Dyes in History and Archaeology 2022

Abstracts

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Dyes in History and Archaeology 2022 – Abstracts

Cover photos: Sara Norrehed (all but one), Ilse Vuijsters Hammarström (below left).

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Papers

Plantae tinctoriae: the 1759 dissertation on dye plants by Engelbert Jörlin

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Engelbert Jörlin was born in Jörlanda, Västra Götaland County, Sweden on June 11, 1733. In 1757, he enrolled at Uppsala University, where he became one of Carl Linnaeus's most skilled students. In 1759 he defended his dissertation *Plantae tinctoriae* in front of Linnaeus. After several journeys abroad, Jörlin became docent in botany at Lund University in 1769 and was appointed 'extra ordinarie adjunkt' (assistant professor) in 1781. In Gothenburg, he was teacher at the gymnasium and ended his profesional career as rector of the trivial school. Jörlin devoted himself to the cultivation of plants in Sweden, which is reflected in his publications the *Flora macelli hortensis - Svenska Köks- och Kryddegården* (Swedish kitchen and herb garden, 1784) and the *Svenska vilda träds och buskars plantering* (Planting of Swedish wild trees and shrubs, 1801). He died in Gothenburg on June 20, 1810.

His doctoral supervisor was Carl Linnaeus (1707–1778), the Swedish botanist, zoologist, physician and 'father of taxonomy', who formalised the binomial nomenclature, the modern system for naming organisms. In 1735, he received his doctoral degree in medicine with a new hypothesis about the cause of malaria (*febrium intermittentium*) at the University of Harderwijk in the Republic of the Seven United Netherlands. Linnaeus was appointed professor of medicine at Uppsala University in 1741, and rector in 1750. With his ennoblement in 1761 by the Swedish king Adolf Frederick, he took the name Carl von Linné. 185 dissertations written by Linnaeus's students were published in his 10-volume work of *Amoenitates Academicae*.

Jörlin's dissertation is written in Latin and consists of 30 pages (Jörlin, 1759; Jörlin, 1760). After a religious text written in Hebrew, eight pages deal with explanations of terms, the physics of colours, colour mixtures and a general part on the materials studied. Information is given on 108 dyeing materials originating from spermatophytes (91 species), clubmoss (1), lichens (7), gall-producing animals (3), molluscan purple (1) and dye insects (5), including kermes, Polish cochineal, American cochineal and Indian lac. Eighty plants are native to or grown in Europe and some originate from Asia and the

New World. Concerning indigo, Jörlin writes that it has to be bought from foreigners although there were efforts to find an European plant as a substitute. He says of red and purple: "dried pregnant women of COCCUS cacti provide such a red colour that today we can live without the purple of our ancestors... the purple of Antiquity, once sung by the Greeks and Romans, was made by a certain snail". Jörlin arranges the plants according to Linnaeus's new *Clavis Systematis Sexualis* (The key to the sexual system), first published in *Systema Naturae* (1735). He obtained information about the application of dyeing materials from dyers, experiments and the literature, such as Linnaeus's publications: *Systema Naturae*, *Iter Oelandicum* and *Iter Gotlandicum* (*Öländska och Gothländska Resa*, 1745), *Flora Suecica* (Flora of Sweden, 1745), *Fauna Suecica* (Fauna of Sweden, 1746), *Flora Zeylanica*. (Flora of Ceylon, 1747), *Iter Scanicum* (*Skånska Resa*, 1751) and *Species plantarum* (Species of plants, 1753).

The presentation will provide an overview of dyeing materials described in Jörlin's dissertation, reflecting the state of knowledge in the mid-18th century.

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Increased Colorant Import during the 18th Century reflects the Start of the Consumer Society in Norway

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Aim of the study: To shed light on the amount and course of colorant imports in order to:

1. Determine the amount and the use of imported pigments and dyes
2. Assess the start of the consumer society in Norway.

Introduction: During the 18th century, increased use of colorants took place in parallel with increased domestic trade, enlightenment and specialization in society. The increasing amounts of imported colorants supplemented the use of plant dyes and increased house painting and decoration.

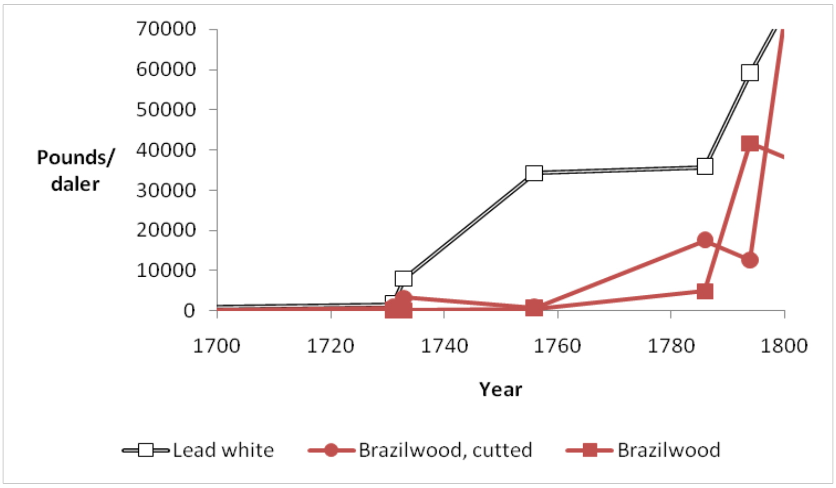
Method: Data on colorant import were obtained from transcribed lists of goods entering Norwegian customs ports by sea and registered for specific years. Figures are based on almost complete registration of colorant imports for the years 1686, 1731, 1733, 1756, 1786 and 1794.

