Boon, unpublished MOLART results. The painting is dated 1659-60 by Vrees (1967), p. 15 and 1665-70 by Braun (1980), p. 259. For the present study the samples were re-examined under the light microscope and analysed using SEM-EDX. Other paintings by Steen wherein indigo was identified include: The doctor's visit and Tavern scene with Pregnant Hostess both in the John G. Johnson Collection, Philadelphia: Butler (1982-83). According to Butler, Steen presumably painted The doctor's visit in the early 1660's and the Tavern scene with pregnant ladies around 1670.

87. His Haarlem colleagues may well have influenced Steen's choice for indigo. According to Butler (1982-83), p. 49, in his early works, Steen preferred more costly and bright coloured pigments, such as azurite, ultramarine and vermilion. From the 1660's on, his palette became more subdued, consisting mainly of earth colours, and small and indigo as his favourite blue pigments.

88. Hendriks & Groen (1994). For the present study samples were re-examined under the light microscope, and additional SEM-EDX analysis was carried out.

89. Massing & Groen (1986). I am grateful to Spike Bucklow, Hamilton Kerr Institute, Cambridge for kindly lending me the paint cross-sections for my renewed microscopic examination for the present study.


93. The modern artists' pigment is considered permanent when used as a full-strength colour paint. However, when extended with a white pigment, the permanence is less; Berne (1997), pp. 199. Eighteenth-century oil paintings with faded Prussian blue and early reports on the fading of Prussian blue have been described by Kirby (1993).

Cromhouthuizen in Amsterdam. Prussian blue may not have been available in Amsterdam at that date - the earliest known reference of its sale is dated 1722 - but it is also conceivable that the painter simply persevered with a familiar technique instead of converting to the use of the new pigment. In the 19th century, indigo seems to have been used only sporadically in oil paintings. The pigment has been identified in works by William Turner (1775-1851), Willem Maris (1844-1910) mixed indigo with various other pigments to depict delicate green tones of the grass in a painting of a group of ducks.

IV. Different qualities of tropical indigo.

Regions from which tropical indigo was imported.

Indigo pigment imported from outside Europe could come from a large number of areas, could be made from various indigo plant species, and was available in a variety of grades and qualities. Since the first half of the 17th century, Lauro indigo, Guatamala indigo and Charkese indigo or Tripoli indigo were marketed in Amsterdam. Lauro indigo came via the town of Lahore in the Indian district of Gujarat where the VOC had a trading post. Guatemala indigo, imported from the Spanish colony of Guatemala, is first referred to in 1609 and is regularly mentioned from 1624 onwards. The Charkese indigo was traded by way of Tripoli and was considerably cheaper than the other indigo types. Presumably, it was a less concentrated product that will most likely not have interested painters of easel paintings. From the second half of the 17th century onwards, Dutch merchants commenced importing indigo from more and more other regions. In addition to Lahore, the Amsterdam courant mentions indigo as coming from the towns of Surat en Jambusar in Gujarat and the district of Bengal, the delta area between the Ganges and the Brahmaputra rivers. In the early 18th century, in both Curaçao and Suriname the first indigo plantations were set up. In 1694, a trial shipment of Javanese

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96. The earliest known Netherlandish painting wherein Prussian blue has been identified is a flower still-life dated 1716 by Rachel Ruysch: Zeldenrust & Wallert (1999), pp. 100-01.


98. Willem Maris, Ducks. Rijksmuseum, Amsterdam. Indigo was identified using DTM by Jaap Boon; unpublished MOLART results.

99. See references in Amsterdam sources published by Posthumus (1910-22), vol. 4.


101. From stock market prices in Amsterdam it is evident that the 1626 price of Indigo 'Carrelse tripod' and the 1638 and 1650 price of 'indigo karkes tripod' was considerably lower than prices of other types of indigo. Nie (1937), p. 112.

102. Nevertheless, the inferior product may have been used in decorative oil painting techniques. John Smith, who was writing about techniques for decorative oil painting, rather than as fine art, maintained that some painters used 'blue balls' instead of expensive indigo. These blue balls may have been balls of partially fermented indigo or wood leaves containing a high amount of plant material: Harley (1970; 1982), pp. 66-67. In aqueous media (like distemper for walls or panelling) inferior indigo species may probably have found little use, since in these media all types of impurities of low refractive index, like chalk, will influence the eventual colour.

103. Hofenk de Graaff (1985), p. 28

104. The cultivation of indigo in Suriname was described in 1714 by Eikelenberg (1679-1704), p. 838.
indigo arrived in Amsterdam, but until the beginning of the 18th century only minor amounts seem to have been imported from this colony.105

Other European countries started to concentrate on the import and cultivation of indigo as well.106 From the second half of the 17th century, the English East Indian Company (EIC) imported increasing quantities of indigo from Gujarat by way of the trading towns of Bombay, Surat and Ahmadabad. Regarding West Indian indigo, the import from the Spanish colonies of Caracas and Guatemala remained the most important during the 17th century. Since the middle of the 17th century, plantations were set up by the French in their colonies of Guadeloupe, Martinique and San Domingo and by the English in their colonies of Jamaica, Barbados and in the course of the 18th century, also in South Carolina and other Southern states of North America. Gujarat, once the main supplies of indigo, was hard hit by the competition from America. However, due to both the abolition of slavery, resulting in more expensive labour, and the civil war, the American indigo culture declined rapidly. In the 19th century, the English therefore concentrated on the cultivation of indigo in Bengal (captured in 1795-97 from the Dutch) while the Dutch went to great lengths to improve the quality of their indigo in Java.107 In 1870 Von Baeyer and Emmerling succeeded in producing synthetic indigo using isatin as the starting material.108 In 1897, this product became commercially available in its purest form from the Badische Aminind Farbenfabrik (BASF) in Germany. At first, the regions cultivating natural indigo tried to keep their market share by focusing on the development of more efficient production processes.109 However, synthetic indigo was soon produced at a much lower price so that it rapidly replaced the natural product.

Tropical indigo plants
In order to determine which indigo plants have supplied the indigo used in European (mainly 17th century) oil paintings, contemporary botanical studies and travel accounts form an important source of information.110 To date, only sporadic attempts have been made to identify the plants described and depicted in these texts, presumably due to difficulties encountered in their terminology. Until Carl von Linnaeus classified plants into family, genus and species in his Species plantarum (1753), botanists did not use a consistent method or terminology to categorise plants.111 In addition, the early descriptions and illustrations are not usually sufficiently specific to identify the indigo species.

105. Java-indigo is only mentioned for the first time in the Amsterdam courant of 1734.


109. When synthetic indigo had become commercially available by the end of the 19th century, for example, the Dutch government made considerable efforts to improve the quality of the natural product made at their plantations in Indonesia. To this end the chemical composition of natural indigo was extensively studied. For an example of these studies: Tulleken (1900).

110. Through the centuries, numerous indigo species have been cultivated in the various regions from where indigo was imported to Europe. Over time, most of these species were transplanted from their indigenous areas to other parts of the world. The original location of cultivation is often unknown today, just as is the period of introduction to the various countries. In addition, in a given period, several indigo plants may have been cultivated in one region. For example, during the 19th century, three indigo species were cultivated in Java: Lookeren Campagne (1890), p. 14.

111. Botanists did not yet consistently classify plants according to family and genus, but often according to the most important characteristics.
In the middle of the 18th century, Linnaeus differentiated three species of the genus Indigofera, which have retained their nomenclature to this day: Indigofera tinctoria L. 'indigo containing plant of the dyer', Indigofera hirsuta L. 'hairy indigo containing plant' and Indigofera glabra L. 'hairless indigo containing plant.' This does not mean that indigo found in paintings came exclusively from these plants. Linnaeus based his denominations on descriptions found in an older work: the Hortus Indicus Malabaricus (1678) by the Netherlandish botanist Henricum van Rheede van Draakenstein. As suggested by the title, this book only gave an overview of plants found in the area of Malabar in South East India. Of the plants in this area, which were cultivated for indigo, I. tinctoria was without doubt the most important in Van Rheede's time (Fig. 4). This is indicated by Van Rheede's characterisation of only this plant as containing indigo. This plant was also cultivated in India and Mid-eastern parts of Africa and introduced by the Spanish on their plantations in the West Indies in the second half of the 16th century. The English physician and botanist Miller (1691-1771), also mentions in the 1768 edition of his Gardener's Dictionary that primarily the I. tinctoria was cultivated in the English West Indies colonies. About half a century earlier, the English doctor Hans Sloane, who, in his Voyage to the islands Madera, Barbadoes, Nieves, St. Christophers and Jamaica (London 1707-25), described his visit to English and French colonies, made no mention of this plant. According to Sloane two other plants were used in these colonies to make indigo. On the basis of Sloane's drawings and descriptions, it is possible to identify one of these as the I. glabra described by Linnaeus (Fig. 35). Apparently this indigo plant, which Van Rheede had encountered in 1678 in the Malabars, was introduced to the colonies of the West Indies in the meantime. According to Miller, this plant was also cultivated intensively in his time. The other plant that Sloane saw on the plantations was almost certainly the Indigofera suffructicosa Mill, which is indigenous to South and Central America and which was cultivated ages ago by the Indians (Fig. 35). It was primarily the indigo made from this plant which was exported to Europe by the Spaniards since the 16th century. Today the I. suffructicosa can be found in practically all tropical parts, however, since Van Rheede does not mention this species in his Hortus Malabaricus it was apparently exclusively found in the Americas at the end of the 17th century. Travel logs of the late 17th century confirm Sloane's of the plants, in this case the production of a blue dyestuff. Thus indigo plants are often classified as woody plant (Isatis). For example Caspar Bauhin's Teatri botanici, Basileae 1571, describes a tropical indigo plant as 'Isatis Indica foliis Rotundatis' (Isatis from India with leaves like the rosemary plant).

112. Linnaeus (1753), vol. 2, p. 751. Some decades later, Charpentir de Cossigny described nine other indigo supplying plants including various woody species in his Essai sur la fabrique de l'indigo (1779).

113. The importance of this plant for the supply of indigo in 17th century Europe is evident from the fact that Van Rheede (1678), vol. 1, plate 54, already denoted the species as Indigofera tinctoria. In various 17th century herbals the plant is referred to as such as well. Personal communication Dr G. Thijssen, Rijkssherbarium Leiden. Indigo plants denoted by Linnaeus as hirsuta and glabra were described by Van Rheede but not yet as 'indigo containing' see Rheede (1678), vol. 1, plate 55 and vol. 9, plate 67.


115. Miller (1731-35; 1768), vol. 9, see under Indigofera.

116. I would like to thank Dr G. Thijssen, Rijkssherbarium Leiden, for his help in identifying the described and depicted indigo plants in the old texts.

117. Today the Indigofera suffructiosa species is subdivided into Indigofera suffructiosa suffructiosa and Indigofera suffructiosa quartzamalis. According to Dr Thijssen, Rijkssherbarium, Leiden both types are strongly related. Differences probably developed due to the cultivation of certain characteristics of the Indigofera suffructiosa at the plantations of Guatemala. However, Balfour-Paul (1998), p. 92 believes that the Indigofera suffructiosa quartzamalis is a separate plant species that is mistakenly considered a subspecies of Indigofera suffructiosa.
observation that this plant was cultivated on French plantations. Sloane apparently did not see the plant in English areas. In 1768, Miller relates, namely, that he had heard that the *I. suffructcosa* could serve the English plantations as well. From this, one can conclude that this sort was not yet common there. The *I. hirsuta*, described by Van Rhee in 1678, was supposed to be promiscuously used to make indigo according to Miller. From this it seems that this indigo plant was cultivated by the mid 18th century. The last indigo plant mentioned by Miller was the *Indigofera carniniana* Mill., a type of indigo that still bears that name. This plant is indigenous to the southern states of North America and since 1700 it was briefly cultivated by the English colonists. Miller related that the cultivation of this plant was quickly replaced by the *I. tinctoria* and *I. glabra* due to their much higher yield.

Regarding the Northern Netherlands, the indigo used for oil paintings during the 17th century was primarily made from the *I. tinctoria* and *I. suffructcosa* plants. In Amsterdam price records indigo from Guatemala (made at that time from the *I. suffructcosa*) is regularly documented only after 1624. This indigo would therefore rarely be used in Northern Netherlands paintings before this time. In paintings dating from the end of the 17th century and early 18th century, indigo from *I. glabra* could easily have been used.

**Assessment of quality of indigo lumps**

The care exercised in the preparation of the dyestuff from *Indigofera* plants differed widely for each region. Pomet stated in his *Histoire generale des drogues* (1693), that the very best quality came from the village of Serquissé (= Sarkhej, near Cambay in India). This indigo was in the form of flat cakes and was therefore called 'plat' indigo (French: *inde plate*; Dutch: *platte indigo*). The indigo made in the nearby town of Agra was of virtually the same quality and was, due to its sliced ball form, called 'inde de maroni.' The lowest quality was imported by the Dutch from Bengal. Regarding the West Indian indigo types, the best quality came from Guatemala and the next from San Domingo. Of lesser quality was the Jamaican indigo, while the worst types were imported from the Caribbean islands. A quarter of a century later, as we can read in a letter dated 1723 by the indigo connoisseur Hendrik van Raat, virtually the same differences between the indigo types from various regions existed. However, place of origin was certainly not the only criterion for determining indigo's quality. From catalogues of drugs, for example, it is evident that indigo from Serquissé was imported in three grades. In the Northern Netherlands, sometimes 'plat' indigo did not refer to the superior product from Serquissé but instead to

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118. According to Dr Thijssse, Rijksksherbarium Leiden, the description by Padre Jean-Baptiste Labat in his *Voyage aux Indes de l'Amérique* (Amsterdam, 1699-1705, Paris 1722, of the indigo plant he found at indigo plantations on the French colony of Martinique must certainly refer to the *Indigofera suffructcosa*. According to Dr Thijssse this plant was probably also drawn by the French Royal botanist Per Charles Plumier during his travels to the Antilles from 1699 to 1704; illustration in Viatte & Aillaud (1987), p. 49, Fig. no. 7. Plumier himself denoted this plant as *ornithopterum juniperinum* in pressa *ornithopterum tinctorium*.


120. Pomet (1694), pp. 153-54, even differentiated two products on the basis of the means of preparation. The *inde* was the most pure as only the leaves were used. This product was only made in Gujarat and Bengal. Indigo that was less pure, since the whole plant was used sometimes with weeds and all, was made at American plantations. According to Pomet only *inde* was well suited to the art of painting. However, most painting manuals do not refer to any difference. Painters will also hardly have been able to distinguish the two products since, as is evident from Pomet's description, good quality *inde* was almost like *inde*.

121. Raat (1723), pp. 178-83. Only the indigo from Serquissé was usually less good than the best types from Guatemala and indigo from Java was now characterised for its great purity.


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128
indigo of an extremely low grade (in addition to flat, in Dutch the word 'plat' can also mean coarse or plain). For example, in 1640 the Leiden textile dyers complained that the VOC had brought far too little indigo Lauron and only a great abundance of plat goods... which plat good is of a bad quality and contaminated goods and... cannot be properly used. The trade name even had a third connotation. At the end of the 17th century, the pigment factory of the firm Pekstok in Amsterdam produced 'platte' indigo consisting of indigo powder from Guatemala ground wet with small. This product was not utilised for dyeing textile or for the art of painting but for housekeeping; a small piece added to the rinse water made linen look whiter and cleaner.

Painter's manuals indicate that differences in quality were also considered of great relevance to painters. Naturally, when dyeing textile, a high percentage of impurities in the indigo is unfavourable as a less concentrated vat solution is obtained. For painters, however, impurities can be particularly problematic. When the lumps are ground as a pigment all of the inferior components end up in the final paint. Reconstructions indicate that these impurities have a detrimental influence on the working properties of the paint and the hue and intensity of the colour. In addition, they may considerably diminish the paint's colour-fastness, as will be discussed in section VI. The Spanish painter Felipe Nunes recommended in his Arte poética, e da pintura (1615), the use of indigo in the form of tablets, which presumably referred to flat indigo from Serquisse. Later in the century, mostly indigo from Guatemala is recommended. In his Aanteekeningen over schilderkunst (1679-1704), the Dutch painter Simon Eikelenberg noted in 1704 from an indigo merchant that laurou indigo from East Indie could be as good as the one from Guatemala although its quality could differ greatly and that Jamaican indigo was extremely bad. Just like textile dyers, painters knew that good quality indigo had to be purchased in the form of lumps that were easy to break exhibiting a plane of fracture with a fiery violet colour. The Dutch painter of 'De grote waereld in 't kleen geschildert' (1692) to choose the most purplish pieces with white spots (Fig. 36). Presumably these spots were a white mould that, according to a late 18th century text on the making of indigo, was formed when the indigo lumps were not sufficiently dry before being wrapped up and transported. Eikelenberg noted that to

123. Posthumus (1910-22), vol. 4, p. 169, no. 156: 'Wel is waar, dat de roers, ophoren grote quantiteit van plat goet zijn medebrengende, welk plat goet een schadelijke en homigigewest goet is en dus door de supplianten, doordien de venen de beste indigo vereischt, niet begaamelijk kan worde gebruyc.'

124. Pekstok (1697): 'Memorie om platte indigo te maaken. Neemt tot 10 Lb. blauwel, 1 Lb. poer van Guatemala, dit dan 't samen door een mostert meulen 3 à 4 vijgen gemalen, en dan op 'n grooten borstel te doen gelegt tot dat men 't in vrekkens stukjes kan snijden, die dan van de borsten op een eijst geleght werden om te droogen, is gemaakt. Wilt men dan indigo beter hebben soe neemt men minder blauwel en meer indigo, als ten voorbeeld tot 50 Lb. poer van guatemala, 1 50 Lb. blauwel, off tot 50 Lb. poerer, 100 Lb. blauwel en oo naar advend. N.B. het blauwel kan wel oan een bij goet zijn die voor 10, 11 à 12 sguinae te bekommen is.'


127. Eikelenberg (1679-1704), p. 798: 'Indigo 1704 is mij door een errare zijde- en stoffereuner, ook handeelaar in 't indigo zijnde, geeft dat de indigo Guatemala de beste is en onder dezelf de laurou van gewijzig, die niet poerer maar... nietziet en veel worde stipped heeft. Dat de indigo laurou, die zoo bij zijf, niet onderlieten komen, wel zoo groot kan zijn als die van Guatamala; maar weten zeer verschillende soorten is. Dat de jamacayt zeer smelt is. Dat als men indigo koopt men regels genoome recept heeft, dezelve te laten zienen, om atoem 7 rand, dat is onder moet zijn waar of te rechende en zuive van onwisselen.' Other authors recommending the use of Guatemala indigo for oil paintings include: Mayenee (1620-46); see Graaf (1958), p. 173, and Colker (1719); see Schiefl (1962), p. 111.


129. Beurs (1692), p. 16: 'Indigo, die men de paartje stukken met wite stippen uitroept.'

130. Dyonal (1788), pp. 44-45.
try whether the indigo is good, one scrapes it with the nail and when it [the lump] appears like copper, and shines, then it is good,' and added that before buying indigo, it was usually sieved to remove remnants of sand.\textsuperscript{131}

In the 17th century, prices for indigo could fluctuate wildly due to its irregular supply over sea.\textsuperscript{132}

Inventories of shops in the Northern Netherlands specialising in painting materials, indicate that these almost always had indigo in stock, often in large quantities and in various qualities. The inventory made in 1648 of the Rotterdam store ‘t Hemelryk by Crijn Volmarijn, indicates that over 13 pounds of indigo were available in qualities costing 26, 18 and 16 stivers a pound.\textsuperscript{133} Naturally, this indigo was used in decorative arts as well and also textile dyers will have bought their indigo in addition to other supplies in Volmarijn's shop.\textsuperscript{134} In 1667, the shop of Cornelis van Bolenbeek had various pounds of flat indigo as well as ground and un-ground round indigo in store.\textsuperscript{135} This round indigo, priced 12 schillings (≈ 72 stivers) a pound, must have been of considerably better quality then the flat indigo that cost only one third of that price. Indigo was rated among the more expensive pigments, including red lakes of average quality and vermillion. Indigo was significantly more expensive than blue azurite and smalt, which cost 5 to 10 stivers a pound.\textsuperscript{136} However, when comparing prices, we must take into account that indigo’s specific gravity is much lower than that of other (inorganic) blue pigments. In addition, due to its strong tinting strength, indigo can be used economically as one only needs a small amount to make deep blue colours.

V. Properties of indigo in an oil medium

Assessment of working properties of indigo in oil media

When mixed with oil, indigo acquires a very dark, almost blackish blue colour. Therefore, to achieve the required shade of blue, white pigment was usually added. This provided a colour characterised in sources as greyish blue, sky-blue, ‘very faint blue’, and ‘a lead-colour’ that differs from the brighter blue

\begin{footnotesize}
\textsuperscript{131} Eikelenberg (1679-1704), p. 735: ‘tende eemt heffernen of d’indigo goot is, schrapt men met de nagel daer op zoo bij adden de eely boosterig zor ende bleuwt, zoo is de cycole goot.’

\textsuperscript{132} For example, in 1638, Amsterdam textile dyers asked for raising their wages since ‘indigo guatemal’ that first had cost 12 or 13 schillings now cost 25 schillings while the price of indigo laurao had increased from 10 or 11 schillings to 23 schillings: Posthumus (1910-22), vol. 4.

\textsuperscript{133} Municipal Archive Rotterdam, Inventory of Trijntge Pieters, d.d. 12 maart 1648. Archief van de weeskamer, Inv. no. 430, f. 187r: ‘3 1/4 pont staer wacht platte indigo a 1 gul. 1 pond a 2 st. 1 pond a 73-18-00.’

\textsuperscript{134} For the use of indigo in decorative arts: Bostow (1996), pp. 14-15. In inventories examined, many materials used for textile dyeing were available, usually in large quantities. See for example, the inventory of the shop of Crijn Hendrickesz. Volmarijn \textit{ibid.}, f.186v: ‘181 pond wyvels a 2-10",onderst ft 13-11-00, 20 pond put as a 2 st. 7 pond st. f.03-18-00.’

\textsuperscript{135} Municipal Archive Dordrecht, Inventory of Maria van Wingenaden, d.d. 16 april 1667. Notariel archief nr 20, notaris Adriaen de Haan, inventariss nummer 225/224, f. 113r: ‘5 1/4 pont s.awer alicie blauw indigo a 1 gul. 4 st. 7 pond 03-18-00, 4 1/4 bone alicie maken indigo a 12 schillingen 7 pond 15-06-00, 25 4/2 pont s.awer alicie ungermale dito 5 gul. 7 pond 03-14-00.’

\textsuperscript{136} See note 133, f.186v: ‘1/6 pond small 7 pond 2 st. f.02-08-00, f.187c: 1 1/2 pond gemen lach a 30 st. 7 pond 03-05-00, 3 3/4 pond Haarlemse ulitramarin a 10 schillings 7 pond, f.188c: 1 pond boever a 38 st. 7 pond 08-07-08, f.188v: 15 pond blauw a 7 pond 5-10 [stivers] 31/2297 and see note 135, f.112v: ‘5 1/2 pont s.awer tintin g in heilis te 41 st. 7 pond f.13-06-08, f.112r: pont en 2 last s.awer alicie fine brede lach a 7 gul. 7 pond f.11-78-00, f.112v: ‘2 last s.awer to barthens blauw in 4 gul. 7 pond f.03-15-00, 1 pond en 2 last s.awer alicie hemel blauw in 8 st. 7 pond f.00-08-08, 5 pont s.awer to barthens alit a 9 1/2 st. pont f.02-02-08.’ Note that indigo had the same prices as a blue pigment denoted Haarlemse ultramarin that in the shops of Volmarijn and Van Bolenbeek a pound cost respectively 10 schillings (= 60 stivers) and 4 gilders (80 stivers).

\end{footnotesize}
nuances obtained when indigo is used as a textile dye (Fig. 37). When the pigment is used in glue or egg tempera the result is a slightly brighter, purplish blue than in oil. The Spanish painter Pacheco wrote in his Arte de la pintura (1638) about this difference: 'When [the indigo is] ground up it appeared black, but later, when made into mixtures, it had a wonderful hue between purple and blue. But if this colour is mixed in oil, it cannot be seen.'

Paint reconstructions indicate that the colour of woad indigo mixed with oil is comparable to that of tropical indigo. Indigo flower results in a slightly more intense purplish blue paint. Indigo extracted from blue wool, however, gives a surprisingly vivid blue.

The other blue pigments that painters had at their disposal, and that produced brighter blue oil colours than indigo, all had particular disadvantages. Beautiful, deep blue ultramarine was extremely high-priced. Azure, that makes a more greenish blue, was rather expensive as well, especially when, in the second half of the 16th century the supply route from Hungary had been cut off by the Turks. Small and blue verditer were rather cheap but had very limited tinting strength and hiding power. As described in chapter II, both azure and small could only be used when coarsely ground, which made paint of these pigments rather very difficult to handle in oil. In comparison to this rather meagre list, good quality indigo had important advantages. The pigment could be ground into an extremely fine powder. John Smith maintained in his The art of painting (1676): 'Note, that the longer this colour is ground, the more beautiful and fair it looks.' In paint cross-sections finely ground indigo is visible as a (light) blue matrix with some larger agglomerates, generally up to a few microns in diameter. Due to indigo's superior colour strength painters rated indigo among pigments 'bearing a body,' which John Smith defined as: 'All these [pigments] may be ground so fine as to be like, even oil itself, and then also may be said to work well, spreading so smooth, and covering the body of what you lay it upon, so intirely, as that no part will remain visible where the pencill hath gone.' Areas in paintings which still appear deep blue, having been shielded from light by the frame, show a surprising quantity of lead-white mixed with the indigo in a cross-section. The blue sash at the left edge of Hals' 1633 group portrait provides an example of this phenomenon (Fig. 17a, h). Practical reconstructions showed that large quantities of lead-white were needed to lighten the colour of paint made of good quality natural indigo (Fig. 37). This was characteristic in particular that made indigo most suitable for painters. In oil, lead-white gives a flexible and malleable paint with which one can obtain a range of effects; the painter can apply broad impasto paint strokes and also

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137. Mayerné (1620-46); see Graaf (1958), p. 148: ‘Noir de lampe... mêlé avec blanc de plomb fait un beau gris brouillard que l’on appelle l’inde;’ Smith (1676), p. 20: ‘Indigo is a dark blue, if wrought by itself; to remedy which, when are usually moist, and then it makes but a very faint blue;’ Smith (1692), p. 51: ‘...a blue-colour is made of indigo and white.’

138. Pacheco (1649); see Sánchez Cantón (1956), vol. 2, p. 17: ‘Demás decir, entre los colores muy precisamente que son el azul (retiene en Italia el mismo nombre) que saca de nuestras de llama azul, y luego de ella se mueve a dais días (como ha hecho a mí), siempre se ha de tener, y en aquéllas tiempos la debía de ver; rompi de la Indias oriental y medieñola purpura, y negro, mas después, hechas sus mezclas, hacía maravilloso color, mezcla de paizuras y azul; esta mezcla no remueve que a día la luz.’ Translation by Velázquez (1986), p. 44.

139. Mayerné (1620-46); see Graaf (1958), pp. 40-41. Afterwards, as is evident from historical sources, azurite was also imported from West Indian colonies. Paulus Van Sommer mentions in De Mayerne manuscript that the blue pigment ‘Céder,’ which was found in silver mines, came from Hungary and the West Indies; Mayerné (1620-46); see Graaf (1958), p. 148. Pacheco mentions the use of ‘Júnta Domingo’ blue. According to Velázquez (1986), p. 207, this term likely refers to a naturally occurring copper blue from the Spanish Indies, of which Santo Domingo was the principal port.


141. Smith (1676), pp. 28-29. See also: Eikkenberg (1679-1704), p. 380: ‘Indigo is not in dearom delhie urel, en se is gret in beharen, maar zij droog qualijjk, das moet gi eemperen met hetrijeur vijfj, maat niet met watar staan;’ Smith (1692), p. 69; Verly (1744), p. 172; Pernery (1756), p. xxiv: ‘Quelques peintres arpentent l’Inde, pour qu’el lors beaucoup de corps avec le blanc; mais elle se déchire beaucoup en restuant; c’est pourquoi on ne doit en user que dans quelques déétories, qu’el faut ensuite missereum glace a l’extreme.’
accurately render the finest details. Thus when mixed with a lot of lead-white even the coarsely ground blue pigments become malleable. However, due to these pigments' limited tinting strength this results in a pale blue paint. The advantage of indigo due to its enormous tinting strength, is that it can be mixed with plenty of lead-white so that it is perfect to handle, while still giving an intense blue colour. In addition, in an oil medium, indigo is well suited for glaze paint. In sources we find indigo sometimes listed amongst pigments used for glazing.\textsuperscript{142} All these characteristics made indigo an excellent pigment in oil, as Palomino simply wrote: \textit{Indigo is a very fine colour, and pleasing to work} (Fig. 38).\textsuperscript{143} Painters seem to have valued indigo's working properties so greatly that they put up with its greyish blue colour and poor colour-fastness. The pigment enabled them to create an extremely convincing illusion of all kinds of blue (and when mixed with yellow also green) fabrics as is evidenced by Frans Hals' masterly depiction of the silk sashes in the Haarlem civic guard portraits (Fig. 15-18).\textsuperscript{144} According to 17th century authors, the characteristic folds of silk required strong highlights that were clearly differentiated in tone from the remaining cloth. As Van Mander (1604) stated: \textit{considering silk... The Venetian painters are highly praised. They know how to work with paint so well and they know how to do it so that the highlights just seem to project.}\textsuperscript{145} The English connoisseur Marshall Smith (1692) wrote: \textit{Taffetas and thin silks' must be rendered full of breaks and flickerings and with rather sharp folds.'} Further, one should give the folds of the drapery a 'sudden light with an extraordinary free hand, and if possibly, work them without fitches; for if they be not delicately us'd they will blunt the briskness of the silk which is the beauty of it.'\textsuperscript{146} In Hals' paintings we see strokes of translucent and more opaque blue paint spontaneously juxtaposed. Indigo's advantageous working properties clearly facilitated a lucid execution with dashing paint strokes that evoke the brisk folds and flickering sheen of silk.

When using inferior indigo types, painters would not have experienced any of the pigment's good qualities. The result is a greyish green paint with little tinting strength and hiding power. In addition, inorganic impurities cannot easily be pulverised into a fine powder and hence result in disturbing pieces visible at the paint surface. Time and again painter's manuals stress only utilising indigo of the very best quality in oil paintings. Inferior types that were easily distinguished from those of good quality were presumably hardly used in easel painting, although they would have found a role in cheap decorative work.

\textsuperscript{142} For example: Mayernc (1623-44), f. 37r: \textit{Couleurs qui gloscent: Verder, Lasure, Esmalco, Indigo, Tonrool, Camboja.'}

\textsuperscript{143} Palomino (1715-24; 1795-97), vol. 2, p. 67: 'El otro azul es el azul, sin mas mezcla que el almizcule, uno y otro con aceite de mani; y este se puede hacer de la primera, y es de mejor; y quanto mas se puede buquescar de blanco, y negro de carbon, si de humo. Y es bellisimo color y muy dulce de labrar, pero tiene también sus condiciones: y la primera es, que los colores; menos esos demasiado claros, porque facilmente atiesca, y asi se ha de labrar siempre sabido de color. La seguida, y mas importante, es que no se quite muy aciencia, sino bien trehadado, y no continuo. La tercera condicion, que ha de ser preparado, o perfumado por alguno de los medios que diremos.' Translation by Veliz (1986), p.166.

\textsuperscript{144} The assertion that silk was used for the sashes of the Haarlem civic guard is based on a militia account of 1593, Haarlem, Municipal Archive. This records a large quantity of silk and 2 el armoijn; a sort of taffeta (fine silk), usually of plain weave. I am grateful to Koos Levy-Van Halm for drawing my attention to this information. Since only 2 el (c. 1.4 metre) of armoijn is mentioned, this cannot have been used for the sashes, implying that they must have been made from the silk. However, this indication still says nothing about the specific type of cloth used. Silk could be woven in numerous different ways, such as satin or plain weave. Judging from the paintings it was almost certainly not satin.

\textsuperscript{145} Mander (1604), f. 43v: \textit{Nu in sijden en werschijnens, voorspelende, worden in't gleemen al gietperzen grootlijk, De Venetianen, die wel l'arheyden, Met de renne water, en zoa hebben, Dat de hoogheels niet schijnen steeken bloudjik.'}

\textsuperscript{146} Smith (1692), pp. 87, 81.
VI. Quality of indigo pigment and colour-fastness of indigo paint

**Historical assessment of colour-fastness of indigo in oil media**

Early recipe books only sporadically advise using indigo in oil paintings. Whenever mention is made of the pigment, such as in the *Strasbourg manuscript*, its use was restricted to areas of drapery cast shadow, and mixed with other pigments.\(^{147}\) Occasionally, 16th-century texts recommend indigo for the more prominent areas of oil paintings.\(^{148}\) The infrequent mention of indigo as an oil paint at this time is notable as contemporary sources on illumination and tempera painting give the pigment an important position. Early 17th-century texts maintain this distinction. Typically, indigo is absent in almost all lists of pigments and methods for oil painting collated by De Mayerne between 1620 and 1646.\(^{149}\) Around the same time the famous English miniaturist Edward Norgate, in his first version of his *Miniatura or the art of limning* (probably written 1621-26), considered indigo of 'exceeding greate use.'\(^{150}\)

Historical texts record that indigo was considered unsuitable for oil painting as many painters had had disappointing experiences with the pigment. While 15th and 16th-century sources describe the preparation of painting materials, they do not describe their properties. Not until the early 17th century does a discussion of the behaviour of painting materials appear widely in the literature. Indigo is thereafter frequently reported to fade by exposure to sunlight. LeBrun asserted in his *Recueil des essais des merveilles de la peinture* (1635): 'Indigo entirely fades if exposed to the sun,' and according to a recipe collection in the *De Mayerne manuscript*: 'Indigo is of no use in oil and fades immediately.'\(^{151}\) The effect of fading must have been rather severe. The Spanish painter Pacheco wrote in the 1630's that he had observed that indigo oil paint faded, in the sun, within two days. Around the same time, as we can read in the *De Mayerne manuscript*, another painter had an even worse experience as his indigo oil paint 'disappeared in the sun in a few hours.'\(^{152}\) LeBrun warned that fading also occurred in contact with water.\(^{153}\) Texts dating from the second half of the 17th century mention in addition to fading, other types of discoloration of indigo.

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147. *Strasbourg MS* (15th C); see Borradaille (1982), pp. 54-60.


149. See for the instructions on oil painting collated by De Mayerne (1620-46); see Graaf (1958), p. 143, 104, 106, 110, 118-124, 248, 254-258, and the studio manual *Portraits and Portraits au nom de deux annes* (1622); De Mayerne (1623-46), ff. 79r.-82v, 108r.-111r. De Mayerne noted down just one instruction on using indigo in top paint-layers by the portrait painter Paulus Van Somer (c. 1576-1621) who was born in Antwerp and lived several years in Amsterdam before he went to London in 1606; see Graaf (1958), p. 148: 'Indigo s'est à la braise, mais il mort sans le vertigo. On en faut en biais aux bains.' However, also Van Somer warned that indigo faded. Indigo is not even mentioned in most printed instructions on oil painting, such as those by Van Mander (1604'-11), Nunez (1613), Biens (1635) and Pacheco (written before 1638, published 1649).

150. *Essai and compendious* (c. 1621-26), f. 3.

151. LeBrun (1635); see Mennifield (1849; 1967), vol. 2, p. 817: 'L'inde devient toute blâquée si elle est mise au soleil, la mine toute de même si elle est à l'eau; de même pour l'étain.' Mayerne (1620-46); see Graaf (1958) p. 143: 'L'inde ne vaudra rien à la braise, & la blanche i'toumeront,' and p. 148 (see note 149). De Mayerne also noted the following remark by 'M. Adam Poinsent Flamand,' see Mayerne (1620-46); see Berger (1901, 1973) p. 298: 'Le maçonat & indigo a laude s'annauisuenc & en tretel dehors si le tableau est exposé au soleil, elles sont en dedans il faut fort peu cunne.' As described in chapter II, section I, paintings were regularly set in sunlight in order to bleach yellowed and darkened oil and varnish layers.

152. For Pacheco; see note 138. Mayerne (1620-46); see Graaf (1958), p. 173: 'Ce qu'elle [the fading of indigo] ne disapperoit, c'est dans peu d'Heures ou solle.'

153. LeBrun (1635), see note 151. Eikelsenburg warned for contact with water as well; see note 141.
Smith (1692) and Eikelenberg warned of indigo turning green or grey of and De La Fontaine (1679) wrote that a mixture of indigo and lead-white, changes and turns black. Due to the oil capacity of indigo, which is approximately 90 to 100 parts oil to 100 parts indigo, yellowing of the oil medium in time gives the paint a greyish and greenish tinge. Areas where indigo is mixed with little or no lead-white can even become dark black.

Images executed in water-based media, such as book illuminations, were generally exposed to less sunlight and hence did not fade rapidly. This would explain why the old literature assessed the use of indigo in water-based media more positively. However, historical texts indicate that differences in appreciation of indigo were also caused by the fact that painters had experienced that fading of the blue took place much faster in an oil than in water-based media. Pacheco, who had advised against indigo's use in oil, insisted: In [glue] tempora, however, it lasts better. Felibien warned in his Des principes de l'architecture de la sculpture et de la peinture (1676) that indigo caused many problems when applied in an oil medium, but that the pigment could be used with success in [glue or egg] tempora paint (Fig. 39). De La Hire claimed that indigo was a marvellous colour in tempura technique while it faded rapidly in oil paint. Artificial light ageing of indigo paint reconstructions, that will be discussed in section X, have confirmed the correctness of the old observations. Fading proceeded significantly faster when indigo was mixed with oil rather than egg white, glue- or gum-water (Fig. 40).