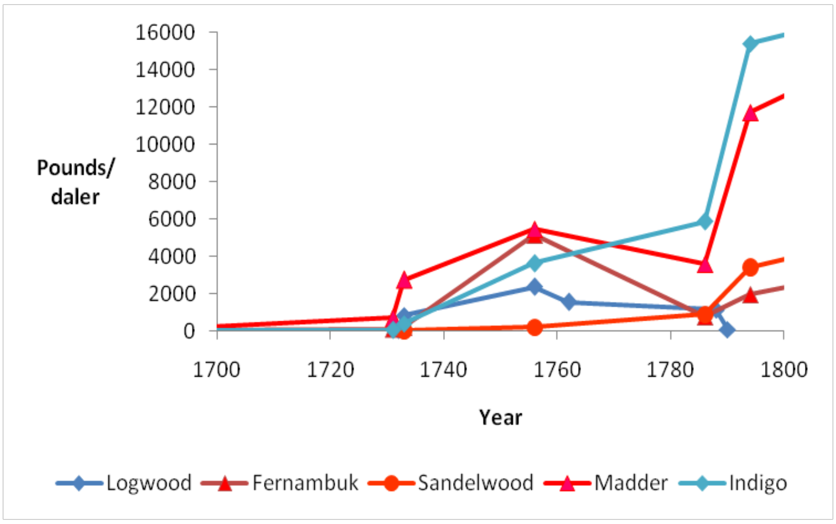
Results:

1. **Imported pigments:** Fifty pigments (including carbon black, chalk, cinnabar, iron oxides, lakes, lead white, ochre, orpiment, Prussian blue, red lead, smalt, stil de grain, turmeric, umber and Spanish green) and 31 binders were imported. Lead white was the dominant colorant, almost exclusively responsible for the use of white pigments.
2. **Imported dyes:** Thirty-three dyes were imported, with brazilwood and expensive indigo accounting for the largest quantities. Due to the higher yield per unit, a majority of textiles may have been dyed blue with indigo. Other dyes imported were red madder, fernambuk, sandalwood and cochineal; blue logwood ("brissel", campecheholt and blauholz); yellow luteolin and yellow annatto; Spanish green and black gallnuts as well as nine mordants (including alum, potash, vitriol and wine stone). Sumac was imported in large quantities and probably mostly used for tanning.
3. **The course of colorant import during the 18th century:** The amounts of imported colorants increased considerably during the middle of the 18th century (called a first chromatic 'revolution'). A further significant increase, as a second chromatic 'revolution', occurred at the end of the century (see figures below).

Discussion: The first chromatic 'revolution' may indicate the beginning of the consumer society in the middle of the 18th century, probably supply-driven by increased trade. The second chromatic 'revolution' took place at the end of the century, probably more demand-driven by 'fashionability' (factors like fashion, styles and social behaviour trends), economic opportunity and preferences, representing a new consumer culture.

Conclusions: Increased imports of dye and pigment, as luxury and consumer products, reflect the increased colouring that took place in Norwegian society during the 18th century. The present study has clarified how imported dyes were introduced during the 18th century. Together with import data for other consumer products, the available data can derive an explanatory model with positive feedback loops, to understand the consumer turn that characterizes the start of the consumer society.





The figures show the course of the amount of import of lead white and dyes during the 18th century

Mapping materials and dyes on historic tapestries using hyperspectral imaging

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Historic tapestry collections have been considered among the most valuable deposits of art from the 15th to 18th centuries in Europe. Historic Royal Palaces (HRP) is the custodian of Hampton Court Palace in London, UK and its important tapestry collection originated primarily by Cardinal Wolsey (1475–1530) and Henry VIII (1509–1547)*. The characterization of tapestry materials is crucial for assessing the condition and formulating suitable conservation treatment strategies for these nationally significant large-scale textiles.

Tapestry is a 'weft-faced' woven textile where the coloured weft threads carry the pictorial intricate design, while contributing to the physical weave structure of the textile. Materials used for the weft are primarily wool and silk dyed in a wide range of colours with natural sources (plants and insects). In the most expensive tapestries metal threads, comprising gold, silver or silver gilt, were also used.

The development of non-invasive analytical approaches for the identification of tapestry materials or the analysis of the natural dyestuffs has progressed over recent years; however, these methods primarily rely on point analysis. Hyperspectral imaging has emerged as a promising analytical method of artworks due to its potential in combining non-invasive analytical capabilities and imaging, allowing the survey of the entire surface, or of a large area of the surface of an artwork, which is a highly significant application for historic tapestries.

This project deployed a high-resolution ClydeHSI Art Scanner, which was used with a push-broom visible and near-infrared (VNIR; 400–1000 nm) or near infrared (NIR; 900–1700 nm) hyperspectral camera. Initial testing focused on the characterization and mapping of the different materials used on historic tapestries (wool, silk, metal threads). To facilitate the dye characterization, a collection of wool and silk samples dyed during the Monitoring Damage on Historic Tapestries (MODHT) EU research project, with recipes based on medieval practices, were used. The samples measured using the system and the data collected formed an external reference library, including the type of the natural dyes and mordants used during their production. Ten fragments from the Historic Tapestry Fragments Collection housed at the HRP Heritage Science Laboratory were initially tested using hyperspectral imaging to define the optimum operational conditions for the instrument, while analytical capabilities were also confirmed with other methods, such as FTIR, and pXRF. Finally, the outcomes of the on-site deployment of this analytical instrumentation for the characterization and analysis of 16th-century tapestries on display at Hampton Court Palace will be discussed.

* These tapestries are part of the Royal Collection

Application of DESI–MS for dye analysis of historical textiles

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One key issue in the dye analysis field is the need to sample culturally significant objects. This issue is amplified when working with more fragile objects, such as historical textiles, where sampling is often impossible without threatening the structural integrity of the object. To circumvent the impact of dye analysis, micro-invasive or non-invasive analytical approaches have been recently developed to the study of museum collections (Tamburini and Dyer, 2019; Sandström *et al*., 2021; Chavanne *et al*., 2022). However, the application of non-invasive techniques, such as fibre optic reflectance spectroscopy (FORS), still requires significant modelling for data interpretation due to the complexity of dyestuff mixtures (Chavanne *et al*., 2022).