By the second half of the 17th century the negative assessment of oil based indigo paint had almost ceased. By then many authors believed that indigo was a suitable pigment for oil technique. In the early 18th century, Croker stated in Der wohl anführende Malher. It is in oil paint a very useful pigment. According to these authors, painters need only assure that their indigo paint was not exposed to bright sunlight.

These texts suggest the increased acceptance of indigo was due to the ability of painters to obtain more colourfast results with the pigment. Artists had, as will be described later, learned to adjust

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134. Eikelenberg (1679-1704), p. 666: 'Om de versterimg der indigo die in de afzij verfzij genoeg is gebracht word te beletten, hakte men dezelfde in een witte of tarwentebruins bol of wat langerzij zoude worden brent is geczelijc geschild, i bruin gestift dan aan de bunden en de indigo wrijftmen dan met liijnol Na dat dit gedaan is, maakt men een bol of broek of almen een in een pot met water enige uren kookt. Als zij dus wel gekookt en gehaakt is, doet men een jaar of anderhalf staan, of wel langer, wijl hij ouder wordt. Sinds men descroer verdobt en miste, is gebleken, dat de olie een blijder en beter wordt, maar met het olie in de blootte gepoort is. Als men nu dezelfde verschuult en het moesten met miste of melt af wrijft, en met smaak verenigd, gietij eene schone bloz in de blootte, en verfzijt niet, gelyk de groen die dus met het indigo, en het blootte met zwart vermengd, of ige groen gelyk wrijft word.' Smith (1692), p. 69: 'Indigo turns green in time, and should be clearly us'd in dead-colouring, but if heyled, or kept longer some years it will hold better.' De La Fontaine (1679), p. 10: 'Auteur bloz van eenne laagde liijnol in eenne bunden ertijt, heult met siette, of zij allemaal worden gaar, ahen de olie alleen noch niet daar.'

155. See note 138.

156. Felibien (1676, 1666), p. 299: 'L'on employe aussi de l'indigo, soit a faire des Cielz, soit a faire des Draperies. Quand il est bien employe il se conserve longtemps bien. Il n'y faut mettre trop d'oil, mais le couleur un peu brun parce qu'il se change. L'on l'ert a delerempe avec assez de sucre, etant bien a faire des verts.'

157. Hir (1709, 1730), p. 128: 'Cette couleur est excellente pour la peinture a detempe... On pourroit se servir de l'indigo a lait, & elle a beaucoup de corps avec la blanc: mais elle se declaing en reduant & perd la plus grande partie de sa force, s'est pourquoy on en use pas a moins que ce soit pour faire quelques draperies que l'on aise d'extremement par-dessus.'

158. Croker (1719); see Schießl (1982), p. 112: 'Eerst in de Oel-Farben zien een nutrijfelijke Farbe... Indigo is geen bestandige Farbe op Saken, in der sonne steen zullen, den er verkleert seine Farbe.' See also Palmolino (1715-24, 1795-97), vol. 2, p. 57: 'El abad le is corno el oil justamente pur a un cantidad si tiene abad, porque si es mucho el oil se lesbran.' Authors rating indigo among the standard pigments for oil painting include Hoogstraten (1678), p. 221, Tractado (c. 1650); see Sanz (1978), pp. 252, 266; Smith (1692), p. 69; Beurs (1692), p. 16, Eikelenberg (1679-1704), p. 785; Collection for mixtures (c. 1603), ff.109 v, 110 r, 111 v; Richet (17th C); see Merrifield (1849, 1967), vol. 2, p. 652, mentions mixtures with indigo and lead-white, or with red lake or verdigris that seem to relate to oil painting technique.
their painting process to extend the life of the blue colour. In addition, painters had discovered ways to improve the stability of indigo oil paint by pre-treatment prior to grinding in oil. It was common knowledge that the light fastness of indigo oil paint was determined by the quality of the pigment. In the manuscript *Modo da tener nel dipinger* (2nd half 17th century), the Italian painter Volpato warned: The last test for the colours is to place the pictures in the sun; if they are not injured they are good, but if the colours fade they are bad. Consequently, when pursuing a durable oil painting, painters only used indigo lumps of the purest quality. In the course of the 17th century, more and more painters must have noticed that even the best quality indigo available contained a too high amount of impurity. Contemporary texts recommend painters purify or calcine the indigo lumps in their workshop in order to make it more permanent when used with oil. These authors explicitly state that paint made with purified indigo was much more colourfast than paint made with un-treated pigment. For example Eikelenberg concluded that: This indigo gives a beautiful blue that does not die while the one that is not prepared becomes similar to lead-white mixed with black or grey. The earliest known instructions for the purification and improvement of lumps of tropical indigo were written down by De Mayerne in 1642 but only in the course of the second half of the century is the procedure commonly described. This does not mean, however, that before that time the practice was unfamiliar to painters. Methods can have circulated in the painters' workshops long before they were written down, or earlier instructions may simply not have come down to us. It is likely that in the early 17th century Frans Hals already used the purifying process when applying the pigment in top paint layers. In his indigo paints regularly a high amount of aluminium compounds was identified. This may well derive from alum, since this substance, as will discussed below, was used to improve the permanence of indigo.

An experiment by the late 17th century painter Simon Eikelenberg demonstrates the extent to which the colour-fastness of indigo was increased by pre-treatment. Eikelenberg was highly interested in science and had an enormous interest in testing and improving painting materials. He was
intrigued by indigo purification processes and wrote down many procedures from books and individuals. He also developed his own method and tested how this procedure improved and by this same preparation protected [indigo] against discoloration. In January 1704, he ground his purified indigo with linseed oil and mixed it with two different amounts of lead-white paint (see Painters’ methods Fig. 12). He applied each mixture to two prepared papers. One series he preserved in his workshop and the other he hung on the Southeast side of his house: where sun, wind, rain and snow, could always get there... waiting what time would show. When he compared the two series after almost four months, he noticed that the indigo paint that had been subjected to the elements had hardly faded but only become slightly more mat at its surface. This is an important difference compared to earlier observations of total fading in a few days or hours.\footnote{\textit{165}}

\textbf{Recipes for purification of tropical indigo}

The earliest recipes for improving the colour-fastness of tropical indigo derived from older methods for preparing vat flower. In 1642, De Mayernë noted an instruction for mixing indigo and calcified rock alum with nut oil to make paint.\footnote{\textit{164}} This practice that would make the colours more intense (orientales) so that they never die when exposed to sun, rain or wind is rather similar to those recipes recommending sprinkling alum water on vat flower. Perhaps Hals employed this technique in his 1627 St. George portrait as in the paint layer translucent aluminium-containing particles are present and indigo agglomerates contain a high relative amount of aluminium (Fig. 15e, f). Another recipe in the \textit{De Mayernë manuscript} for indigo that will never die also corresponds to older procedures. An earthenware vessel filled with strong vinegar and lumps of Guatemala indigo were place in the sun for two or three days. The vinegar that takes away all the grease and dirt was poured off and the indigo was dried. According to this recipe urine could also be used but then soaking would take twice as long.\footnote{\textit{165}} Later instructions no longer recommend soaking indigo but always advise boiling the lumps in urine or distilled vinegar.\footnote{\textit{166}} Boiling would certainly hasten the removal of impurities. Alum water was also recommended to extract water-soluble impurities in the lumps.\footnote{\textit{167}} Other recipes simply advised using fresh water. The following instruction was received from an anonymous author in 1691 by the still-life painter Jacob Bogdani (i.e. 1660-1724).\footnote{\textit{168}}

\begin{quote}
‘He told me to make indigo bold. He says some boil indigo in piss or in vinegar. He boil it in fair water on the fire till it extracts a red tincture so pours away the red water & boil it with fresh water ‘till there will come no more red tincture, for he says it is the red tincture that keeps it from drying.’
\end{quote}

\footnote{\textit{163}} We have to take into account, though, that Eikelenberg’s mixtures of indigo and lead-white – 1:1, 1:3 – must have been strongly coloured. He might have had a different experience of the light fastness of his purified indigo if he had mixed this with more lead white.

\footnote{\textit{164}} Mayernë (1620-46); see Graaf (1958, p. 173); I.I.H (1772-84) p. 149 recommends boiling indigo in vinegar and adding alum afterwards.

\footnote{\textit{165}} Mayernë (1620-46); see Graaf (1958, p. 173). A recipe in the Rosse (17th C.); see Merrifield (1849; 1967), vol. 2, p. 677, seems to be based on recipes for preparation of vat flower as well: ‘Come s’accomodi l’indigo che in opera resili bella: Mischnà ben con acqua semplice, poi mettila a sorrere sopra carta dell’ombra, e poi torna a macerare con aceto, e torna a rossàr, c quando si vol adoperare così polvere mischiana con bina con mani’che si potrà, e così resterà bella in opera macerando prana la bustà un poco tempo poi tempererà l’indigo.’


\footnote{\textit{167}} For example by: Palomino (1715-24; 1795-97), pp. 67-68.

\footnote{\textit{168}} Bogdani (1691); see Raini (1993), p. 92.
Reconstructions confirmed that boiling indigo in water liberates a reddish tincture (Fig. 41; Appendix). Using HPLC, this liquid was found to contain a high percentage of an unknown orange component also found in small amount within the indigo pigment. Possibly, this component dries more slowly than indigotin, implying that Bogdani’s method would make indigo oil paint dry quicker.

In order to obtain a more effective purification, some painters experimented with grinding indigo lumps before exposing them to a boiling liquid. However, finely dispersed indigo would take days to settle to the bottom of the cauldron, and only then could the liquid be poured off. Most painters, therefore, would probably have stuck to boiling indigo in small lumps. The drawback of this was that, as Eikelenberg explained in 1704, the liquid would not penetrate the centre of the lump. Eikelenberg found it more efficient to grind a lump of indigo to the size of a small walnut with linseed oil before boiling. Reconstructions indicate that the advantage of making the indigo into a paint before boiling is that although the indigo dye is dispersed during boiling, on cooling, the dye coagulates and the liquid can easily be poured off. Other painters used this process as well, since Beurs (1692), Sprong (1738) and the Spanish painter Palominó (1715-24) describe this procedure. Palominó advised to change the water three times, so that dirt was no longer extracted.

Comparative analysis was carried out with oil paints made of 1. un-treated natural indigo, 2. pulverised natural indigo that has been boiled in distilled water and 3. oil paint made of natural indigo that had been boiled in distilled water (Appendix). When studied with the polarising microscope and SEM-EDX, it was evident that boiling removed only very small quantities of inorganic material. Certainly, the procedure was not developed for this purpose since, at the time, indigo lumps that contained high amounts of inorganic impurities were not considered suitable in easel painting. HPLC comparisons of the ratio between indigotin, indirubin, isatin and three other orange and yellow components in the above indigo types indicated that, except indirubin, the percentage of all minor components was considerably lower in the boiled indigo pigments than in the un-treated indigo (Fig. 42). Apparently, these compounds had been removed to a great extent, by boiling the indigo in water. That the percentage of indigotin increases by boiling is also evident when paints of un-treated and

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169. Analysis by Maarten van Bommel (ICN). HPLC also identified in the liquid a large amount of an unknown yellow component that had not been detected in the indigo pigment. This is possibly a breakdown product of isatin, or one of the other orange-red or yellow components present in the pure pigment. HPLC analysis of an indigo pigment that had been boiled indicated that these minor components were present in much lower quantities than in the untreated pigment (Fig. 42).

170. When powdered indigo is boiled, recipes advise to reduce the liquid by evaporation, which results in a less pure product than when the liquid is poured off. See, for example, Emery (1676; 1694), vol. 1, pp. 274-75; T.L.H. (1772-84), pp. 29, 152.

171. Eikelenberg (1679-1704), pp. 783-84: ’Eerst en Indigo 1704 Dins. 5 december, aanscherende de versusieled heerlijckheden van ths indigo. 666, en 724’ besloven en gedooende dat het regt, daarr met die mede kwakken. ’t zij dus py, acryg, of water in de kookte, te wieren als wij met zijt gewonnen is, net hoe en ’t binnent van de kook doordrongt, herelijck dat de volgende wijze. Eerst wreef ik die redelijk fijn met lijnolij, doe kookte ik ’t gewon brokje omtrent een okerkrig groot beschreven en geloizeerde dat Ixt iwgf, daar men die mede kookte, ’t dün pis, aëlj, of water in de kookselah na de ruek, maar %j was meest droog, dog nog alk %ijn oly fanfan de brok doordringt, benijde die op de wlgende wij^e. Eerst wreef ik die redelijk fijn met lijnolij, doe kookte ik ’t gewon brokje omtrent een okerkrig groot beschreven en geloizeerde dat Ixt iwgf, daar men die mede kookte, ’t %j was meest droog, dog noch alk %ijn oly fanfan de brok doordringt, benijde die op de wlgende wij^e. Eerst wreef ik die redelijk fijn met lijnolij, doe kookte ik ’t gewon brokje omtrent een okerkrig groot beschreven en geloizeerde dat Ixt iwgf, daar men die mede kookte, ’t %j was meest droog, dog noch alk %ijn oly fanfan de brok doordringt, benijde die op de wlgende wij^e. Eerst wreef ik die redelijk fijn met lijnolij, doe kookte ik ’t gewon brokje omtrent een okerkrig groot beschreven en geloizeerde dat Ixt iwgf, daar men die mede kookte, ’t %j was meest droog, dog noch alk %ijn oly fanfan de brok doordringt, benijde die op de wlgende wij^e. Eerst wreef ik die redelijk fijn met lijnolij, doe kookte ik ’t gewon brokje omtrent een okerkrig groot beschreven en geloizeerde dat Ixt iwgf, daar men die mede kookte, ’t %j was meest droog, dog noch alk %ijn oly fanfan de brok doording
boiled indigo are extended with the same quantity of lead-white paint. The paint mixtures with boiled indigo give a much darker blue colour than the one with untreated indigo. The boiled indigo paint (no. 3) also dries considerably faster than paint made of untreated pigment. Once the boiling liquor was poured off, the indigo was often further processed. Several recipes advised spreading the indigo-oil-water mixture on paper and drying the substance in the shade or over a fire or a stove. Palomino recommended wrapping indigo paint, that had not been boiled first, in absorbent paper and to leave it overnight in a pastry-baking oven so that the oil will have hardened and been consumed. Reconstructions show the paper absorbs so much grease and impurities that it, as the sources describe, turns a brown colour. Absorption of impurities must also have been the rationale behind recipes noted down by Bogdani, Palomino and Eikelenberg. They all recommended baking (boiled) indigo paint in bread pastry or baking the paint for some time in a cake wrapped in paper. According to Eikelenberg and Palomino, one could also grind indigo with brandy and set this mixture on fire. Alcohol soluble impurities will burn off with this procedure. Eikelenberg asserted that after all these treatments, the indigo could be used to complete satisfaction. However, he wrote the colour would acquire even greater durability when the pigment was kept in a closed bottle for at least one and a half-years. In fact, Marshall Smith claimed that indigo oil paint had to be buried for eight to ten years! A recipe noted down by Eikelenberg may give a clue about the effect of this treatment. Indigo paint was buried in a covered pot in cow’s dung for some weeks. Subsequently, the white mould formed on the indigo was removed and the pigment could safely be used in oil painting. Apparently, the temperature at least 50°C obtained in dung accelerated ‘the process’ that could take several years under lower temperatures.

174. Eikelenberg (see note 171) pointed out that after boiling, the indigo, although apparently dry, still contained some linseed oil since he needed for processing this indigo into paint not half as much oil as with untreated indigo. Reconstructions confirm this observation.  

175. Emsney (1676; 1684), p. 275; Eikelenberg (1679-1704), pp. 742, 664 (see note 166); Sproing (1738), p. 57; L. vers. remissae (1767), p. 103; 1.3.11 (1772-84), p.152; Reste (17th C); see note 165.  


177. Bogdani (1691); see Rajnai (1993), p. 92; Palomino (1715-24; 1795-97), vol. 2, p. 67; Eikelenberg (1679-1704), p. 666 (see note 154). Eikelenberg pointed out that after this procedure, the indigo, although apparently dry, still contained some linseed oil. Indeed, my experiments show that processing this indigo into paint requires, as Eikelenberg described, not even half as much oil as with untreated indigo.  

178. Eikelenberg (1679-1704), p. 664 (see note 166); Palomino (1715-24; 1795-97), vol. 2, pp. 67-68.  

179. Smith (1692), p. 69, 72.  


181. Personal communication: Hans Laagland who made experiments making lead-white using different types of dung.
Fig. 42

HPLC analysis of proportions of indigotin and other coloured components (calculated at 254 nm) in un-treated and two types of purified natural indigo.

<table>
<thead>
<tr>
<th>Compounds (retention time in min)</th>
<th>1. Un-treated indigo</th>
<th>2. Indigo boiled in water</th>
<th>3. Indigo oil paint: boiled in water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigotin (27.38)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Indirubin (28.32)</td>
<td>1.6</td>
<td>6.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Isatin (7.8)</td>
<td>28.8</td>
<td>14.3</td>
<td>10.0</td>
</tr>
<tr>
<td>Unknown orange compound (25.55)</td>
<td>18.8</td>
<td>7.7</td>
<td>7.0</td>
</tr>
<tr>
<td>Unknown yellow compound, probably a flavonoid (21.7)</td>
<td>13.4</td>
<td>5.8</td>
<td>10.6</td>
</tr>
<tr>
<td>Unknown yellow compound, probably a flavonoid (20.97)</td>
<td>5.3</td>
<td>0.8</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Purification of indigo was not always done in the painters' workshop. At least in the Northern Netherlands, the time-consuming procedure was also carried out in retail trade. The inventory made up in 1667 from the shop of Cornelis van Bolenbeek in Rotterdam, mentions in addition to flat and round indigo 3 pound minus 2 lost heavy weight distilled indigo. This specification suggests that this indigo was treated with distilled vinegar or strong alcoholic liquor. The extra process lead to a pigment that cost five guilders a pound, and was the most expensive indigo available in the shop. Around 1661, the painter Jacob Bherens who worked in Breda, paid almost the same price. His handbook notes that fried indigo cost 5 to 6 guilders a pound.

The diverse and numerous recipes for purifying indigo indicates how much experimentation was undertaken in the 17th century. There was no best or universally accepted method. Presumably, the procedure for purifying indigo only started to develop when tropical indigo became easily available. Only then was it worth the trouble to make indigo more suitable for oil painting. Given the positive assessment of indigo reflected in late 17th century texts, the development of effective processing techniques was successful.

Light ageing tests with synthetic and natural types of indigo

In order to investigate the light fastness of indigo pigments of varying purity in oil, paint reconstructions were made with synthetic indigo and two types of natural indigo (Appendix). The indigo oil paints were used as such and mixed with lead-white. All paints were subjected to artificial light ageing (Appendix). It became apparent that the light fastness of indigo oil paint is greatly determined by the purity of the pigment used. Paints made with synthetic indigo, which is almost pure indigotin, when used as a pure pigment and when mixed with lead-white exhibit a very good light stability (Plate 39a). In contrast, all paints made of natural indigo fade considerably, especially when lead-white is added (Plate 39b). Fading is strongest in indigo paint that contains the highest amount of inorganic impurities (Plate 39c). These differences in light fastness are partly due to the relative concentration of indigotin in the various indigo samples. When the colorant is present in a lower

182. See note 135.

183. Bherens (1661), p. 22b: 'Indigo [sign of pound] 3 à 6 gij (gebruiken) met spruiken.' That Bherens was active in Breda is evident from an introduction (in the beginning of the manuscript) to the persons mentioned in the manuscript.
concentration the colour saturation is less and discoloration is observed sooner. However, in the experiment in which synthetic indigo is mixed with lead-white to lower the concentration of indigotin, the indigo paint is remarkably stable. This suggests that impurities in the natural indigo are accelerating the degradation of indigotin. Another explanation would be to assume that the physical form of the natural and synthetic indigo aggregates used as pigment in the paint differs. In that case the synthetic indigo would be more finely divided in more compact aggregates which are less accessible for degrading agents. The production method of indigo from plants could easily retain more inorganic counter ions which would affect the physical structure of the pigment particles.

The degradation rate and the chemical nature of the degradation products of synthetic and natural indigo have been investigated recently in light ageing experiments of indigo saturated dichloromethane solutions (DCM).\textsuperscript{184} DCM provides a strongly oxidising environment in which the photochemical degradation of indigotin is accelerated. Various types of indigo pigments were 'dissolved' in this liquid until saturation, as determined with visible spectroscopy.\textsuperscript{185} During light ageing optical and chemical changes were monitored. It was found that similar degradation products of indigotin were formed from synthetic and natural indigo during ageing in about the same relative percentages.\textsuperscript{186} It was concluded that the chemical pathways of the degradation of indigo do not differ substantially between the various types of indigo. However, the initial rate of degradation does differ. The degradation of natural indigo proceeds faster than synthetic indigo and there are also differences between various indigo's derived from natural sources. An explanation for this is that organic impurities in the indigo pigments, which have dissolved in the DCM, may act as catalysts in the degradation of indigo.\textsuperscript{187} However, in view of the particulate nature of indigo in solution, it seems more likely that the physical form of indigo can explain the differences in the initial rates of degradation.

These experiments demonstrate that the composition of the indigo pigment i.e. its chemical purity and its particulate state play a role in the rate of degradation of indigo. For the indigo oil paint in traditional paintings, this implies that the colour-fastness can differ considerably, due to differences in the chemical and physical composition of the indigo pigment preparation. The enthusiastic evaluation of purified indigo in documentary sources suggest that the old masters' purifying methods retarded the breakdown of indigotin in a paint layer. The old prescriptions to purify indigo would have removed most of the undesirable organic impurities from the pigment preparation leading to a more concentrated pigment compared to the unrefined preparation. Preparation methods which involve some form of heating of the indigo pigment (such as boiling or baking) will also have an influence on the physical state of the resulting indigo pigment. We can now deduce that recipes which prescribe this approach resulted in an indigo that could withstand the conditions in oil paint more effectively.

Pure and impure indigo in easel paintings

SEM-EDX analysis of indigo agglomerates in old master paintings identified great differences in the composition of the indigo pigment used by the various painters.\textsuperscript{188} Sometimes, even in paintings

\begin{itemize}
\item \textsuperscript{184} Novotna et al. (in preparation); Brink et al. (1999).
\item \textsuperscript{185} Although the indigo appears to dissolve in the DCM solution, most of the indigo will still be present in the DCM as small aggregates.
\item \textsuperscript{186} Novotna et al. (in preparation).
\item \textsuperscript{187} Brink et al. (1999).
\item \textsuperscript{188} SEM-EDX analysis of cross-sections of paint reconstructions made from various types of natural indigo pigments in oil (used as such and mixed with lead-white) indicated that the spectra obtained from the larger indigo agglomerates within the paint-layers matches closely those spectra obtained from the pure pigments. The amount of silicon, aluminium, potassium, calcium and iron identified in indigo
\end{itemize}
concurrently painted by one artist great differences were found. The indigo Frans Hals used in his 1627 portrait of the St. Adrian company, contains little inorganic material; chalk, aluminum, potassium, and silicon are present as traces (Fig. 16g). In the St. George portrait, painted in the same year, these elements are present in much higher percentages (Fig. 15f). Calcium, phosphorus and potassium compounds are detected in especially high amounts. Perhaps the presence of the first two components indicates that wood indigo was used. Indigo agglomerates also contain a high relative amount of aluminum and in the paint there are particles high in aluminum content. As described, this may derive from mixing calcified rock alum into indigo paint. Today, Hals’ two portraits show a striking difference in colour preservation of the blue sashes and patterns. In the St. George portrait, the indigo paint has severely faded to a pale grey-blue (Plate 15a, b), while in the St. Adrian civic guard portrait, the colour of the sashes still exhibits a vivid blue (Plate 16a, b). As will be described later, differences in painting technique as well as environmental conditions, may explain the difference in colour preservation in the two paintings. However, the discrepancy seems rather great to be due to this alone. Maybe, the more pure indigo paint used for the St. Adrian portrait contributed to the relative good preservation of its blue colour.

VII. Opinion about indigo’s light fastness and painting technique

‘Traditional’ techniques: indigo restricted to shadow areas and under paint layers

From the 16th century onward, authors recommend indigo for strengthening shadows of passages painted with other blue pigments. For example, according to an instruction in the Dr Mayerne manuscript: ‘The blue work is made with small or azurite from light to dark while adding a little bit of indigo or coal black to deepen it when it is not dark enough.’ With ultramarine, azurite, blue verditer and smalt it was difficult to achieve a dark blue that covered in one single layer underlying preparatory layers. In order to obtain the tones that painters wanted in shadows, the addition of indigo could be useful. Likewise, traditional instructions considered indigo useful as an addition to other relatively transparent pigments, such as red lake. In 17th century paintings especially there are numerous examples of this technique. Rubens’ Elevation of the cross (1610-11, Antwerp Cathedral), indigo was added to an ultramarine glaze that was superimposed over an opaque layer of lead-white, ultramarine and indigo.

agglomerates in old paint-layers may, therefore, be indicative of the purity of the indigo pigment preparation used. However, ascribing meaning to the presence of inorganic components must be done carefully. Painters sometimes added glass or alum to their indigo paints; substances that contain silicon, potassium or aluminum. Because the radiation penetrates the light material of the indigo particle, one must take the composition of the particle’s surrounding into account as well. In addition, a number of particles must be examined since the distribution of inorganic material is anything but homogenous.

189. Although we may not exclude that Hals had added some bone white into his indigo paint; see note 62.

190. Mayerne (1620-46). see Berger (1901; 1973) p. 282: ‘Le labeur d’oeuvr a fait de smalt ou de azur de charou il brun en y alliant un peu d’inde ou de charbon de sou... pour le refroidir, s’I ne est assez brun.’ Other texts recommending the use of indigo in shadow areas of ultramarine, small or azurite blue drapery include: Collection for mixtures (c.1600), ff.110r, 111v: ‘Blau. Azur and deepned with Indiblau or lake & heightened with white.’ Bherens (1661), p. 240: ‘Blau. Eerst met small angelyght. Indigo en small grijshalwaer, small en wit gelengt en daerna alt wel droog er NB. Eerst met smallh net gemaakt, het drogge, en da met ultramarine, no admeten gelaercr.’ Pakranen (1715-24; 1793-97), vol. 2, p. 68; Cröker (1719); see Schell (1982), pp. 112, 114. Griner pp. 106-09, also advises indigo paint to strengthen shadow areas of passages made with malachite or verdigris.

191. Goeghebeur et al. (1992), p. 133. A similar build-up was identified in Rubens’ Descent from the cross (1612-14). In this painting indigo mixed with several other pigments was used in the landscape; see Coremans & Thissen (1962). Anthony van Dyck painted the shadows of the ultramarine blue cloth of Charity, National Gallery London, with indigo. In his The Bathers children, in the same collection, Van Dyck achieved the refined effect of the background curtain by applying glazes of red lake, indigo mixed with red lake and pure indigo, over orange red undercolours. see Roy (1997), pp. 63, 66.
As described in chapter II, technical treatises frequently advised restricting pigments that were less colourfast or had a less bright colour to the dead-colouring. Here, these pigments could be of great use since they were inexpensive, had great tinting strength, hiding power or were easy to manipulate. Indigo was a typically considered suitable for underpainting. De Laressé advised in his *Groot schilderboek* (1707) to underpaint blue areas with indigo, since preparatory layers did not require a painter to use fine and costly paints but common ones so long as they have body and cover well.292 Until the end of the 17th century, many authors also explicitly advised limiting indigo’s use to underpainting because of its fugitive character. The treatise *The art of painting in oyle by the life* (1664) advised: ‘for you must glaze over anything where in you use... indico, or else they will spoil all.’ Wilhelm Beurs (1692) was convinced that: if one wants to make indigo and its colour permanent, it is necessary to glaze or finish with ultramarine, as it appears lighter or darker in nature (Fig. 44).293 Painters’ opinions will have been influenced by the fact that discolouration of indigo will not be particularly disturbing when this paint is covered by another layer. Moreover, the upper paint layer functions as a filter and reduces the intensity of light to which the indigo is exposed to and thus would slow its fading. Many 17th methods are based on the above principles. This technique is also used to achieve certain colours. In the treatise *The Art of painting in oyle by the life* recommended: ‘if you make a great blue & use indeed in it glaze it over with lake, and fait oyle & it will be a purple garment.’294 There are also various instructions for using indigo as the preparatory layer for ultramarine, azurite or smalt paint, used pure or mixed with lead-white.

Examination of paintings has indicated that the above formulas reflect a long tradition in both tempera and oil technique. Many painters used indigo deadcolours for azurite, smalt and red lake layers.295 During the 17th century in particular, the combination of indigo under ultramarine seems to have been widely used. In his *Adoration of the magi*, Bloemaert underpainted the blue cloth of Mary directly on the beige coloured ground with a thin (6-8 μm) layer of indigo and lead-white (Fig. 45). Paint cross-sections indicate that modelling was rendered with strong tonal contrast, using almost pure lead-white for light areas and adding a red (lake?) pigment for the forms in shadow.296 In the

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192. De Laressé (1707), vol. 1, p. 333: ‘Toch deze gronden zal men geen fijn en kostelijk verouwen opleggen, maar gemeene, als zij wel vloei en en wel dekken. Tot het blauw zal men neemen indigo en wit.’ Of limning in oyle colours (c. 1650); see Hardie (1919), p. 94: ‘To make a fake Blew. Blew of India is to make a fake ground for a Blew and much be ground with Oyle.’


195. In late 14th-century oil paintings in Walcourt (Belgium) azurite and lead-white drapery is underpainted with indigo and lead-white; see Colman (1960), p. 41. 15th-century Italian, mostly Venetian, tempera paintings show a similar build-up. Indigo paint is also used under glazes of pure ultramarine or semi-opaque layers of ultramarine and lead-white; personal communication Marika Spring, National Gallery, London; Dunkerton, *et al.* (1987), pp. 22-27; Smith *et al.* (1981). In oil technique the combination of indigo under ultramarine was used, for example, by Paolo Veronese for the drapery of Christ in his *Christ addressing a kneeling woman* in the National Gallery, London; Penny & Spring (1995), pp. 7-8. In Rubens’ *Transfiguration* an indigo underpaint was used under a copper carbonate blue that was used pure and mixed with lead-white; Roux & Djoux (1980), p. 94. For the bluish green satin tressure and cloak in his portrait of the two princes, Van Dyck applied scumbles of azurite and some indigo over indigo underlayers: Roy (1999), p. 81. Indigo was used in 1624 by Abraham Bloemaert (1566-1651) for small paint used for the sky in his *Adoration of the magi* in the Central Museum, Utrecht (Fig. 45). Smalt was mixed with little lead-white and a lot of binding medium, which today has darkened severely.

196. The painting was investigated in 1977 by Karin Groot (ICG) using light microscopy, chemical analysis and SEM-EDX. For the present study indigo samples were re-examined under the microscope and additional SEM-EDX analysis was carried out.

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142
subsequent ultramarine layer, Bloemaert rendered light and shade in greater detail. In the highlights lead-white was added to the ultramarine, middle tones were glazed thinly with ultramarine and chalk, while several glazes were applied to obtain the darkest blue shades. High quantities of silicates present in the ultramarine suggest it was an inferior grade (Fig. 45c, d). The paint was applied with much binding medium and brushed out so thinly, that the indigo layer is visible through the brush marks; an effect that has been exacerbated by abrasive cleaning procedures in the past (Fig. 45b). When compared to smoother surface of the rest of the drapery the obvious brush marks in the blue suggest that the ultramarine was rather difficult to spread.\(^{197}\)

Pieter de Ring (1615-60) painted the deep blue velvet-like tablecloth in his *Still-life with golden goblet* (Rijksmuseum, Amsterdam) partially following another procedure (Fig. 27).\(^{198}\) As in Bloemaert's painting, there is a rather thin layer of indigo undercolours with strong tonal contrast between light and shade. However, De Ring's use of ultramarine differs greatly from Bloemaert's. Light- and middle tones were rendered with a rather thick layer (c.36\(\mu\)m) of ultramarine and lead-white. For strong highlights characteristic of velvet cloth, touches of pure lead-white were applied in the wet paint layer. For the shadow tones De Ring used a layer of indigo, ultramarine and some lead-white. A glaze of apparently good quality ultramarine (only small quantities of silicates are present) mixed with a little lead-white was applied over the whole drapery. Finally, shadows were deepened with glazes of good quality ultramarine.

Examination of contemporary French paintings in the Louvre Museum, Paris, revealed a comparable contrast rich underpainting but with yet another use of the ultramarine.\(^{199}\) For the blue robe of the Virgin in Laurent de la Hyre's (1606-56) *Apparition de Jésus aux trois Maires*, ultramarine was mixed with much lead-white and applied as a semi-opaque layer (Fig. 46).\(^{200}\) As visible in a few passages where the paint was brushed out rather thinly, De La Hyre rendered in his indigo underpaint the folds of the drapery with a wide range of nuances using strong light effects. His technique was described some decades later by his son, the painter Philippe De La Hire (or De La Hyre). He stated in a lecture held in 1709 (published as *Traité de la pratique de la peinture in 1730*): *one paints the underlayer particularly light and even pure white for the strongest highlights and one paints the shadows as usual.*\(^{201}\) The layer of ultramarine

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197. Jacob Bherens advised oiling out the paint surface with nut oil before glazing indigo dead-colours with ultramarine; see note 190. When the paint surface is slightly moistened with oil, the subsequent glaze can be spread out more easily into an even layer without leaving brushmarks. As described in chapter II, Painters sometimes allowed oiling out layers to dry before continuing their work. In this case, thin layers of binding medium may be recognised in paint cross-sections by their strong fluorescence. In samples from Bloemaert's painting none of such layers were visible. Possibly, Bloemaert worked in a wet binding medium layer although the distinct brush marks make it more conceivable that he simply did not apply any.

198. See note 83.

199. Indigo was identified in the Laboratoire de Recherche des Musées de France; see notes 91, 92 and verbal communication: E. Martin (Laboratoire de Recherche des Musées de France). For the present study, paintings were examined in the Louvre museum by the author and Ella Hendriks, Head of Conservation at the Van Gogh museum Amsterdam. I am grateful for her valuable comments.

200. De la Hyre used a stiff paint for his undercolours so that the relief of the brushstrokes contributed to a convincing modelling of the drapery. Today the relief is flattened, presumably by the application of a wax-resin lining. The blue cloth was partially painted on top of a red drapery. The red colour is visible through the brush marks. In these passages the paint film exhibits many drying cracks follow the direction of the brush stroke.

201. Hure (1709; 1730), p. 683: *'on peut le dessous fort clair, et l'on va même jusqu'au blanc pour les plus grands rebuts, et pour les bruns on le paint à l'ordinaire.'* Similar instructions can be found in sources from other countries. For example, the Spanish painter Hidalgo (1653; 1665), p. 8, recommended: *'leuyages de soleil, y blanc, les clairs bien clairs, si le queren hermoso.'*
subsequently applied by Laurent de la Hyre was rather deep blue in the light passages while relatively pale in the shadow areas, so that the strong tonal contrast in the underpaint was moderated. Philippe de la Champaigne (1602-74) in his *La Vierge de douleur au pied de la croix*, softened the sharp under modelling of the Virgin’s mantle with a rather uniform tint of ultramarine and lead-white that was applied very thinly (Fig. 34). This technique resembles a method with an indigo underpaint that the English painter Daniel King (d. 1664?) noted down from Cornelis Johnson: ‘*All the folds and shadows to be neatly and perfectly finished. And when dry glaze it over with ultramarine and fair white.*’ As the ‘glaze’ of ultramarine contained ‘fair’ (good quality) lead-white, it must have been used as an opaque scumble. Nicolas Tournier (1590-1639) used indigo underpaint with little contrast between light and middle tones but with sudden dark shadows for the blue robe of the Virgin in his *Le Christ en croix*, (Fig. 47). Above this layer, paint of ultramarine and lead-white was scumbled to make the highlights; for the mid tones this same blue was applied opaque and in the shadows a pure ultramarine glaze was employed. Likewise in the blue drapery of Bloemaert’s painting, brush marks are clearly visible while this is not the case in other coloured drapery in the painting.

17th and 18th century sources always stress the durable property of using ultramarine over less permanent blue pigments. The *excellency of pen and penell* (1668) asserted ‘glaze it [paint layer of indigo and lead-white] with ultramarine, which will never fade.’ U. Sprong stated in his *Kabinet der verf-stoffen* (1738):

> Ultramarine or overseas blue is, because of its high price not used as much by painters as the other paints. The painters glaze over underpaint, made with cheaper blue, very thinly with this very ultramarine: this looks beautiful and makes the painting durable, so much (as is said) that it will keep its colour for almost two hundred years."203

Indeed, De Ring’s painting, after more than 350 years, preserves the beautiful blue colour. However, he did not use a ‘very thinly’ applied glaze of ultramarine, as mentioned by Sprong, but a series of opaque and glaze layers with a combined thickness of c. 40-50μm. When ultramarine was used according to Sprong’s instructions, the technique was usually not so permanent. For example, in the thinly (5-20μm) applied medium rich ultramarine layer in Bloemaert’s painting (Fig. 45c, d) the oil has darkened considerably and, due to over cleaning, the blue has become rather worn so today the indigo layer is much more visible than originally. This has resulted in the robe having a greyish and spotty appearance.