Mass spectrometry is one of the main techniques used in heritage science due to its high sensitivity and selectivity, but its use is still restricted by the sampling requirement. The development of ambient mass spectrometry techniques, such as direct analysis in real time mass spectrometry (DART-MS) and desorption electrospray ionisation mass spectrometry (DESI-MS) (Takáts *et al*., 2004), bypass the need for sampling, enabling the analysis of hitherto inaccessible objects, without reducing the information gained from the analysis. Although DART-MS has successfully been applied for dye analysis (Selvius DeRoo and Armitage, 2011; Armitage *et al*., 2019), DESI-MS was only recently developed for the study of ink in historical manuscripts (Newton, 2019) and is yet to be fully introduced for the analysis of dyes in historical textiles.

A DESI source was built and optimised for dye analysis at the University of Edinburgh. The source has the sprayer holder mounted onto positioners for manual control of the x-, y- and z-axes and a rotation mount for manual adjustment of the sprayer angle. A Bruker 7T SolariX FT-ICR-MS was used for all analyses. Initial testing and optimisation were undertaken on silk, wool and cellulosic samples dyed with a range of natural and early synthetic dyes. The versatility of the DESI technique was tested on a variety of objects, including embroidery samplers from 1800–1838 and a reference book by the dye chemist Adolf Lehne dated to 1893. Overall, the project has demonstrated the applicability of DESI-MS for dye analysis of historical textiles.

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The study of Chinese dyes recipes on silk from the Ming and Qing dynasties for conservation purposes

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The paper presents three Chinese manuscripts containing natural dyes recipes and two containing synthetic dyes carefully analyzed. These five documents together represent most of the dyes one can find on Chinese silk exported to Europe and America for over 300 years (Zurndorfer, 2004). The study of these materials allows western conservator-restorers to better understand the Chinese textile heritage and the degradation process they suffer, as well as to compare the dyes of other places during the same period.

The manuscripts of natural dyes are 多能鄙事 (*duoneng bishi*) from 1541, 天工開物 (*tiangong kaiwu*) from 1637, and 布經 (*bu jing*) from 1795 to 1850. The first contains over ten mentions of dyes and more than eleven recipes where brown tones predominate. It has a more limited color range compared to the two other documents. The dyes used are made up of easily accessible dyestuffs such as teas, black beans, and lotus leaves. The author pays special attention to the mordanting process as the fundamental step toward a good color. In the 天工開物, the bluish and reddish tones are prioritized. The chapter on textiles is subdivided into five sections, in which the first distinguishes 19 reddish colors. New dyestuffs appear and a more complex color palette can be appreciated. The Book of Clothes (*bu jing*) is the most descriptive among them. A better extraction method of the dyes and the sophistication of baths and equipment can be observed. More than 60 types of reds, blues, greens, yellows, oranges, purples, blacks, grays, whites, and browns are registered. The most used additives described in these historical records are potassium alum ($KAl(SO4)_2.12H_2O$) and green vitriol ($FeSO_4$), while the most common dyes are sappanwood (*Caesalpinia sappan* L. = *Biancaea sappan* (L.) Tod.), followed by safflower (*Carthamus tinctorius* L.), indigo (*Indigofera tinctoria* L.), and sophora (*Sophora japonica* L. = *Styphnolobium japonicum* (L.) Schott).

The information about synthetic dyes was extracted from customs documents and foreign company catalogs (Liu *et al.*, 2016). The first synthetic dyes detected in China on silk were from England back in 1870. The results show that mainly blue (specifically synthetic indigo), green and violet colors were imported. This is probably because they are difficult to obtain in natural dyes. In fact, investigation of synthetic dyes in China is a difficult task and one of the reasons is the randomness with which they named the colors that arrived.

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'Caillet de Recetes et Segrets', 'Livret contenant la manière de bien gouverner le guesde (…)': two un-published French dyers' books from the 17th century

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In January 2022 in Lyon, the National library for Art History, housed by the Institut national d'histoire de l'art (INHA), Paris, bought a rare manuscript untitled 'Caillet de Recetes et Segrets'. Bearing on its first page the indication 'Livres pour servir à la tainture 1649', this manuscript comprises 37 pages and 65 recipes for dyeing wool and silk as well as leathers and skins. After being transcribed, this collection of dyeing recipes seems to have been written down by a professional scribe, without being familiar with the products and processes. Recipes are quite diverse, unequally detailed.

During the same period, we transcribed another dyers' manuscript, 'Livret contenant la manière de bien gouverner le guesde et préparer le pastel pour teindre en bleu. Avec autres teintures tant escarlattes rouges qu'autres, telle que je les ay veu faire et pratiquer chés Monsr Chenevix en la bonne teinture des Gobelins au faubourg St-Marcel à Paris, es années 1666 et 1667', Bibliothèque centrale du Muséum national d'histoire naturelle, Paris, Ms RES 2018. Comprising 86 pages, this unpublished dyer's book is of great significance, testifying to dyeing processes performed in the faubourg Saint-Marcel of Paris by the middle of the 17th century among the Gobelin family (Etienne Gobelin, Paul Chenevix) and their neighbours (Pierre Masson). Probably also written down by a professional scribe, this dyer's book is extremely informative, giving precise quantities of dyestuffs, mordants and other products, with regards to yardages to dye. In 1750, Jean Hellot, a chemist belonging to the Royal Academy of Sciences and working as Inspector of textile manufactories for the French Kingdom, incorporated in his famous book on dyeing the entirety of the recipes concerning the woad vat, with very few changes from the manuscript, therefore attesting to its quality (Hellot, 1750).

Quite different from one another, these manuscripts are in some way related by a quotation. At the beginning of the 1667 manuscript, 'Alexis piedmontois' is mentioned among authors having contributed to history of dyeing processes (Alessio Piemontese, 1555; Eamon, 1994). Referring to the Renaissance books of secrets to which the 1649 'Caillet de Recetes et Segrets' is affiliated, the 1667 'Livret' appears on the contrary to be the very first French dyeing treatise belonging to a new type of scientific literature which has been recently studied and designated (in Latin) as *ad artem redigere* (art reduction) (Dubourg Glatigny and Vérin, 2008; Sarda and Eude-Devaux, 2023).