In all the French paintings examined, abrasion of the thinly applied ultramarine layer has disturbed the modelling of the drapery. In almost all pale passages of Tournier’s painting the indigo undercolour is exposed (Fig. 47). The greyish colour of this layer makes the light areas optically recede in relation to the middle tones where more thickly applied bright blue ultramarine has been better preserved. The almost black shadows -possibly caused by darkening of the binding medium- contrast sharply.204 In De la Champaigne’s painting the ultramarine layer is so worn that the harsh tonal contrast in the

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202. King (c. 1653-57), 48: ‘*Blue draperies flower etc. are to be made w[i]ith indigo ground in drying gyle and mixt w[i]ith smalt and white. All the folds and shadows to be neatly and perfectly finished. And when dry glaze it over with ultramarine and fair white. Mr. Jowne.*’

203. Respectively: *Excellency* (1668), p. 104; Sprong (1738), pp: 29-30: ‘*Den ultramaryn of overzeelsblauw, wordt om haar grote dierte op eer na, van de schilders zoo veel niet gebruukt, als met de andere verfken, maar laatiken 3 grijff al temee met untkwichter blauw geschildert hebben, met deynse denetheyt over dat zeer fruay staat, en een schildery heel bestendig maakt, tot zoore verre (gelyk eenige zeggen) dat 't begyn te honderd jaren zijn oven ryne behouden.*’

204. In some places Tournier has changed the drapery folds with his ultramarine layer. Due to its increased transparency, these repaints are clearly visible and the already disturbed modelling is even less legible.
undercolours is no longer effectively softened. Severely darkened shadow areas increase the impression of randomly applied blue paint (Fig. 34).

'New' technique: indigo used in top paint layers.
In 15th- and 16th-century oil paintings, indigo was rarely used as a top layer. The earliest example is supposedly an altarpiece by Bartlémé d'Eyck (documented at first in 1444 in Aix-en-Provence and active until c. 1470) made in the 1440s for the Cathedral St. Sauveur in Aix-en-Provençe (Fig. 48). In the inner side panels, which depict Mary Magdalenè (Boymans Van Beuningen, Rotterdam) and Christ (Koninklijke Musea voor Schone Kunsten, Brussel), a blue background was painted with indigo and lead-white on top of an almost black paint layer. Also during the first half of 17th century, indigo was mainly restricted to preparatory layers. Although Rubens and Van Dyck occasionally used the pigment in the final paint layers, it was always as a small addition to colours made of other pigments. For their important painting commissions, these painters simply did not risk using the unreliable indigo in prominent paint areas. Frans Hals may have been the first painter who, for a prestigious commission, utilised indigo abundantly in the top paint layers. When he used the pigment in 1627 for the blue sashes in his portraits of the St. George and St. Adrian civic guards, most painters still believed indigo would discolor in a few hours or days. One wonders what could have prompted Hals to experiment with the pigment in these important paintings that were commissioned to decorate the headquarters of the St. George and St. Adrian companies. Hals' choice of indigo may have been influenced by the wish to achieve a most convincing illusion of the silk cloth. There was every good reason for Hals to depict the costumes made of Haarlem textile as splendidly as possible. In the early 17th century, Haarlem had become a pre-eminent textile centre with a flourishing linen, silk-weaving and, to a lesser extent, wool industry. Hals' attention to realistic detail is demonstrated in the damask tablecloth of the 1616 civic guard portrait. Comparison of the motif depicted with actual 17th-century samples of damask has even enabled the maker of the tablecloth to be identified. Seen in this context, the choice of indigo to paint the blue sashes would presumably have added an extra touch of realism, reflecting actual practice in textile dyeing. Even today, Hals' indigo colours are still fairly well preserved. The painter appears to have taken no chances with his choice of pigment and must have known that he would achieve a durable colour with the material.

Hals' trust in indigo paid off. Six years later, in 1633, he chose this pigment for the sashes in his St. Adrian civic guard portrait and again in the 1639 in his St. George civic guard portrait (Fig. 17, 18). Other Haarlem painters now started to utilise indigo in final paint layers as well. Around 1630 a master

205. Bartlémé d'Eyck Christ (reverse of the Jeronmi) panel 152 x 86 cm. Koninklijke Musea voor Schone Kunsten, Brussels, Inv. no. 950. Research on the Mary Magdalenè was carried out in 1975 by Karijn Groen (ICN) and in 1994 by J.R. van Asperen de Boer. For the present study samples were re-examined under the light microscope and additional SEM-EDX analysis was carried out. Binding medium analysis (using DTMS) was performed on an un-imbedded paint sample kept in the collection of Van Asperen de Boer. One new sample was taken from the blue background of Mary Magdalenè. I am grateful to Jeroen Giltay, Curator Boymans van Beuningen for allowing sampling. Stephan Lochner (active in Cologne 1442-51) used indigo for rendering the shadow areas of a greyish blue drapery in an altarpiece. Top layers of indigo were also found in the two 16th-century copies after Hans Holbein's Younger, see note 71.

206. Contemporary descriptions of civic guard portraits show that the ability to correctly render costumes (i.e. the skilful depiction of different cloths) was greatly valued. Van Mander (1604), f. 292v, praised this very aspect in Cornelis Cornelisz. van Haarlem's 1563 portrait in his biography of the Haarlem painter.


208. Hals' sophisticated painting technique seems inseparable from the message it portrayed: that economic prosperity and flourishing trade thrive best under conditions of peace and order symbolised in the painting; Levy-van Halm (1988).
of the Haarlem school used the pigment for blue sashes in another St. Adrian civic guard portrait (Fig. 1). During the 1630’s and 40’s, Jan Miense Molenaar (Fig. 23) Judith Leyster (Fig. 21, 22) and Verspronck (Fig. 2, 20) used indigo paint to depict blue drapery. Indigo was most probably used during the 1630’s by two Amsterdam painters in their civic guard portraits based on Hals’ work. Verspronck utilised indigo mixed with the yellow lake pigment weld (Fig. 2, 19) to render prominent green woollen tablecloths in two Haarlem Regentesse group portraits (dated 1641 and 1642). This combination may have also corresponded to that used for dyeing the cloth depicted. The widespread employment of Hals’ new and unorthodox technique in Haarlem indicates how much authority he must have had with his colleagues. By the middle of the 17th century, painters working in other places started to employ indigo more frequently. Jacob Jordens, who previously had restricted indigo to the deadcolour, in his *Triumph of Frederik Hendrik* (1652) now applied indigo in the upper layer, although still for a drapery of little prominence at the bottom left of the painting (Fig. 49). More extensive use of the pigment is mainly found in works by the younger artists Johannes Vermeer, Peter Lely, Cornelis Johnson and Godfried Schalcken (Fig. 26, 29, 31, 32). In the second half of the 17th century, texts describe the use of indigo in top paint layers more often. The praise indigo received in these texts suggests the paintings just described had not yet faded.

### VIII. Painting techniques for indigo in top paint layers

In almost all old master paintings where indigo was used in the final paint layer, its colour has faded. It appears that the painting technique, has greatly affected the stability of the paint. In this section, I will present an overview of the painting techniques used for indigo in final paint layers. In the following section, the influence of each technique on the paint’s colour preservation is examined.

**Mixtures with lead-white or chalk.**

Old texts generally recommend a procedure for modelling indigo blue by adding only various quantities of white pigment, usually lead-white. Analysis of paintings has shown that the texts do reflect contemporary painting practice. SEM-EDX analysis of paint samples indicates that painters consistently mixed indigo with the purer form of lead-white, referred to as *schulp* or *sclertpat* in Netherlandish sources, rather than the cheaper form of lead-white that was extended with chalk, referred to as *loottaw*. Usually, the cheaper pigment was restricted to ground layers as was the case in Hals’ civic guards’ portraits or Peter Lely’s portrait of *Lady Dysart*. Occasionally, painters deliberately

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210. In contemporary textile industry the combination of weld and indigo was most commonly used for dyeing green. Nie (1937), p. 226.

211. For example: *RiBte* (17th C); see note 165; Groher (1719); see Schiell (1668), pp. 111-12; *Excellony* (1668), p. 102; Palomino (1715-14, 1795-97), vol. 2, pp. 67-68.

212. Palomino (1715-24, 1795-97), vol. 2, p. 67 (see note 143). Another example is a remark by the painter Paulus van Somer: a note was added by De Mayerne (see note 149) and a recipe in *RiBte* (17th C) (see note 165).

213. Goedings & Groen (1994). In some samples traces of calcium were identified. The amount was too little to be present as an extender for the lead-white and the percentage of chalk appeared to be higher in the indigo lamps. Most likely the chalk is an impurity in the indigo.

214. 17th century painters also restricted the cheaper form of lead-white extended with chalk to their monochrome undercolours while using the purer form of lead-white for their top paint-layers. An example of this technique is Rembrandt’s *The night-watch* Rijksmuseum, Amsterdam: Wetering et al. (1976).
used a mixture of lead-white and chalk for their indigo colours. Chalk's low refractive index results in a translucent layer of more saturated blue compared to a mixture of indigo and lead-white. In the Portrait of a gentleman, Cornelis Johnson used indigo with a mixture of chalk and lead- for the background's lighter blue tones while using indigo with pure chalk to achieve a dark blue (Fig. 29). Indigo blue drapery in Jan Steen's paintings contains little lead-white and a lot of chalk. The mix of white pigments is not specific for Steen's indigo colours. Samples taken from different colours and paintings from various periods in his career, almost always show both lead-white and chalk.

**Lead-white pigment particle size**

For the rendering of folds in drapery the two pigments were mixed in a range of values so that painters will probably have ground each pigment separately into paint. A Venetian manuscript named Ricette per far ogni sorte di colori that was presumably written in the latter half of the 17th century, recommended, however, another procedure: *first you must grind the white [together with the oil] into a paste and then gradually add the indigo powder.* Comparative measurements of pigment particle size distributions have indicated that the lead-white mixed with indigo shows a wide range of particle sizes. This is typical of lead-white at that time made with the so-called Dutch or stack method. The lead-white Hals mixed with his indigo was of a particularly coarse grade. The white pigment contained fine material, with some larger particles measuring 8-22 µm across and a few very coarse particles measuring 32-70 µm. Honthorst also used rather coarse lead-white, with many particles measuring c. 50 µm. Usually, painters preferred a more finely ground lead-white. The pigment used by Bloemaert, De Grebber, Jordaens, the Haarlem master, Verspronck and Lely was rather fine material, with few particles in the middle size category (14-24 µm diameter) and no very coarse grains. An even finer grade was used by Johnson and Schalken (biggest particles between 5 and 10 µm diameter).

**Mixtures with smalt**

Treatises regularly advise adding smalt to indigo to achieve a brighter blue colour. In a 17th century English manuscript Peter Lely is quoted: *'When you paint a blew garment with indigo... put a little fine smalt to...'*

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217. This practice is evident from a paint sample (126/7) from Hals' 1633 St. Adrian civic guard portrait. In subsequent indigo paint-layers the indigo particle size varies from very fine to relatively coarse while in all layers lead-white particles generally have the same size.

218. Ricette (17th C.) (see note 165).

219. For producing lead-white, strips of metallic lead were exposed to a weak solution of vinegar for three months in clay pots. The pots were stacked in rows in a shed and covered with fermenting horse dung that produced heat and carbon dioxide. The combined action of acetic vapours, carbonic acid and heat transformed the outside of the strips of lead into white basic lead carbonate. This product was scraped from the surface and after washing, drying it could be used as a pigment: Gettens et al. (1993), p. 68.

220. The largest diameter i.e. the length of some oblong shaped particles was measured at 1000x magnification under the light microscope using an eyepiece micrometer.

221. In the majority of paintings a coarser grade of lead-white was used in ground layer only. Lumps of up to 50 µm were found in Lely's painting and very coarse lumps of up to 100 µm diameter were used by Verspronck. In paintings by Hals and Honthorst there was no obvious difference in the grade of lead-white used in different paint-layers. Records show that Honthorst's painting was primed by François Olieviers, a specialist in his task; see Bovelet (1995), p.135.
your indigo to heighten it (or enrich it) because indigo looks dirty if itself. Hence, for the satin dress of Lady Dysart, Peter Lely may have had in mind a greyish ‘dirty’ blue as here he used indigo without any smalt (Fig. 31). In both his 1627 St. Adrian and St. George civic guard portraits, Frans Hals enriched the blue colour of the indigo sashes with some smalt. Notably, he no longer considered this practise necessary when painting his 1633 and 1639 portraits. Godfried Schalck depicted the background in his Portrait of a gentleman with an intense, rich blue colour (Fig. 32). His indigo paint contains much smalt and just a little red and yellow pigment. This blue passage has faded severely, into a pale grey hue. Where protected by the frame, the original colour has been preserved.

Mixtures with yellow lakes

Several 17th century instructions describe mixing indigo with yellow lake pigments. In oil, this combination produced a green glaze which colour was characterised as ‘a sad green.’ Vermeer used this dark subdued green, made with indigo, a yellow colorant identified as weld and a touch of lead-white and yellow and red ochre, in the background of his Girl with pearl earring (Fig. 27b). In order to make weld into a yellow lake pigment, recipes usually recommend adding alum and alkali to the dyestuff solution so that hydrated alumina is formed as a substrate. Frequently chalk was added to the solution. Then the resultant substrate would contain a precipitated calcium salt as well as an aluminium salt. High quantities of calcium and aluminium compounds identified in Vermeer’s green paint using SEM-EDX, suggest that this latter procedure could have been used. The yellow lake in this painting is still well preserved, and in cross-sections the particles appear unaltered throughout the whole paint layer. In his Sick lady, Jan Steen used virtually the same pigment mixture for the curtain of the box bed (Fig. 30). The paint contains high amounts of aluminium and calcium containing compounds, but here the latter component may not be associated with the preparation of the yellow lake, since, as indicated, chalk was consistently found in Steen’s paint. For the green tablecloths in his 1641 and 1642 Regentesses group portraits, Verspronck used a comparable pigment mixture. He only added small amounts of an organic red pigment (Fig. 2, 19). SEM-EDX identified relatively high quantities of calcium and very little aluminium containing compounds in these paints. Verspronck’s yellow dye must have been precipitated on chalk. Sometimes this substrate was used in order to make a

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222. King (c. 1653-57), f. 48v (see note 202); also Eikelenberg (1679-1704), p. 666 (see note 154); Collection for mixtures (c.1603), f.111v.


224. Excellency (1680), p.106: ‘For a sad green, India and pink [= yellow lake pigment] heightened with masticate.’ Sources commonly recommend a mixture of indigo and orpiment to produce green colours. Cennini (c. 1400); see Thompson (1932), p. 31, recommends the mixture for fresco and secco painting as well as glue tempers. However, this mixture is not recommended for oil media. The 15th century Strasbourg MS (15th C.); see Borradaille (1967), p. 55, mentions, in addition to tropical indigo, ‘endebeskit’ as a pigment for oil painting. This could be an indigo-yellow mixture.

225. Indigo and weld were identified using wet-chemical analysis and (HPLC): Groen et al. (1998), p. 173.


227 The paint-layer contains indigo, weld, some lead-white, chalk and very little fine red pigment (ochre, umber?): Karin Groen, unpublished report (ICN). Weld was identified using HPLC at the ICN.

more opaque yellow pigment. In both portraits, the lake has faded almost completely. In cross-sections not a single yellow particle can be seen under the microscope. That the dyestuff was precipitated on chalk may have contributed to the pigment's inferior stability. That the tablecloths still appear green today is perhaps due to the yellowed oil medium.

**Binding media and siccatives**

As described in chapter II, sources often advise applying ultramarine, azurite and smalt with poppy or nut oils, media that yellowed less severely than linseed oil. Water-based media including gum-water and glue tempera were recommended as well. Since, due to its high oil content, in time indigo paint can also acquire a grey or green hue, various authors advised mixing indigo with nut oil. Other authors though, believed that indigo should be mixed with linseed oil. This oil dries quicker than nut oil and also produces a more tough paint layer. The choice of the binding medium for indigo seems thus dictated sometimes, by a desire for maintaining the colours, and other times for the best drying and working qualities. DTMS analysis of green paint from the curtain of Steen's *Sick Lady*, suggests the presence of linseed oil, most likely with an addition of a nut oil. Steen may have used a mixture of these oils. If he used pure nut oil, the linseed oil may derive from the indigo purification process. DTMS results on samples of Frans Hals and Honthorst indigo paint media stand midway between nut oil and linseed oil. Pure linseed oil was identified in paint from the blue apron and the green tablecloth from Verspronck's 1642 Regentesses portrait and in paint from the background of Vermeer's *Girl with Pearl Earring*.

Painters occasionally mixed indigo with a water-based medium. In the panel painting of *Mary Magdalene* by Bartlém y d'Eyck, which was painted for the most part with oil, DTMS analysis identified very low quantities of fatty acids and high amounts of proteins in the indigo paint. The medium was probably glue tempera. Gas chromatographic analysis indicated that Godfried Schalken used a mixture of oil and egg for the blue background in his *Self-portrait*. Tempera might have been particularly useful for this paint, which contains a lot of smalt. In the curtain of Steen's *The sick lady*, relatively high

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229. The yellow pigment obtained with a chalk substrate also has a brighter colour. In an oil medium, however, this colour difference is hardly noticeable.

230. The source of the yellow dyestuff, the manufacturing method and the type of substrate determine the exact colour, strength of hue and permanence of the pigment. Lakes with an alumina substrate are generally more light fast then those precipitated on chalk: Saunders & Kirby (1994)1.


232. For example: Smith (1692) p. 72; Volpato (17* or 18* C); see Merrifield (1849; 1967), vol. 2, p. 738.

233. Unpublished MOLART results. Samples were analysed with DTMS since with this technique, in addition to the information on the presence of indigo, much information can be obtained regarding the binding medium used, including information about the type of oil (nut oil or linseed oil) and the presence of a heat processed oil (boiled oil) in a paint sample. In addition, traces of added wax, resins, gums and proteins can be identified; Boon et al. (1995).


235. Massing & Groen (1988), p. 106. The addition of egg may perhaps explain why, when the cross-section is examined under UV light, the indigo/smalt paint layer exhibits a strong fluorescence (Fig. 32d).

236. See chapter II, section I.
quantities of proteins were identified in addition to linseed oil. By contrast, samples from other areas of the same painting contained only linseed oil. The proteins thus seem to derive from a glue or egg medium deliberately added by Steen to his indigo/weld oil paint.

Eikelenberg warned: *Indigo... mix it with turpentine when mixing as otherwise it will become ugly when dry.* Paint reconstructions bear this out. Due to indigo's high oil absorption, on drying, a surplus of oil can migrate towards the paint surface and result in an ugly, spotty, 'greasy' appearance. This phenomenon is especially true when indigo is applied over a ground with little absorptive capacity. Adding oil of turpentine or other volatile oils, easily prevents the problem. The addition dilutes the binding medium so that less oil is necessary to obtain a flowing paint. In addition, as the paint is thinner more medium can be absorbed by layers underneath.