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Eise Eisinga's celestial blues: archival documentation and the revival of woad blues in the Netherlands

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The Dutch amateur astronomer Eise Eisinga (1744–1828) is famed for the world's oldest working planetarium that is housed in the marvellous blue painted interior of his former living room. However, the heavens did not set a limit to Eisinga's knowledge of sky-blues. A new biography that highlights Eisinga's professional entrepreneurship as a successful wool producer points us towards a much less known documentation of Eisinga's remarkable expertise in celestial blues (Dijkstra, 2021). This paper presents and discusses two noteworthy documentations of Eisinga's chromatic craft knowledge as a *blauwverver* (blue dyer) that have survived in his own hand: a small handwritten collection of dye recipes dating from 1808 and a single sheet with a set of labelled blue dyed wool samples that have been dated to 1820, when Eisinga won a prize for his wool at a fair in Belgium (HS 1162, 1808; Eise Eisinga Archief Nr. 6, 1820).

The recipes convey knowledge of the art of blue vat dyeing with the indigenous woad plant (*Pastel*) and additions of imported indigo pigment. Woad vat dyeing had been brought to perfection in Medieval Europe, but faded into oblivion when the indigo sea trade and import of dyewoods expanded explosively in the seventeenth century. Only a few Dutch recipes of this precious art have survived. We will compare Eisinga's recipes with a rarely detailed description of woad vat dyeing in Dutch from one of the oldest surviving printed dyer's handbooks, *Tbouck va Wondre* (Antwerp, 1513) (*Tbouck va[n] wondre*, 1513; Frencken, 1934). Eisinga's recipes date from a later period when woad vat dyeing saw a revival in Europe due to an embargo on imported indigo under Napoleon (Grab, 2003). Today we can witness another renaissance of woad blue dyes as testified in the official acknowledgement of this art as immaterial cultural heritage in France (Fiche d'Inventaire du Patrimonie Culturel Immatériel en France, 2021).

We will present the first results of historical-material research of the archival sources and discuss the interest of the artist and activist Claudy Jongstra and the Pleed wolcommunity in Friesland (6) in reviving wood-blue dyeing in the Netherlands today (Schwab, Stichting Pleed and Koninklijk Eise Eisinga Planetarium, 2021), and dye experiments that have been conducted at Studio Claudy Jongstra, close to Eise Eisinga's place of birth and the city of Franeker where he run his *wolkammerij* (wool company) and built his planetarium.

The research project is an interdisciplinary collaboration between Dutch and Belgian universities, the Cultural Heritage Agency of the Netherlands, the Koninklijk Eisinga Planetarium and Frisian archives, and the renowned artist and activist Claudy Jongstra, a specialist in plant-based wool dyeing.

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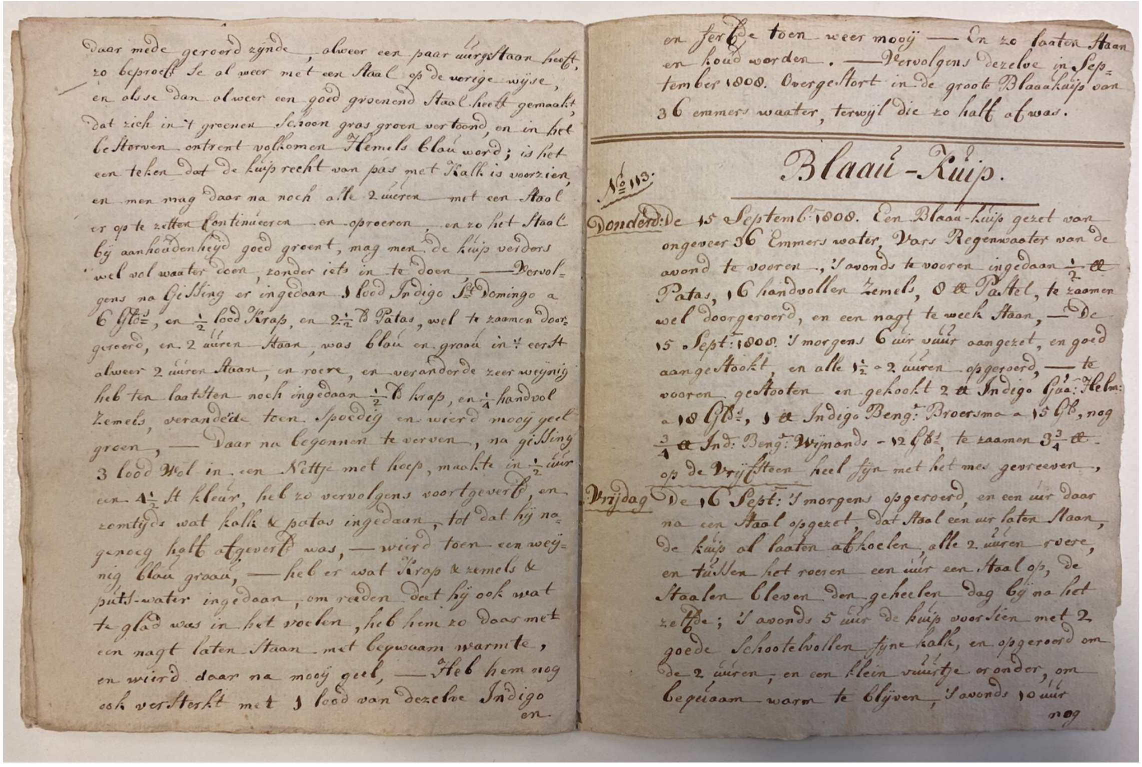


Daar mede geroerd zynde, alweer een paar uurgstaan heeft,
zo beproeft Se al weer met een Staal op de vorige wyse,
en alsse dan alweer een goed groenend Staal heeft gemaakt,
dat zich in 't groenen Schoon gras groen vertoond, en in het
bestorven ontrent volkomen Hemels blau word; is het
een teken dat de kuip recht van pas met Kalk is voorzien,
en men mag daar na noch alle 2 uuren met een Staal
er op te zetten Continueeren en oproeren, en zo het Staal
by aanhoudenheyd goed groent, mag men de kuip verders
wel vol waater doen, zonder iets in te doen — Vervol=
gens na Gissing er ingedaan 1 lood Indigo St Domingo a
6 Gld:, en ½ lood Krap, en 2½ lb Patas, wel te zaamen door=
geroerd, en 2 uuren staan, was blau en graau in 't eerst
alweer 2 uuren staan, en roere, en veranderde zeer weynig
heb ten laatsten noch ingedaan ½ lb krap, en ¼ handvol
Zemels, veranderde toen Spoedig en wierd mooy geel
groen, — Daar na begonnen te verven, na gissing
3 lood Wol in een Nettje met hoep, maakte in ½ uur
een 4½ St kleur, heb zo vervolgens voortgeverft, en
zomtyds wat kalk & patas ingedaan, tot dat hy na=
genoeg half afgeverft was, — wierd toen een wey=
nig blau graau, — heb er wat Krap & zemels &
puts-water ingedaan, om reeden dat hy ook wat
te glad was in het voelen, heb hem zo daar met
een nagt laten staan met bequaam warmte,
en wierd daar na mooy geel, — Heb hem nog
ook versterkt met 1 lood van dezelve Indigo
en

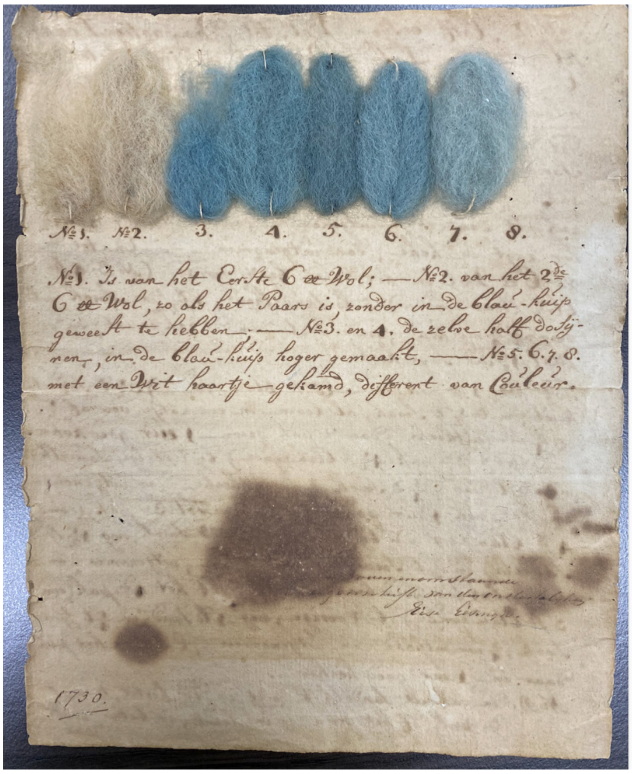
en ferfde toen weer mooy — En zo laaten staan
en koud worden. — Vervolgens dezelve in Sep=
tember 1800. Overgestort in de groote Blaaukuip van
36 emmers waater, terwyl die zo half af was.

No 113. Blaau-Kuip.

Donderd: De 15 Septemb: 1800. Een Blaau-kuip gezet van
ongeveer 36 Emmers water, Vars Regenwaater van de
avond te vooren, 's avonds te vooren ingedaan ½ lb
Patas, 16 handvollen Zemels, 8 lb Pastel, te zaamen
wel doorgeroerd, en een nagt te week staan, — De
15 Sept: 1800 's morgens 6 uur vuur aangezet, en goed
aangestookt, en alle 1½ a 2 uuren opgeroerd, — te
vooren gestooten en gekookt 2 lb Indigo Gua: Helm:
a 18 Gld:, 1 lb Indigo Beng: Broersma a 15 Gl, nog
¾ lb Ind: Beng: Wijnands - 12 Gld:, te zaamen 3¾ lb -
op de Vryfsteen heel fyn met het mes gevreeven,

Vrijdag De 16 Sept: 's morgens opgeroerd, en een uur daar
na een Staal opgezet, dat Staal een uur laten staan,
de kuip al laaten afkoelen, alle 2 uuren roere,
en tussen het roeren een uur een Staal op, de
Staalen bleven den geheelen dag by na het
zelfde; 's avonds 5 uur de kuip voorsien met 2
goede Schootelvollen fyne kalk, en opgeroerd om
de 2 uuren, en een klein vuurtje er onder, om
bequaam warm te blyven, 's avonds 10 uur
nog

HS 1162, Tresoar, Leeuwarden, The Netherlands; photo by Jenny Boulboullé



No 1. No 2. 3. 4. 5. 6. 7. 8.

No 1. Is van het Eerste 6 lb Wol; — No 2. van het 2de
6 lb Wol, zo als het Paars is, zonder in de blau-kuip
geweest te hebben. — No 3. en 4. de zelve half doSyj-
nen, in de blau-kuip hoger gemaakt, — No 5. 6. 7. 8.
met een Wit haartje gekamd, different van Couleur.

1730.

Eise Eisinga Archief Nr. 6, Gemeentearchief Waadhoeke, Franeker, The Netherlands, photo by Jenny Boulboullé

Determination of the Malacological Provenance of Archaeological Purple Pigments via the "Di-Mono" Index

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About 30 years ago, Jan Wouters and André Verhecken published the first HPLC analyses of purple pigments produced from certain sea snail species and successfully separated four to five major components of those pigments(Wouters and Verhecken, 1991; Wouters, 1992). With that breakthrough, advancements in HPLC analyses have shown that the purple pigment can consist of about 10 colorants constituting the following groups (Koren, 2008):

- Indigoids: blue indigo (IND), violet 6-monobromoindigo (MBI), reddish-purple 6,6'-dibromoindigo (DBI);
- Indirubinoids (all reddish-crimson): indirubin (INR), 6-monobromoindirubin (6MBIR), 6'-monobromoindirubin (6'MBIR), 6,6'-dibromoindirubin (DBIR);
- Isatinoids (yellowish): isatin (IS), 6-bromoisatin (BIS).