Oil paint made of synthetic indigo, which consists of almost 100% indigotin, dries very slowly. There are regular complaints in the sources about the paint's slow drying rate. Slow drying indigo paint causes little problems when it is mixed into a lighter blue shade with the succedaneum lead-white. When little or no lead-white is added, as is common in drapery shadows, it can take several weeks before the paint is sufficiently dry to be overpainted. Many authors thus advise processing indigo with a drying oil, usually specified as a light coloured drying oil. Today, the term drying oil refers to an oil that polymerises into a solid non-tacky layer. In the examined period, however, drying oil has the additional meaning of an oil that had been processed in order to accelerate its drying. As described in the previous chapters, the polymerisation process was induced by heating the oil or exposing it to sunlight, often in combination with succinates. The light coloured drying oil often referred to in the sources was likely to have been processed using sunlight since this bleaches the oil. Drying oils with a thick consistency helped the brushstrokes flow so that the paint could be applied easily as a smooth layer, which maintained its shine on drying. The fluid consistency of the paint in the tablecloth in Verspronck's portraits of regentesses could indicate that the painter used a pre-processed oil i.e. a drying oil for these passages. By no means all painters thought a fluid oil suitable for indigo. Examination of the paint surface of Lady Dysart's dress indicates that Peter Lely used a viscous paint that was rich in pigment (Fig. 31). Various greyish blue tones are loosely blended into each other imitating the typical broad highlights and deep shadows of satins. The different flow of Verspronck's and Lely's paints suggests that their oils were processed in a different manner. Currently, oils that have been pre-polymerised by heating can analytically be detected in an aged paint-layer. However, it is not yet known how in an aged paint-layer an oil that is pre-polymerised without heat (for example the light coloured oil

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237. With DTMS it was not possible to determine the origin of the protein component (egg or glue) in this sample. This information might be obtained with HPLC or GCMS analysis.


239. As is evident from paint reconstructions, paint dries faster when inferior quality indigo is used. Naturally, the percentage of indigotin is lower. In addition, inorganic impurities may have a succedaneum effect on the drying process.

240. For example Eikelenberg (1679-1704), p. 380 (see note 144); Delormois (1733; 1753), *Byron Het* 'De snaelm drenge selp, de indigo want s na,'.

241. In *The small* and *The touch* by Jan Miense Molenaar, the darkest shadows of the indigo robe of the woman exhibit small drying cracks. Possibly, these were caused by the slow drying of paint that contains little lead-white.

242. Beurs (1692), p. 16: 'Indigo... Als men ze daar niet gebruikt, zyn moeten ze met een klaren droop geheizede olie temperen.' King (c. 1653-57), 49r. (see note 204). Other sources recommending the use of 'drying oil' for indigo include: Lairesse (1707), vol. 1. p. 333; Cröker (1719); see Scheff (1982), p.112; LeBrun (1635); see Merveld (1849; 1967), vol. 2, p. 813.
prepared with sunlight) can be differentiated from an un-processed oil. It would be desirable to be able to indicate such differences.

The painters' manuals often advise adding siccatives to indigo paint, especially when the author does not recommend a drying oil. In general, sources recommend the use of finely ground lead glass or small. Because of the lead, and in the case of small also the cobalt, content, these components would have accelerated the paint's drying. Most painters thought that these colourless or light blue particles did little to influence the blue colour of indigo paint.243 Nevertheless, Palomino warned it [the finely ground small] should be used with moderation... because if much used, it kills the colour. Instead, he preferred the copper pigment verdigris because for a quantity of indigo the size of a hazelnut, the amount of verdigris like the head of a pin is enough.244 SEM-EDX analysis identified a trace of copper in the indigo paint taken from the green tablecloth in Verspronck's 1642 Regentesses portrait.245 The small Hals added to heighten the indigo colour in both his 1627 portraits, may have functioned as a dryer as well. In the majority of samples examined, neither glass nor small was identified.246 Dutch painters may have preferred a lead siccative such as lead oxide in a drying oil for accelerating the drying of their indigo paints. Besides, as will be discussed in the following, most painters mixed their indigo with lead-white, even in the darkest shadows, whereby the drying time of the blue paint was considerably reduced.

**Modelling of indigo drapery**

In his *Lettre à un de ses amis contenant quelques instructions touchant la peinture* (1669), the French painter and art theoretician Antoine Le Blond de la Tour advised the following mixtures of indigo and lead-white for modelling blue drapery:

*For the first tint you must apply a lot of lead-white and very little indigo because this last pigment is extremely strong and solid; in the second [tint] more white than indigo, in the third [tint] more indigo than white and for the fourth [tint] indigo, completely unmixed.*247

Le Blond de la Tour recommended rendering the darkest shades with unmixed indigo paint. Other authors, including Beurs, thought it useful to add some lead-white to these dark passages as well.248 Most likely, the addition of lead-white was not just to obtain lighter shadows but also to speed up the drying time of the blue paint.

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243. Hidalgo (1693, 1665), p. 8; Reiss (174 C); see note 168; Eikelenberg (1679-1704), p. 666 (see note 157); Palomino (1715-24, 1795-97), vol 2, p. 68.

244. Palomino (1715-24, 1795-97), vol 2, pp. 56-57: 'Sesante de esmalte remolida... y puede servir para el ultramarino y el óxido, pero también con moderación, especialmente en el ultramarino, porque si es mucho, le mata el color.' p.68. 'Sesante para el óxido... se le da de color para que siga un poco de esmalte remolida, o reducido mucho, o usar del esmalte que decimos, del aceite de amon, a una pintura de cardenal, la cual tengo por mejor, porque para tanto útil como una arpillera, hasta de cardenal tanto como la cabeza de un alfiler, y de la otra es menester mayor cantidad, y en esto no mucho perjudicia.' Translation by Vellis (1986), p. 167.

245. This does not necessarily imply a consciously added copper-containing siccative such as verdigris or copper sulphate. It is conceivable as well that an oil was used which was simply preserved in a copper container: Groen (1997), p. 219.

246. When examined in UV light, cross-sections of indigo paint from both Verspronck's Regentesses portraits exhibit small splinterly transparent particles (Fig. 19c, d, 2g, h). SEM-EDX analysis indicated that these contained an abundance of silicon and very little potassium. No cobalt, nickel and arsenic were identified so that the interpretation as discolored small can be rejected. The very small quantities of potassium in the particles make it unlikely that these are glass. The particles are likely merely ground sand, present as an impurity.

247. Blond de la Tour (1669), pp. 65-66: 'Il faut mettre beaucoup de blanc de plomb, & tres-peu d'inde; dans la premiere teinte, parce que cette derniere couleur est extrêmement forte & solide; dans la seconde, plus de blanc que d'inde; dans la troisième, plus d'inde que de blanc; pour la quatrième, de l'inde tout pur.'

248. See note 195.
drying of the indigo paint. In fact, in most paintings examined in this study, even the darkest shadows of indigo drapery contained some lead-white or chalk. For example, a cross-section from a dark shadow area of Michiel de Waal’s sash in Frans Hals 1639 portrait shows that the artist mixed his indigo with a little lead-white and deepened the shade by adding some brownish black pigment (Fig. 18b, c). In *A game of tric-trac*, Judith Leyster obtained very dark shadows in the blue sleeve of the man by applying a translucent paint made of indigo and lead-white on top of a dark brown layer (Fig. 21).  

Historical sources emphasise that in a painting, various types of cloth should be distinguished by the way in which they form folds. Painters had, for example, to take into account the intensity of the tonal contrast between illuminated forms and those in shadow and whether there should be a gradual or abrupt transition between these passages. The sequence used for the application of light and dark paint, however, was more or less the same for most types of drapery.  

According to many 17th century instructions, such as those in the *De Mayerne manuscript*, in the first coloured paint layer, light and shade were rendered with relatively little tonal contrast. Some authors even advised applying this layer as a flat colour. Subsequently, light and shadow should be worked up in increasing detail. This implies that the middle tone of the drapery is the thinnest paint layer. My examinations have shown, that indigo drapery is often built-up according to these procedures, although within this practise there are considerable differences. To paint Lady Dysart’s dress, Peter Lely first applied a solid layer with little tonal contrast. Upon drying, light and shade were added with increasing detail. Cross-sections taken from both highlights and shadows exhibit two or three indigo layers which measure 50-75 μm thick (Fig. 31c).

Cross-sections taken from the blue sashes of Hals’ 1627 and 1633 portraits consistently show a subdued coloured, medium rich layer of indigo and lead-white, sometimes extended with some black and ochre pigments laid over the light ochre ground. Cross-sections of other drapery colours show muted, sometimes even greyish, underlayers as well. These undercolours probably formed part of the deadcoloured sketch, which set down the composition and colour scheme on the primed canvas.  

Over the deadcolours, Hals painted the middle tone of the blue sashes so thinly that they usually reveal the underpaint (Fig. 15b, 16b, 19b, c). In more elaborately worked light and dark parts, the undercolour is more thoroughly covered. Here paint cross-sections typically show that 2-3 layers of indigo paint were applied, although one sample contained as many as 6 thin layers. In six of the samples from the blue sashes, the total thickness of the indigo layers falls within the approximate range of 40-84 μm and is usually more than 60 μm. Hals sometimes applied paint layers wet-on-wet (Fig. 16c, 17e). Samples show that varying quantities of lead-white are present in succeeding paint layers and they are applied in no apparent order, i.e. without systematic modelling from dark to light blue, or vice-versa (Fig. 15c). This multi-layer build-up is typical for Hals’ modelling technique for drapery. Over the deadcolour various tints of paint were loosely swirled together. Subsequently, light and dark un-blended paint


250. Only the rendering of velvet was considered an exception to the general rule; see chapter 1, *Recipes for the indication of light and shade in the rendering of objects*.

251. For example the recipe for ‘Travail de rouge’ in *Le petit peintre de Mr de St. Jelme Mayerne* (1620-46); see Graaf (1958) p.151. A recipe in the *Euvres (1668)*, p. 104 recommends a comparable system, with thin middle tones, but advises applying the light areas first with pure lead-white paint: *For Blew Garments. Take indica and white, first by the white in its due places, and then you mean colour, namely indica and white mixed in their due places, then deepen it with indica only… But if you will have a blew garment without glazing, lay the ground as before, with indica and white, heighten and deepen it with the same colours. See also a recipe in *Collection for mixtures* (c. 1605), f.111v: *moss satin, Indehblow & white first then depened with Indehblow.’

strokes were juxtaposed so that they overlap, providing the sharp tonal breaks of the fabric. Various samples from Hals’ blue sashes show layers of binding medium present between indigo paint layers, or between layers of grey underpaint (Fig. 16c-e). As described in chapter II, this practice corresponds to written instructions to wet out or oil out the paint surface between the painting sessions. The layers that Hals applied are intermittent and very thin (up to 4 μm, but usually less 1 μm). As described in chapter II, this follows historical instructions, to smear the medium out as thin as possible. Due to the thinness of the layers their composition could not be ascertained. One of the described functions of wetting out was to provide a smooth surface on which the artist could easily and quickly spread his paint. In this case, the medium layers possibly helped Hals to achieve the rapid juxtaposition of fluid brush strokes so characteristic of his technique.

The indigo blue flag in De Grebber’s Triumphal procession with sacrificial bull (1651) shows yet another paint structure (Fig. 24). On the light coloured ground, the composition was sketched in with lines and washes of umber coloured paint. Next, the flag was underpainted with little modelling using a light greyish blue paint (c.15-30 μm thickness) made of indigo, lead-white, black and brown pigments. Subsequently, De Grebber applied stiff, bright blue indigo paint, mixed with various amounts of lead-white depending on the shade of blue required. This paint was also applied in the middle tones, sometimes as a covering layer and sometimes brushed out very thinly. Finally, highlights, the darkest shadows and smaller folds were rendered with spontaneously applied overlapping brush strokes that reflect the technique of De Grebber’s older colleague Frans Hals. Examination of the paint surface and cross-sections indicates that a rather impasted paint was used for the lighter tones while shadows were applied with fluent, medium rich paint.

17th century authors emphasise that in order to obtain a convincing pictorial illusion a skilful depiction of reflection was extremely important. These were areas in the half shadows, which were partially illuminated by an adjacent light area. In painting drapery, the artist had to consider the colour and light reflections from adjacent objects. If the fabric was pleated, the shaded parts also reflected the highlights of the raised folds. In the dress in Verspronck’s Portrait of a girl, we repeatedly see a light blue band of reflection along the contour of the fold’s shaded side (Fig. 20a, b). The material from which a drapery is made, shiny or matte, determines the nature of the reflection. In this dress, the reflections were produced with a narrow band of a slightly lighter tone than the shadows. This can be seen in a passage of indigo paint, which was covered by the frame. To imitate the shining satin dress of Lady Dysart, Peter Lely made use of the effect of broad, sudden reflections (Fig. 31, a, b). Verspronck and Lely’s paintings conform to contemporary instructions which describe how to render reflections within drapery; the value reflected stands midway between the middle and shadow tones. The reflection was rendered with the same cool blue used for other passages of the drapery. By contrast, for reflections in the flesh-tones, Lely and Verspronck used a slightly warmer hue than the one used for the shadow and middle tones. Frans Hals also consistently made use of warm reflections in his indigo drapery. A notable example can be seen in the half shadows of the sash of Captain Johan Schatter, who stands in the middle foreground of the 1633 St. Adrian civic guard portrait (Fig. 17a-c). Surface examination suggests that in the half shadows, Hals brushed out the indigo thinly, on top of a local layer of pale ochreish underpaint. This colour shines through and gives these areas a green tinge. Although certainly

253. See chapter II, section 1.

254. See descriptions by Mander (1604), ff. 33r-33v; Hoogstraten (1678), pp. 262-63; Lairesse (1707), vol. 1, pp. 216, 262-65.

255. See recipes by Beurs (1692), pp. 28-43, for depicting, light, middle tones, reflections (weersteutinge) and shadows for white, yellow, red and blue flowers and draperies.
amplified by ageing and abrasion from cleaning, the effect seems intended. It lent a warm sheen to the unsupported, stiff and lustrous silk fabric. Comparison with the orange sashes in the same picture plane shows that Hals also painted the reflections in the half-shadows a noticeably warmer, orange red hue (Fig. 17a).

In order to achieve a convincing suggestion of space on the painting's flat surface, 17th century painters depicted objects in the background with more subdued colours, less tonal contrast and the modelling was rendered with more gradual transitions. Consequently, tonal contrast and colour intensity of indigo drapery depends on whether the fabric is depicted in the forefront or background of the picture. Thus, the rather flat modelling of the blue flag in the background of De Grebber's painting is in harmony with other drapery and objects placed nearby (Fig. 24a). In Frans Hals' portraits the indigo sashes are usually worn by figures placed close to another figure in the assembly. Only in his 1639 St. George civic guard portrait are there clearly separable planes (Fig. 18a). The more distant sashes have softer shadows and highlights, and their colours are more subdued. Conspicuously, unlike Hals' other militia pieces, in the 1639 portrait there is no subdued blue deadcolour. Instead, Hals depicted the sashes directly on the ground layer, which is in this painting noticeably darker than in the earlier portraits. In the 1639 painting, Hals achieved the desired warm undertone he used for rendering atmospheric colour effects, with a subdued medium brown ground colour. To achieve a range of intense and subdued blue colours, Hals deliberately varied the thickness of the paint layers so that the ground layer was masked to a varied extent. The colours of the sashes now range from greyish to pale, to bright blue. This range of blue colour, which described the transition from background to foreground figures, corresponds to a general increase in the thickness of paint application with the most fully saturated paint being the thickest.

While De Grebber, Lely and Hals used an elaborate paint structure, other 17th century painters applied their paint in a single thin layer, often measuring only 10 to 25 µm in thickness. Some artists believed that the commonly employed sequence of deadcolouring, working-up and retouching did not need to be followed when using this pigment since it was so easy to apply. The colour could simply be applied once and then various tones were swirled in wet-in-wet. Palomino announced 'with this indigo you can paint the blue colour de la primera, and this is the best.' This practice is evident in Verspronck's Regentesses portraits. While other passages were consistently prepared with deadcolours, the green tablecloths were painted directly on the light beige coloured ground, modelled in one thin layer (up to 20 µm) by varying the amount of white pigment and oil (Fig. 2). Likewise, Jan Steen painted the box bed curtain, directly on the light ochre coloured ground, in one thin layer (Fig. 30). Cross-sections of other paint areas usually exhibit a more elaborate paint build-up, although Steen here seems to have used an alla prima application as well. For modelling the box bed, Steen used a wide range of techniques. Naturally, he varied the amount of white pigment according to the value needed but he also differentiated the thickness of the layer (0.13 µm), the amount of binding medium, and he accentuated forms of the bed by the direction of the brush strokes: in the bed's canopy there are horizontal strokes whereas its curtain is depicted with vertical strokes. In a shadow area inside the bed, dark blue paint is

256. These qualities are often described in contemporary art-theoretical texts. See for example Hoogstraten (1678), pp. 264-65.

257. See note 146.

258. Hendriks (1998). Due to fading, today the indigo paint has become almost transparent. From an area protected under the frame it is evident, however, that Verspronck intended a more covering layer although the ground must have been visible to some extent from the start.

259. These observations are based on paint cross-sections published by Butler (1982-83).
applied as a semi-opaque layer, while lighter areas contain more binding medium and are more thinly painted so that the ground shines through. Certainly, by now, both fading and abrasion have greatly accentuated the intended effect. In the *Triumph of Frederick Hendrick*, Jordaens depicted the blue drapery of the boy, in one single layer over the boy’s flesh paint and red and brown background colours (Fig. 49b). For the darkest shadows, indigo paint was extended with a little lead-white and applied so thinly that the underlying warm colours shimmer through. In the lighter tones there are loose, overlapping strokes of impasted paint (20-55 μm). The tones are so little blended that underlying paint layers are visible between the blue strokes.

Instead of using indigo directly on a light coloured ground or deadcolour, some painters first applied a dark coloured underlayer. In his altarpiece (c.1440), Bartémy d’Eyck consistently applied a uniform black layer (c. 20μm) on the white ground before painting with indigo (Fig. 48). We do not know whether the artist used flower or the pigment imported from outside Europe. In either case, however, economical use of his pigment may have been his rationale, since at that time prices for both flower and Indian indigo were considerable. On top of the black, the painter obtained a dark and saturated blue with a thin layer of indigo (20μm). This would have been impossible directly on the white ground layer. Palomino advised, although he considered indigo well suited to an *alla prima* application, if a large area was to be painted, a preliminary underpaint made of white and carbon or lampblack should be applied. Painters may have exploited the blackish underpaint to enhance the blueness of indigo by means of the turbid medium effect, in which the preferential scattering of blue light and the absorption of red and yellow light causes a light paint layer applied over a dark coloured layer to look cooler. On a beige coloured ground, Cornelis Johnson applied a dark grey wash, at few microns thick, before applying a thin (20 μm) layer of indigo mixed with chalk and sometimes lead-white (Fig. 29d). Especially in those areas where only chalk was added, the dark grey undercolour contributed to the darkness and intensity of the blue. This can still be seen in the small dark blue strips where the background was covered by the frame. In his *Girl with pearl earring*, Vermeer applied his green glazes over a thin (c.12 μm) blackish layer. The layering of a translucent green over near-black produced an optically mixed, saturated cool green colour (Fig. 26b). Today, the background paint looks matte and milky today although in places where the paint was covered by old retouchings, the colour is more saturated.

IX. Different states of preservation of indigo paint areas

Most of the paintings examined have areas of indigo paint which were covered by an old frame or retouchings. Having been shielded from light and partially against degenerative atmospheric effects, these passages provide a glimpse of the original value and intensity of colour as intended by the painter. It appears that each painting exhibits a widely divergent degree of fading. Fading has caused paint layers

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260. See note 146. The Spanish painter Hidalgo (1603; 1663), p. 8, also recommended underpaint made of black and white for paint made of small and indigo.

261. The fading of the indigo seems to have caused the discoloration, since in cross-sections seemingly unchanged bright yellow particles are visible Groen et al. (1998).

262. Schweppes (1997), p. 87, Grosjean et al. (1988), Whitmore & Cass (1988), Daniels (1989), have pointed out, that indigo is very susceptible to fading by chemical oxidants. Therefore, it is likely that, as noted by Saunders & Kirby (1994): “The rebate of the frame might partially protect the edge of the painting from chemically-induced colour change as it protects from colour change caused by light.” An overview of the literature on indigo’s fading by atmospheric pollutants is presented by Phenis (1997), pp. 8-10.
to become more transparent as well. When indigo contains lead-white, loss of hiding power may also be due to a chemical change on the surface of the lead-white particles in the oil.203

The side-panel from the altarpiece by Barthelmy d'Eynck depicting the Mary Magdalene, has a depiction of Isaiah with a still life with books above it on the outside. When the large altarpiece was dismembered, presumably during the French Revolution, the still life was detached from the prophet to form a separate picture.264 The indigo paint on the upper quarter side of the Mary Magdalene became the reverse side of the still life, and, most likely, has been kept in the dark ever since. The indigo paint on the remaining Mary Magdalene panel was exposed to light. Despite the thick layer of dirt accumulated on the reverse side, comparison to exposed paint shows that the latter is somewhat lighter, although the difference is rather small.

Evidence for the extent of colour deterioration in Hals' militia pieces is provided by a sash at the left edge of the 1633 group portrait. Where it has been shielded from light by the frame, the indigo retains a more saturated blue (Fig. 17h). Nonetheless, the exposed indigo sashes have a bright blue colour and their folds are convincingly modelled. Late 18th century watercolour copies of Hals' civic-guard series, executed by Wybrand Hendriks (1744-1831), depict the sashes in a relatively unfaded state (Fig. 50). These copies may thus provide an idea of the original colour harmonies between the deep blue and the orange and white sashes. This does not mean, however, that the blue in Hals' paintings looked exactly as Hendriks portrayed it. As described in chapter II and III, in the 18th century, it was common practice to correct the effects of age when copying the old masters. That Hendriks was not reluctant to do so, is demonstrated by the watercolour copy he made of a militia piece (c. 1642) by Pieter Claesz Soutman (c. 1580-1657). Hendriks noted on the back of the sheet, that he had made the copy — a light and bright coloured aquarelle — after an original that had become completely black and unclear.265 Assuming that Hals rendered the sashes in the four portraits with blues of similar colour value and intensity, in the various paintings their state of preservation differs considerably (Fig. 15-18). In the 1627 St. Adrian portrait the sashes have been preserved best, followed by the 1633 portrait of the same company. The 1639 St. George portrait exhibits paler indigo colours, and the most severe fading is evident in the 1627 St. George portrait. Earlier in this chapter, the possible influence of quality differences on indigo's colour preservation was considered. In the following, the influence of the light intensity to which the works have been exposed, and the painting technique will be scrutinised.

At the far left of Jordaeus' Triumph (Fig. 49), a strip of indigo paint was covered since c. 1767 by the frame as well as by a severely darkened varnish layer.266 The colour of this strip is only slightly more intense than the exposed paint. The portrait of Lady Dysart by Peter Lely was only studied framed (Fig.

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263. See chapter II, section IV, Causes for the increase in transparency of oil paint-layers.


265. Wybrand Hendriks, Officers and sergeant of the St. George civic-guard squared on paper, 26 x 37.2 cm. Teylers Museum, Haarlem, Inv. no. W 48. Hendriks noted on the back of the sheet, that he had made the copies on the back of the sheet, that he had made the original portrait. Hendriks wrote at the bottom left of the reverse of the paper: 'W. Hendriksen na een schilderij van F. Hals dat geheel zwart en onbestemd was geworden en gelegen heeft veertien jaar op een gang in 't Proveniershuis te Haarlem thans bewaard op stuifmuts achtbaar.' I am grateful to Koos Levy-Van Halm for bringing Hendriks copy and his note to my attention.

266. Around 1767, Jan Van Dijk restored Jordaeus' painting; he removed the old varnish layer and applied a new one. During the subsequent restoration of 1806, at the far left of the painting a strip of Van Dijk's varnish was not removed. This indicated that at that time, this part of the painting was covered by the frame. The painting was re-varnished in 1850. Since the varnish was also applied on top of Van Dijk's varnish, the strip at the far left was no longer covered by the frame. Only during the most recent restoration (1998-2001) was Van Dijk's severely darkened varnish layer partially removed, exposing a slightly more saturated indigo blue than can be seen in the main body of the picture: Personal communication: Lidwien Speeers, Stichting Restauratie Atelier Limburg.

156
The indigo satin dress with its refined nuances and reflections is just as convincingly modelled as the satin drapery of other colours painted by Lely. This suggests that the indigo colour is still well preserved. The indigo flag, depicted in the centre of De Grebber’s painting (Fig. 24), has a vivid blue colour and its modelling is quite similar to the white flag next to it. An obvious disparity between exposed indigo blue and blue which was covered by a frame is visible in Verspronck’s portrait of a girl (Fig. 20). The dress is still blue, however, and although fading has certainly lead to loss of the original modelling, the way the dress forms folds is still convincing. The indigo pattern of the Persian tapestry on Honthorst’s portrait has faded noticeably but is still blue (Fig. 28).

Severe loss of colour and with it, the suggestion of folds, has occurred in the woman’s skirt shown in panels of Jan Miense Molenaar’s series *The five senses* (Fig. 23). A comparable phenomenon is evident in the blue skirt in Verspronck’s 1642 Regentesses portrait. In the Militia piece by an unknown master of the Haarlem school, the blue coloured sashes and standards have almost completely faded. The paint has become translucent and exposes underlying paint layers (Fig. 1). Again, a water-colour copy of this painting by Hendriks may provide an insight into the picture’s original colour scheme (Fig. 51). Other 17th century examples exhibit passages of even more seriously degraded indigo. In Verspronck’s two Regentesses portraits, the original intense greenish-blue colour of the tablecloth visible at the selvedge of the 1641 painting, is almost completely lost due to the fading of both the indigo and the yellow lake pigments (Fig. 2). Comparison of exposed and shielded passages of the indigo background in the portraits by Johnson and Schalken, reveals vast differences in colour value and intensity (Fig. 29, 32). Both paintings have had two frames, each with a different size rebate. One can now see, along the edge of both paintings two bands of less faded blue. In each case the outer most band is the most intense.

In order to examine the degree to which faded indigo is visible in cross-sections, samples from single brush strokes of Verspronck’s *Portrait of a girl*, and Honthorst’s *Portrait of Amalia and her daughters* were taken. The brushstrokes had been partially protected under the rebate of the frame, and two samples were taken from each; one from the end faded by light, and the second, from the protected, unfaded, end. The effect of fading is clearly visible in the cross-sections of these two once homogeneous indigo paints. The upper part of the indigo layer is lighter and more translucent than the preserved paint underneath (Fig. 20c, d, 28d, e). In Verspronck’s portrait, paint had faded to a depth of c. 8 to 10 µm and in Honthorst’s painting up to c. 10 µm. These measurement are approximate, as the depth of fading in the samples is neither uniform, nor well defined. This is due to the light scattering caused by the adjacent white pigments lead-white and chalk. The boundary between the faded and unfaded part of a paint layer can sometimes be discerned by viewing the sample under UV illumination, since the faded part appears paler than the remaining paint layer. Notably, cross-sections taken from paintings with severely discoloured indigo paint areas, sometimes also exhibit a deeper fading. In the painting by an unknown master of the Haarlem school (Fig. 1e), for example, paint has faded up to 16-20 µm depth and in Johnson’s painting up to 20µm (Fig. 29e).

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267. In this painting, however, white sashes also show their underlying colours and brushstrokes. Since the Haarlem master mixed his indigo with a lot of (most likely the same type of) lead-white, the paint’s translucency seems also be due to the saponification of the lead-white particles mixed in an oil medium.

268. Feller (1994). Sometimes the ill-defined boundary between faded and unfaded paint might raise doubt as to whether the lighter part at the top of the sample was faded, or in fact a separate paint-layer, applied wet-on-wet so that it had blended into the underlayer. Further confusion is caused by the fact that more lead-white seems mixed into the top part of the layer, suggesting a lighter paint mixture applied as a separate layer. This phenomenon may be explained instead by the fact that the lead-white particles appear more distant where fading has occurred, since they are no longer masked by a dark matrix of indigo.
Environmental influence on indigo's colour preservation.

The different states of preservation observed in the paintings is to a great extent due to the varying amount of light these works have been exposed to. Earlier studies have demonstrated that air pollution also has a significant detrimental influence on indigo's colour preservation. Furthermore, over time, paintings may have been subjected to detrimental cleaning procedures. It is difficult to quantify the effect these factors have had on the ageing of indigo. Only occasionally do we know precisely where a painting hung through all its centuries and even then, we can only estimate the amount of light and atmospheric pollution to which the indigo paint was subjected. For example, De Grebber's painting and Honthorst's portrait hung opposite windows on the rear wall of the Oranjezaal. Jordaens' large Triumph was positioned perpendicular to the wall of windows. The indigo blue drapery depicted at the far left of the Jordaeus' abutted, as it were, Honthorst's painting (Fig. 52). All three paintings are diffusely lit for the large part of the day and are directly lit for a short time in the middle of the day. It is not known whether the window shutters were usually open or closed. This suggests that the paintings were subjected to a considerable amount of light. This is supported by cross-sections from all three paintings, which show faded indigo up to c. 10 μm beneath the paint surface. Honthorst's painting shows a stronger optical colour difference than works by De Grebber and Jordaeus. As will be described below, this may be explained by these masters' different painting techniques.

The role environment plays in the preservation of indigo is sometimes most apparent when paintings made by one artist at the same time are compared. Visual examination of the indigo colour from the Mary Magdelene in Rotterdam and the Jeremiah in Brussels shows that in the Mary Magdelene the colour is slightly less saturated. Before the altarpiece was dismembered, both panels had been exposed to the same amount of light. The colour difference now visible presumably occurred after they were separate. Hals' four militia portraits were made within a time span of about 12 years. Since the early 18th century all portraits hung in the hall of the St Adrian civic guard. In 1820, the paintings were transferred to the town hall and in 1913 to the Frans Halsmuseum where they still are. The indigo colours in the paintings Hals made for the St. Adrian civic guard (1627 and 1639) are better preserved than those for the St. George civic guard (1627 and 1633). This differences may be related to where the paintings were hung until the early 18th century: the head quarters of the St. Adrian and St. George companies. However, although the paintings hung at similar locations for about three centuries, the environmental circumstances for the individual paintings did differ. For example, in the hall of St. Adrian guard, where there are windows on one side only, two of Hals' portraits hung on the wall opposite the windows and two on the wall perpendicular to the windows. Likely, the amount of light the paintings were exposed to differed considerably. From the beginning of the 18th century to 1820, also the painting by the Haarlem master was kept in the hall of the St Adrian civic guard. This painting hung directly to the left of the large windows. In this painting the deleterious effect of the light seems obvious by the fact that the right side of this painting that was nearest to the window is more severely faded than the left

269. See note 265.

270. We also have to bear in mind that it was likely to have been common practice to bring a (small) painting now and then outside in the sun in order to bleach yellowed and darkened oil and varnish layers; see chapter II, section II.


side. Only at the far right, where the frame cast its shadow on the painting, is a small, though not rigidly defined, strip of a better preserved blue.

**X. Impact of painting technique on indigo's colour preservation**

Often within one painting, some indigo passages areas have faded severely whereas others are relatively well preserved. For instance, the tablecloths in Verspronck's Regentesses portraits, occasionally exhibit surprisingly vivid blue brush strokes (Fig. 2) and in Hals' portraits, light and dark passages in the sashes are still blue while in mid-tones have a pale greenish appearance (Fig. 17a-c). In Johnson's portrait, the left side of the blue background has faded less severely in comparison to the pale greyish blue evident at the right side (Fig. 29). These examples suggest that the way the indigo paint was applied, i.e. the painting technique, plays an important part in its preservation. Time and again, historical texts emphasise that a proper painting technique greatly improves the colour-fastness of indigo oil paint. In 1676, Felibien warned: "When it [indigo] is well used, it stays beautiful for a long time." The sources usually explicitly state what this proper technique entailed. The following section aims to determine the role painting technique played for indigo's colour preservation.

*Influence of binding medium*

When indigo is used as a textile dye, its light fastness is strongly influenced by the nature of the substrate. On proteinaceous fibres such as wool or silk, indigo blue is much more stable than on non-proteinaceous fibres such as cotton. Artificial light ageing of paint reconstructions indicated that when indigo is used as a pigment, the type of the binding medium also influences its colour stability. For the experiments natural indigo, both pure and in combination with lead-white, was mixed with purified linseed oil, egg yolk, egg white or glue (Appendix). The samples exhibited vast differences in colour stability (Fig. 40). Fading was most distinctly observed in oil closely followed by the egg yolk mixtures. Significantly better light fastness was obtained when indigo was mixed with egg white, gum arabic or glue. These observations may be explained by the fact that during the oxidative drying of oil and egg yolk reaction products are formed that are harmful to the indigo. These products are not formed in a paint film made with egg white, animal glue or gum arabic so that in these media the indigo

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273. See note 159.


275. For a more extensive description of the set up of these reconstructions; see Eikema Hommes & Hendriks (1998).

276. Aldehydes derived by oxidation of the poly-unsaturated fatty acid moieties in the oil are likely candidates for reaction with indigo: For the oxidative drying of oils: Chan (1987). Kuramoto & Kazo (1979), (1982) have pointed out that indigo is primarily vulnerable to the oxidative fading. According to Griffiths (1980) and Mason & Lee (1979), who studied indigo as a textile dye, amino acids are capable of quenching singlet oxygen. Therefore, when indigo is used as a pigment, proteinaceous binding media may possibly also protect indigo against fading. A preliminary series of paint reconstructions indicated that fading of oil paint can also be minimized by pre-treating indigo with glue, egg white or gum media. For these reconstructions, finely ground natural indigo was mixed with egg yolk, egg white or glue. The samples were dried and subsequently mixed with linseed oil and lead-white paint in order to obtain blue colours with similar colour value. After the paints had dried, they were subjected to 72 hours of Xenon light ageing together with a sample of pure indigo lead-white oil paint as a control (Appendix). The tests showed that the light fastness of the paints made by pre-treating indigo improves considerably. Little difference is observed between the sample with pure oil paint and the sample of indigo ground fine in egg yolk. In all other water-based media, especially glue, the difference is considerable. It seems the pre-treatment with a water-based medium forms a coating around the indigo particles that protects them from the attack of fatty acid degradation products in the oil medium. Preparation with aqueous media however has two important drawbacks. First, it results in a less fluent, sticky paint, which is difficult to process. Second, the indigo paint becomes almost grey in colour. It seems unlikely therefore that painters would have used the pre-treated pigment.
is better preserved. When the polymerisation process of the oil is initiated before being used in the paint, the oil is far less reactive. In that case, far fewer of the reaction products harmful to indigo will be formed while the paint is drying. Presumably, the indigo will then fade less rapidly. When, as suggested in the sources, painters mixed their indigo with a pre-polymerised light coloured drying oil, this working method may have contributed to the preservation of their colours.

The fact that Bartłemy d'Eyck mixed his indigo with a glue medium probably explains the excellent colour preservation of a paint that is over 550 years old (Fig. 48). In the landscape in Dieric Bouts' The Entombment, which was painted with glue tempera on fine linen during the middle of the 15th century, the green tints were mixed with indigo and lead-tin-yellow (Fig. 14). Over time the indigo has faded so that the lead-tin-yellow component of the green has become more prominent. A bright turquoise strip now visible at the protected edge of both sides of the painting reveals the extent of this change. The colour change is still relatively small, though, when compared to the pronounced fading visible in so many oil paintings of a much more recent date. As indicated, in his portrait, Godfried Schalken had used a mixture of oil and egg as a medium for his indigo smalt paint. Notably, in cross-sections from exposed paint areas, no fading of indigo was observed. Instead, the severe discoloration of the paint surface appeared to be caused by degradation of the medium that has led to chalking. Light scattering of the degraded paint surface of the indigo background appears as real fading; there is an overall loss of saturation and lightening of the colour. Steen used a mixture of oil and egg or glue as his paint medium in the curtain of The sick lady. Compared to passages painted with pure oil, the curtain's green paint is very worn and degraded. Possibly, the emulsion medium has made the paint more vulnerable to abrasion and solvents. Since the paint layer was so thin and degraded it was impossible to determine in paint-cross-sections whether the indigo had faded.

Influence of mixtures with lead-white and chalk.

Comparison of shielded and exposed indigo passages indicates that there usually is a more pronounced loss of colour in the lighter areas than in the dark tones. For example, the dark shadows of the skirt in The smell by Jan Miense Molenaar exhibit only small differences in colour saturation, while these differences are more distinct in the middle tones and especially the light areas (Fig. 23b, c). Artificial light ageing of indigo oil paint extended with various percentages of lead-white, demonstrates that fading proceeds faster when more lead-white is present. These observations correspond to earlier studies of other organic pigments, which have shown that adding lead-white exacerbates fading, due to its strong light scattering properties. In addition, lead-white is known to be a catalyst for oxidative processes in oil paint. The detrimental influence of lead-white on indigo can be seen in paint cross-sections. In a sample from one of Frans Hals’ civic guard group portraits, 1000x magnification of the largest agglomerates of lead-white clearly shows that the indigo matrix was more faded around them. This was especially so along their upper sides where the most scattering of incident light had occurred (Fig. 16d-f). The role lead-white takes in the fading process is also exemplified by the gradual transition from the faded top to the rest of the indigo paint layer. This was noted in all cross-sections of faded


279. Thus it has been established experimentally that a paint film containing red lake mixed with white is more vulnerable to internal reflection and fades more quickly than a pure glaze: Johnston-Feller (1986); Saunders & Kirby (1994).1.

280. The catalytic activity of lead-white on the cross linking of drying oil is much more moderated in prepolymersed oils.
paint examined. This transition becomes more gradual as the proportion of the scattering pigment (lead-white) increases in relation to that of the absorbing pigment (indigo). 281

That indigo fades more when mixed with higher proportions of lead-white implies that subtle material effects in the rendering of drapery have often been lost. The middle and light tones of the young girl's dress painted by Verspronck, approach the same tonal value. The contrasts between these passages and the deep shadows are now stronger than originally intended. The reflections within the dress also exhibit more marked tonal contrast within the shadows (Fig. 20a, b). The fall of the folds are therefore less convincing.