With the powers of such multicomponent HPLC analyses, one of the main research questions that arose in this area was whether we are able to determine which malacological species produced these archaeological pigments and dyes. Fortunately, the answer is in the affirmative. Though principal component analysis (PCA) is a powerful statistical tool that has been used in the analysis of these components (Karapanagiotis *et al.*, 2013), it contains many parameters and subjectivity is involved in choosing the more important ones. There is a very simple formulation that was first published in 2008 (Koren, 2008), which has now been expanded to include the results of more recent analyses of archaeological purples. This parameter is known as the 'Di-Mono Index' and is simply the ratio of the peak areas of DBI relative to MBI, evaluated at the standard wavelength of 288 nm, which has been used for such peak calculations. This index is a bonafide simple parameter and not only can it determine the species that was used (nearly always the *Hexaplex trunculus* sea snails), but also whether the IND-rich or the DBI-rich varieties, or both, of *H. trunculus* were used to produce the purple as a paint pigment or as a textile dye.

This talk will discuss these results.

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Ancient Chromophores and Auxiliaries: Phrygian Colorants from Tumulus MM at Gordion, Turkey, c. 740 BCE

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This paper discusses colorants found in Tumulus MM, the tomb of

King Midas or his father, at Gordion, the capital of the Phrygian kingdom. Chromophores, colorants, and auxiliaries are preserved largely independent of the textiles they once colored (Ballard *et al.*, 2010). The Tumulus MM textiles are now fragmentary due to the degradation processes that occurred inside the tomb chamber (Blanchette, 2010).

For DHA 26, held in Vienna, Austria, in 2007, we discussed a group of golden-yellow fragments from Tumulus MM that appeared to be tabby cloth but were skeletal lattices of goethite, αFeOOH (yellow ochre), as identified by FTIR, with SEM/EDS, XRD with molybdenum Kα radiation, NIR, and Raman spectroscopy. The 'dyeing' has been replicated using a patented method that appears to involve a controlled redox reaction (Kuhn, 1998; US patent #6,022,619, 2000; US patent #6,764, 969, 2004), based on our preliminary experiments.

Amidst the goethite lattices, some skeletal fragments were green, with near-black lines within the yarn spiral, identified as indigo by FTIR at the time. Other masses with colorations of red, orange/brown, and purple with deep red veins did not yield identifiable inorganic coloration profiles with SEM/EDS. A purple fragment [2007-Tx-6 front] was assayed by ICP-MS as a mordant or bromine, but neither could be found (Dussubieux and Ballard, 2005).

Recently, direct analysis in real time mass spectrometry (DART-MS) enabled us to successfully detect organic colorants. For one fragment, indoxyl, isatin, indigo, and leuco-indigo were identified. One striated red-to-brown mass [2007-Tx-3] contained alizarin, purpurin, xanthropurpurin, lucidin, and other madder substituents; it also contained indigo/isatin but not indoxyl or leuco-indigo. A beige-brown mass [2007-Tx-5] and a darker mass [2007-Tx-10] contained alizarin, xanthopurpurin, rubiadin, and lucidin, but no purpurin or indigo-related compounds. The purple [2007-Tx-6] shared the madder analogues of the browner hues. The versatility appears related to that found in later Anatolian pile carpets and flat weaves (Böhmer, 1987; Schweppe, 1989). Our new analyses confirm that the Phrygian textile colorists were indeed superb, creative dyers.

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Heritage science contribution to the understanding of meaningful khipu colours

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Khipus have usually been described as 'Andean knotted records', but they are much more than knotted cords: a great part of their encoded information resides in the khipus' incredible colours. If recent research disclosed relational meanings of colourful cords (Hyland 2016), still no physical-chemical analyses have been carried on Andean khipus to date.

With the advent of data science, urgent calls for digitisation and computational analysis of khipus are raised in order to decipher khipu writing (Medrano 2021). However, colour remains a largely uncharted territory: taphonomic processes and conservation practices have surely altered the original khipu colours and with that our possibility to understand a vast part of the khipus' meaning, but these issues have never been systematically addressed before. No standard protocol for recording khipu colours has been developed to date.

This paper aims to present preliminary results of the project *Meaningful materials in the khipu code* with the intent to start shedding light on the difficulties and possibilities of investigating khipu colours and dyestuffs. Starting with the study of two Wari (pre-Inka) khipus conserved at the Museum of World Cultures in Gothenburg, this work will demonstrate how the collaboration between heritage scientists and textile and khipu experts, with the support of European museums and IPERION-HS laboratories all over Europe, can create new opportunities for the understanding of dyeing technology in the khipu code. The X-ray fluorescence (XRF) and technical photography maps have already allowed us to rethink critically the data collected with morphological analysis. Further chemical analyses, using micro-XRF mapping and high-performance liquid chromatography (HPLC) with UV-Vis (diode array detector) and electrospray ionisation–mass spectrometry, of dyestuffs and mordants on samples from seven khipus will be carried out in summer 2022. These results will be included in this paper in order to elaborate a new, critical and scientific approach to the understanding of khipu dyeing technology and interpretation of this colourful writing system.

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Recreating Dye Results From Stockholm and Leyden Papyri Methods

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The fourth-century Stockholm and Leyden Papyri are the world's oldest surviving written records of dye methods. Yet, outside of some limited academic research, they have not been substantially explored from a practice perspective (Kreuzner, 2013; Martinez Garcia and Armero, 2013). The most complete English language translation, by Professor Earle Radcliffe Caley in 1926–7, includes some limited interpretation of materials and methods from the author's perspective as a chemist. However, to date, there have been no comprehensive efforts to interpret these methods from the perspective of knowledgeable natural dye practitioners (Caley, 2008). The aim of this project is to bring together a global network of dyers and textile specialists, whose experience working with a wide range of ingredients and processes and collective understanding of historical and contemporary dye practices provides unique and valuable insight into these ancient papyri. There is a sometimes dismissive assumption that these methods are 'alchemical', and intended to mimic, for example, the very expensive Murex purple-dyed fibres of the time by using colourants that were much less expensive and reliable. We will show that some of these methods produce results with good colour fastness, and may have been used less to deceive and more to provide affordable alternative dyed goods that could be redyed as necessary. In this study, 21 natural dye practitioners on four continents attempt to recreate 42 of the 79 dye-related methods across the two papyri to produce a range of final colours. Methods tested include those related to cleaning fibres, mordanting and dyeing. Where historical ingredients are not available, substitutions have been identified and incorporated into some of the methods. While wool and linen were the most commonly used fibres in fourth-century Egypt, in this study many methods have been interpreted using additional fibre types commonly used by contemporary natural dyers. There are challenges in interpreting these ancient methods in translation, and that were abbreviated even in their original language. Our understanding of archaic terms for ingredients, and of recreating these methods using modern ingredients and equipment, will be described, along with the final colours achieved and lightfast test results.

Stockholm & Leyden Papyri Dye Recreation Project
Figure 1: A subset of study results

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Yellow Dyes of Historical Importance. V. A handful of weld yellows from the 18th-century recipe books of French master dyers Antoine Janot and Paul Gout

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Antoine Janot and Paul Gout were 18th-century master dyers specialised in piece-dyeing of fine wool broadcloths manufactured in Languedoc (South of France) for exportation to the Levant. They wrote treatises similarly entitled *Mémoires de Teinture* (Memoirs on Dyeing), illustrated with dozens of dyed textile samples. Janot's is dated 1744, Gout's 1763 (Cardon, 2016; Cardon, 2019; Cardon and Brémaud, 2020; Cardon and Brémaud, 2022). When analysing Janot's recipe book, one cannot help but notice the considerable percentage of recipes for yellows and light browns, almost a fourth of the total recipes (Figure 1). Most greens and some oranges were also produced by mixing blue/red with a yellow dye. In Gout's book, weld figures in 33 % of the 157 recipes still illustrated with samples. Hence, yellow dyes are a striking presence in these books.

The weld (*Reseda luteola* L.) yellows of both master dyers belonging to recipes described as *Jaune* (Yellow) were reproduced. The influence of the ingredients, in both the mordanting and the dye bath was assessed, and the timings for both baths, which in many recipes are not clear, were tested. This will provide key knowledge on the technological processes for dyeing with weld from these 18th-century French masters.

The resulting reference samples were preliminarily analysed by microspectrofluorimetry, to set the foundations upon which a database of reconstructions of yellow dyes will be built and analysed through a methodology already developed and validated for identification of red lake pigments (Nabais *et al.*, 2021). Their chromatic specifications, expressed in the CIEL*a*b* and CIE LCh° systems, were compared with those in the Memoirs. At a later stage, these references will also allow us to test ageing conditions, for a better understanding of the photostability of these molecules (Sharif et al., 2022).

This first approach to the reconstruction of the dyeing processes of Antoine Janot and Paul Gout will, in the long term, feed the design of a Map of Influences, clarifying the knowledge shared between the French and Portuguese Wool Manufactories of the 18th and 19th centuries.

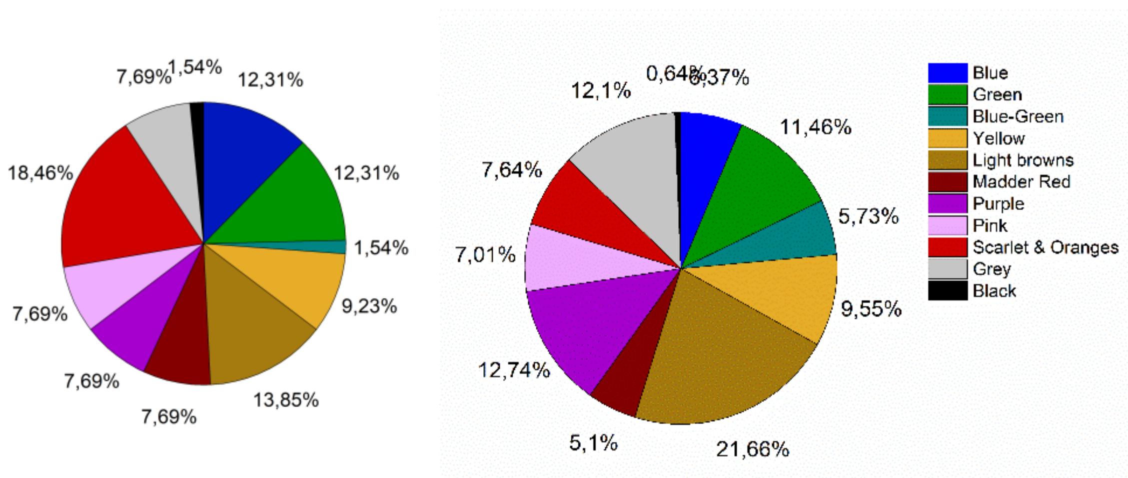

Figure 1. Wheel maps of the recipe percentage per colour from the recipe books of, left, Antoine Janot and, right, Paul Gout.

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Dye identification in mounting textiles of late Joseon Korean paintings

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In the framework of the Amorepacific Project at the British Museum sponsored by the Amorepacific Corporation to study and conserve historic and contemporary Korean pictorial art, three Korean paintings have been investigated with the aim to support their conservation and obtain information about the dyes used in the mounting textiles and other mounting elements.

The paintings include a rare example of late 18th-century traditional Korean portraiture (accession number 1996,0329,0.1), representing *Ch'ae Che-Gong* (1720–1799), Prime Minister of Korea under King Ch'ongjo (reign 1776–1800) of the Joseon dynasty (1392–1910), and made in 1789, possibly by court artist Yi Myong-Gi (ca.1760–1820); a late 19th-century two-panel screen silk painting of *Pyeongsaeng-do – Scenes of daily life* (accession number 2016,3028.1); and a late 19th-century twelve-panel screen silk painting representing *the Five Confucian virtues* (accession number 1957,1214,0.1).

The mounting textiles were investigated non-invasively by fibre optic reflectance spectroscopy (FORS), and the results guided a minimally invasive sampling campaign. Fourteen samples were analysed by high pressure liquid chromatography with diode array and tandem mass spectrometry detectors (HPLC–DAD–MS/MS), leading to the identification of the natural dyes indigo, sappanwood and safflower in the mounting elements of the 18th-century *Portrait of Ch'ae Che-Gong*. These results confirmed the non-invasive observations and supported the hypothesis of the mounting elements being original and contemporaneous with the painting.