That lead-white is harmful to indigo presents a dilemma; namely, the lead-white that is necessary to attain a satisfactory blue, at the same time, accelerates its colour deterioration. Historical sources reveal that, at least by the end of the 17th century, painters were aware of this danger. As described in chapter II, the Spanish painter Palomino warned that in a drapery painted with indigo and lead-white the lights should not be made too light, i.e. should not be mixed with too much lead-white, since the indigo colour is easily washed out; therefore it must always be worked high in colour. Also other writers, including Dupuy du Grez (1699) recommended applying the indigo dark. 282 Apparently, painters tried to overcome indigo's tendency to fade by using little lead-white, and therefore opting for a dark and intensely blue colour.

Areas of the indigo curtain, where lead-white has been completely substituted by chalk, in Cornelis Johnson's portrait, show particularly severe degradation (Fig. 29). 283 Areas of the background painted with indigo and lead-white showed discoloration due to fading. However, the blanched appearance of areas that contained indigo mixed with chalk alone was due, not only to fading, but also to the erosion of the binding medium, which caused chalking. 284

Influence of thickness of indigo paint layers
As described above, the depth of fading visible in paint films is finite, penetrating approximately 4-20 μm. Often the faded portion becomes so transparent and colourless that it cannot be readily distinguished from overlying varnish layers. It seems clear, that the residual blue visible on a painting is reflected from underlying residual indigo, which has not faded. As one might expect, fading is more extreme in paintings where the indigo was applied as a thin layer. Verspronck's portrait of the Regentesses and the militia portrait by the Haarlem master are two such examples. A cross-section of the latter painting shows the paint has faded to a depth of 16-20 μm, virtually through the whole layer of c. 20μm! Only immediately on top of the ground is a little bit of blue colour preserved (Fig. 1e). The well preserved blue in Lely's portrait may well relate to the painter's consistently thick paint application


282. For Palomino see note 146 and for Dupuy du Grez note 163. Eikelenberg (1679-1704), pp. 786-87 (see note 165), described that in 1704 he prepared panels in order to test the permanence of purified indigo. He applied indigo mixed with different amounts of lead-white to two test panels. He probably expected the different quantities of lead-white to affect his results.

283. The apparent contribution of chalk to the degradation of indigo paint was investigated at the Courtauld Institute using SEM: North (1996).

284. Why this phenomenon occurred in this specific paint area is unclear. Perhaps it was the absence of a lead's reactive action that led to problems in the drying of the oil. Earlier experiments by Saunders & Kirby (1994), have shown that when calcium carbonate is present in excess as a substrate for yellow lake pigments, so that it acts as an extender, it may improve the working properties of the pigment, but it will also have a detrimental effect on its permanence. However, artificial light ageing experiments on oil paint reconstructions made of both indigo and lead-white, and indigo and chalk do not give evidence that chalk has exacerbated the degradation of indigo blue as well.
In Hals' paintings, the multiple indigo layers also contributed to the general good preservation of the indigo sashes. The same goes for the indigo colour in De Grebber's painting in the Oranjezaal. In cross-sections the total thickness of the indigo layers varies between 60 and 40 μm. The paint has faded to 5-15 μm beneath the surface (Fig. 24c). In the blue pattern of the carpet on the portrait by Honthorst that is also in the Oranjezaal, the same depth of fading (c. 10 μm) has led to a more distinct colour change (Fig. 28). This is because the indigo paint was generally brushed out thinly on the red carpet paint (the cross-sections give a distorted picture as they were taken in the thick areas of the pattern).

Since according to contemporary systems for modelling, middle tones were generally applied in one layer, in 17th century paintings the most pronounced loss of indigo colour has usually taken place in these passages. The costume of the boy with the violin in *The merry couple* by Judith Leyster is an example of this phenomenon (Fig. 22b). In Hals' 1633 portrait, thinly applied middle tones and reflections to a greater extent reveal the ochre coloured underlayer, that had been used to lend the warm sheen of silk, and now appear more greenish blue than was originally intended (Fig. 17b, e).

Several 17th and 18th century sources stress that, in order to provide a lasting effect, multiple paint layers of more-or-less the same colour should be applied. These advices suggest that the underlayers were added to counteract the anticipated effects of the paint's increasing transparency, whether caused by fading or not. To what extent the application of indigo in multiple paint layers was calculated by Hals, De Grebber and Lely to preserve the blue colour is debatable. Cross-sections from their other coloured drapery demonstrate that these have a similar thickness. Relating samples to the paintings themselves shows that particularly in the case of Hals this multi-layer build-up partially results from his spontaneous juxtaposition of overlapping paint strokes.

### Influence of pigment volume concentration

Authors from different countries warn that to obtain a durable blue colour one should not mix indigo with too much oil. The *Ricette per far ogni sorte di colori* asserted that indigo, to stay beautiful should be mixed with as little oil as possible. Felibien (1676) indicated why this very technique prevented fading: One should not use too much oil, but apply it a bit dark because it discharges. Apparently, as in their advice for mixing indigo with little lead-white, painters tried to diminish the effect of fading by using a lot of indigo pigment. Notably, historical texts do not mention this advice when describing the use of other light sensitive pigments such as red and yellow lakes.

Various 17th century painters applied indigo paint according to the above procedure. The dress in Lely's portrait is perhaps the most obvious example of the technique. For a loose juxtaposition of light and dark paint strokes, Hals, Jordaeens and De Grebber regularly used impasted indigo paint. In some paintings, indigo paint has faded so severely that underlying paint layers are no longer effectively

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285. The depth of fading visible in paint cross-sections is 4-16 μm, that is approximately a quarter of the way through the top layer of indigo. In the case of the sample showing six thin layers of indigo, virtually the whole of the 14-μm thick top layer has faded (Fig. 15c).

286. See chapter II, section II and IV.

287. Palomino (see note 146) considered the *more important precaution for the preservation of indigo's colour that it not be used with a great deal of oil, but rather well worked. Similarly Dupuy du Grez (see note 163) thought that indigo colour would preserve a long time provided that on applied it with little oil.

288. See note 159.
covered. In these cases a particularly medium-rich paint is suggested. Thus, in the woman skirt in Molenaar's The smell, it seems the indigo-lead-white paint was applied with a lot of oil, especially in the middle tones. An adjacent area covered by the frame, however, shows a surprisingly impasted paint. Traces of the brush's bristles, which run under the frame in the lit area, indicate that there is no question of severe abrasion (Fig. 23). This indicates that the indigo paint was applied rather as an impasto. Areas of the tablecloths in Verspronck's portraits that have been well preserved by the frame, exhibit a flowing glaze (Fig. 2c, d). The paint contains a lot of chalk, which absorbs a lot of oil. The particular strong fluorescence of the oil medium in UV light, also suggests that the paint contains a high percentage of medium. Visual examination of the 1641 Regentesses portrait demonstrates that the high amount of oil has indeed exacerbated fading. Around the contours of the hand lying on the tablecloth of one of the Regentesses, Verspronck filled in the green colour separately, with paint richer in pigment that was brushed out thinly (Fig. 2e). Originally, the colour of this paint may not have deviated strongly from the colour of the rest of the tablecloth. Today, since it has faded less severely than the rest of the cloth, the impasted paint stands out as a dark halo around the hand. Consequently, it may be expected that the relatively well preserved indigo colour evident in paintings by Hals, Honthorst, Jordaens, De Grebber and Lely is related to these painters' generally pigment rich application of indigo paint.

Influence of light or dark underpaint layer

Johnston-Feller (1986) has investigated the role of the ground colour in the fading of red lake pigments, used both as a pure glaze and mixed with white pigment. She demonstrated that as long as a paint mixture provided complete spectrophotometric hiding, which might not be the same as visual hiding, the rate of fading was the same for a black and a white ground. The same held true at all wavelengths when the paint layer provided incomplete hiding. However, as a faded paint mixture provided differential hiding according to wavelength, the colour of the ground came to influence fading. A correlation between the darkness of the underpaint and the extent of fading of an overlying red lake glaze has been demonstrated in Gainsborough's portrait of Dr. Schomberg. The darker the brown underpaint, the less the red glaze appeared to have faded. Theoretically, one might anticipate that semi-transparent indigo paint layers would be more subject to fading when applied on a pale ground than on a dark one, since they would reflect more incident light back into the surface paint. In addition, when applied on dark undercolours a faded indigo layer with incomplete visual hiding appears better preserved than when applied on a pale ground layer, since the turbid medium effect helps the paint appear more blue.

Examination of the paint surface tends to substantiate the above hypothesis. Obviously, by visual inspection alone, the role of the light absorbing capacity of the ground cannot be separated from that of the turbid medium effect. In the group portraits by Verspronck, the indigo tablecloths were painted directly on top of the light pink ground layers (Fig. 2, 19). Notably, the paint appears bluer in an area where the indigo paint overlaps the dark brown deadcolour of the dress of one of the Regentesses. Verspronck placed the figure more to the left at a later stage in the painting process (Fig. 2f). Likewise, blue costumes painted by Judith Leyster appear better preserved where they were painted on brown underpaint rather than on a light ground (Fig. 21b, 17b). The excellent condition of the dark blue background in the altarpiece by Bartlēmy d'Eyck also resulted from the black layer consistently applied under the indigo paint.

289. Regularly the effect of binding medium rich paint is exaggerated by the increased transparency of lead-white containing paints due to a chemical change on the surface of the lead-white particles in the oil medium; see references in chapter II, section IV.

Influence of overlying varnish

De Mayerne recorded a remark on using indigo in top paint layers by the portrait painter Paulus Van Somer (c. 1576–1621) who was born in Antwerp and lived several years in Amsterdam before he went to London in 1606. Van Somer was still very uncertain about the colour-fastness of this paint since he warned: *One uses indigo in oil but it dies without the varnish... one must apply the varnish and it will continue* (Fig. 53). Van Somer was the only painter to explicitly link the varnishing of indigo with the preservation of its colour. Yet, as described in chapter II, in the 17th century painters sometimes varnished certain paint areas once they were dry, in order to prevent their discoloration. Presumably the varnish layer applied over the indigo served to inhibit to some extent the penetration of light, especially UV, or maybe even the penetration of oxygen and/or atmospheric pollution. The thin intermediary varnish or medium layers between the indigo paint layers in Hals' portraits may thus have contributed to the preservation of the blue colour. However, whilst his practice appears well suited to painting with indigo, this probably was not intended by the artist. Intermediate layers of binding medium were found in many places on the civic guard portraits, where they did not serve to protect fugitive colours. Hals probably used oiling out layers just to provide a smooth surface on which to easily spread his paint.

Influence of particle size

For white pigments there is an optimum pigment diameter in order to achieve the maximum scattering of light. Parker Mitton (1973) used empirical methods to establish some average values for the optimum diameter of a lead-white pigment; ranging from 0.26 μm diameter for blue light (450 nm) to 0.40 μm diameter for red light (590 nm). The historical paint systems considered here, include many lead-white particles that far exceed this dimension, and cause less than optimal scattering. One might expect that the particularly coarse lead-white used by Hals and Lely, has helped preserve their indigo colours. Microscopic examination of the paint surface of reconstructions that have been subjected to light ageing, indicates that larger indigo particles (larger than several μm) exhibit better colour retention than smaller particles (<1μm). This behaviour can be explained by the greater surface area of the small particles in relation to their mass, and therefore to their greater surface exposure to detrimental environmental influences. In the paintings examined, however, indigo was always applied finely ground with only very few larger particles. Indeed, the fact that the pigment could be particularly finely ground was precisely why the artists chose to use it.

XI. The impact of fading of indigo on the colour harmony and the effect of spatial illusion

The original colour harmony and spatial illusion in a representation often have been seriously disturbed by colour and tonal changes in indigo paint. For instance, in the group portrait by the Haarlem master

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291. Mayerne (1620-46); see Graaf (1958), p. 148 (see note 152).

292. Chapter II, section II. Recipes for a durable application of discolouring pigments in the top paint layer.

293. By the end of the 19th century, the English chemist Arthur Church carried out light ageing tests with indigo paint that had been used pure and mixed with white pigment. His report in *The chemistry of paints and painting* (1890) p. 195; see Carlyle (2001), p. 476, confirms Van Somer's observation: 'As an oil-colour, indigo loses from one-third to one-half of its intensity when exposed to sunlight for five years; in dry being at the same time, either in a greyish or greenish blue... Locked up in oil in or amber varnish it is more slowly changed. The fading is due to oxidation.'


295. Observation by Katrien Keune, FOM institute AMOLF.
(Fig. 1) the intense blue, bright orange and white sashes must have originally stood out strongly against the black costumes of the militiamen. The vividly coloured clothing with distinct tonal contrasts in the modelling optically pushed the figures forward vis à vis the architecture painted in muted grey and earth tones. Presently, the faded grey-blue and the shallow modelling of the indigo sashes agree more with the colour in the background which, however, spoils the suggestion of three-dimensionality intended by the painter. The originally dark coloured tablecloth in Verspronck’s group portrait of 1641 unified the black-dressed regentesses positioned around the table into a tightly knit group standing out clearly against the light beige and brown background (Fig. 2). The convincingly modelled table with its intense green colour contributed to the optical effect of the group being more in the foreground. Currently, the women are situated around a light, flat streaked shape which counteracts the suggestion of depth and the unity of the group portrayed. In the portraits by Johnson and Schalken, the figures garbed in black were originally set against a deep blue background (Fig. 29, 32). In that state, a subtle transition was visible from very dark blue at the left to a lighter, more intense blue at the right. The skin colour of the faces, which were illuminated from the left, must have showed up well against this. In both paintings the right side of the background is now a pale grey, while the left side is still dark, though with a greyish cast. Consequently, the right side of the background seems to be powerfully spotlighted, which contradicts the softer modelling of the faces that appear to be illuminated from the left. The background in Johnson’s painting has become particularly blotchy. Instead of against a neutral deep blue, the figure is now set before an agitated greyish green wall, which presses forward optically in an annoying manner.

No matter how disturbing the above-mentioned effects may be for present-day viewers, most will not experience the loss of spatial illusion in the old works as insurmountable, accustomed as we are to looking at modern paintings in which the spatial proportions are usually anything but unambiguous. The old masters and their contemporary beholders would most likely have been far more disturbed by these changes. The paintings with a serious degradation of indigo paint were all made around the mid-17th century by Northern Netherlandish painters. As described in the previous chapter, in the Northern Netherlands at the time there were distinct views about the pictorial function of colour in which the concept of houding was central. This concept had to do with the subtle balance of strong and weak nuances of colour as well as light and dark tones enabling the spatial relationships between objects in a painting to be clearly defined so that a logical suggestion of three-dimensionality could emerge without sharp divisions or shifts. It follows that even minor colour changes must have already been considered as highly disruptive. After all, even small deviations in colour hue, intensity and value can negate the suggestion of space.

Conclusion and summary

This chapter has presented a broad overview of the use of indigo in Renaissance and Baroque oil paintings and explored the factors which influence the colour’s stability. To this end a range of contemporary texts on the preparation and application of indigo by painters has been reviewed. Oil paintings deriving from various European countries have been visually and chemically examined and paint reconstructions were made that were exposed to artificial light ageing.

Until the second half of the 16th century in Europe a variety of indigo products were used to paint with. Indigo was extracted from leaves of tropical Indigofera species and the native woad plant. Painters also used the froth skimmed off the dyer’s woad or and indigo vat and occasionally a product made from fermented indigo dyed blue wool seems to have been used. Increasing quantities of tropical indigo brought to Europe by the early 17th century resulted in the almost exclusive use of this product in easel painting. It also resulted in the growing importance of indigo as an artist’s pigment. Tropical
indigo, which was sold in the form of lumps, contained widely different types and percentages of organic and inorganic impurities. Paint reconstructions and experiments with indigo in DCM demonstrate that the composition of the indigo pigment i.e. its chemical purity and its particulate state play a role in the rate of degradation of indigo. For the indigo oil paint in traditional paintings, this implies that the colour-fastness can differ considerably, due to differences in the in chemical and physical composition of the indigo pigment preparation. In the course of the 17th century, painters became increasingly aware of that some indigo specimens faded faster than others. The prescriptions in the sources indicate that painters developed sophisticated methods to ‘purify’, ‘calcine’ or ‘prepare’ the indigo lumps. Reconstructions demonstrate that these procedures removed most of the undesirable organic impurities from the pigment leading to a more concentrated pigment. Preparation methods which involve some form of heating of the indigo pigment will also have an influence on the physical state of the resulting indigo pigment. We can now deduce that recipes which prescribe this approach resulted in an indigo that could withstand the conditions in oil paint more effectively.

Until the middle of the 17th century, because of its fugitive character, many painters still considered indigo unsuitable for oil painting. By the second half of the century there was obviously a more positive consideration of the material. This was not only because painters knew to all kinds of methods to ‘purify’ their indigo, but also because they had learned beneficial painting techniques. Their persistence must be associated with the advantageous working properties of indigo oil paint compared to the other blue pigments available. In addition, ultramarine and azurite were very expensive and smalt and blue verditer could also rapidly discolor in an oil medium. It appears that changing opinions regarding indigo’s colour-fastness are reflected in the way the pigment was used in paintings. In the period that painters believed that indigo faded extremely quickly, we find the pigment primarily used either for the application of shaded parts that were painted with other pigments or as underpainting. As trust in indigo grew, we see its use correspondingly increased in pictorially prominent parts of the painting, and in the uppermost paint layer where it was directly exposed to sunlight. Frans Hals is the earliest known artist to use indigo this way in important commissions.

When indigo was used in the upper paint layer, the paint has usually faded considerably today. Examination of paintings and historical texts and paint reconstructions have indicated that the painting technique plays an important part in the colour preservation of indigo. In an oil or egg yolk medium, degradation of indigotin proceeds much faster than in gum, glue or egg white media. Other factors that accelerate the discoloration of indigo paint include the presence of a high percentage of lead-white, low pigment to volume concentration, a thin indigo paint layer and a light paint layer underneath. Sources indicate that 17th-century painters were usually aware of techniques suitable to indigo’s colour preservation. The aim of a durable colour, however, was not always a determinant in their choice of technique.

Fading of indigo has resulted in paintings with lighter and less intense blue colours. Often underlying paint layers are no longer effectively covered and a yellowed oil medium is disturbingly visible. Painters used indigo almost exclusively for depicting folds in drapery, the tonal range of which required them to vary the composition of the paint. Therefore, one indigo passage can exhibit widely different degrees and types of discoloration. Consequently the modelling as conceived by the artist may have flattened or, on the contrary, may have become more pronounced resulting in the loss of specific material effects. Regularly, changes have also negated the original spatial illusion. In this study the various optical changes caused by the degradation of indigo were investigated. It was demonstrated that the knowledge thus garnered, offers the possibility to theoretically deduce the paintings’ original appearance and thus gain insight into the intentions of the painter.