Both natural and synthetic dyes were identified in the mounting textiles of the panel screens. Among the synthetic dyes, fuchsin (C.I. 42510), methyl violet (C.I. 42535) and an aniline blue, most likely Nicholson's blue (C.I. 42780), were identified. These are early synthetic dyes discovered between the end of the 1850s and the beginning of the 1860s, suggesting that the silk textiles are likely to have been dyed significantly before the end of the 19th century. The hypothesis was also supported by the detection of interesting mixtures of natural and synthetic dyes, such as fuchsin and sappanwood, and fuchsin and tannins, to obtain brownish shades of red and pink. This may also suggest that the dyeing occurred at a time when synthetic dyes had just started to be introduced, hence dyers were still experimenting with these newly available colours.

18th-century glazed brocaded worsted satins Hemdroks from Zeeland

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Two 18th-century hemdroks (long-sleeved waistcoats) from the collection of the Zeeuws Museum were examined in order to determine the provenance of the fabric. The fabric is described by some as 'damask', but is actually 'brocaded satin'. Both hemdroks are woven entirely with worsted (wool) yarn. However, hemdrok M96-029 has one thread lancé system made of worsted yarn plied with cotton. Both hemdroks have the same kind of flower pattern woven in satin weave, but the fabrics differ in colour. The hemdroks were both tailored in Zeeland, the Netherlands, but are confected in a different fashion.

Two studies were conducted: the first study aimed at determining whether the dyes and mordants used corresponded to dye mixtures found in 18th-century sample books from the Norwich textile industry. The second study aimed at assessing whether beeswax was used in the gloss finish applied to the fabric after weaving and to understand the composition of the glaze.

Firstly, technical photography was applied using multi-spectral cameras (VSC-8000 and Crime-Lite) to draw up a sampling plan. For the gloss-finish study, Atmospheric Pressure Solids Probe Analysis with High Resolution Mass Spectrometry (ASAP-HRMS) was used, and the results were visualized with Kendrick Plot analyses. For the dye analyses, high-performance liquid chromatography with photodiode array detection and high-resolution mass spectrometry

(HPLC–PDA–HRMS) was used.

Finally, for the mordant and fibre analyses an electron microscope with energy-dispersive X-ray spectroscopy (SEM–EDX) was used.

The ASAP-HRMS analyses showed that the gloss finish of both hemdroks contained beeswax. In addition, the presence of a natural resin and probably polysaccharides was suggested. This mixture has also been found in other glazed fabrics from Norwich.

HPLC–PDA–HRMS and SEM–EDX showed that hemdrok M09-151 was dyed with indigo and monosulphonated indigo carmine (also known as Saxon blue), probably mordanted with an aluminium salt; orchil with an aluminium mordant; quercitron and Indian madder with a tin mordant; lac dye with zinc sulphate, tin and aluminium salt mordants, and cochineal with a tin and an aluminium mordant (Barry red).

Hemdrok (M96-029a) was dyed with orchil and di-sulphonated-indigo, indigo, cochineal and weld, with mordants like aluminium, tin and mixtures of these two.

Hemdrok (M09-151) was made sometime after the early 1790s because of the use of quercitron extract, a dyestuff that became popular around this time. Hemdrok (M96-029a) was probably made after 1784–5 because of the dyes and mordants found, and because it coincides with the introduction of the manufacturing of cotton goods in Norwich.

©Zeeuws Museum Inv. No. M09-151

©Zeeuws Museum Inv. No. M96-029a

It is highly likely that both brocaded satins were manufactured in Norwich. Another possible location is Spitalfields in London, which produced some worsted stuffs in the eighteenth century.

Transition from natural to early synthetic dyes in the Romanian traditional shirts decoration

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The traditional shirt (*ie*) is the most well-known element of the Romanian anonymous textile art. Apart from the aesthetic and utilitarian roles, it has strong symbolic significances, mainly through the colours used for decoration. Very recently, the traditional shirt with decoration over the shoulder (*ia cu altiță*) was introduced as a Romanian identity element in the UNESCO Heritage (National Inventory of Active Intangible Cultural Heritage Elements, 2020). Depending on the ethnographic areas, the traditional shirt with decoration over the shoulder has acquired special expressive particularities over time. A special place is taken by that from Valea Hârtibaciului, an area in the very centre of Romania. Sober in appearance through the large fields of white canvas, it is discreetly decorated in the sleeve bracelets, over the shoulders and the neck, with elaborate embroideries. Although the colour range and decoration motifs remain unchanged in time, evolution in the materials used and a subtle transition from natural hues to more strident alternatives were observed in the late 19th and early 20th centuries.

For the present study, samples were taken from representative objects in the collections of the ASTRA Museum, Sibiu and Ethnographical Museum, Brasov, documented as belonging to the area of Valea Hârtibaciului and dated to the last decades of the 19th century and beginning of the 20th century. The textile materials and the dyes used for the shirt embroideries were monitored.

Fibres identification was made by optical microscopy and infrared spectroscopy (FTIR-ATR). Dye analysis was performed by liquid chromatography with UV-Vis (diode array) detection while part of the samples were also analysed by liquid chromatography with mass spectrometric detection (LC–DAD–MS). Dyes were extracted from the fibres by acid hydrolysis. Identification was based on data collected on standards, dyes and dyed fibres. For the early synthetic dyes, a dedicated library of references was built, which includes information for the most relevant representatives used between 1850 and 1900, the so-called Helmut Schweppe list (Ballard, 1991). According to the study, in the last decades of the 19th century, natural dye sources such as dyer's broom, madder, Mexican cochineal and indigoid dyes are gradually replaced by early synthetic dyes: fuchsine (1856), methyl violet (1861), synthetic alizarin (1871), brilliant green (1879), brilliant yellow (1886), rhodamine B (1887) and others.

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Unveiling the composition of native Japanese dye plants by a combined analytical protocol

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Plants have a great importance in Japanese culture and the great variety of available vegetal species has been and still is widely employed in traditional medicine, body treatments, food flavour, fashion and textile dyeing. With regards to dyeing processes, recipes have been passed from generation to generation and the meaning behind the choice of dyes and mixtures to attain a desired hue are still relevant aspects in traditional Japanese textile artistry. Thus, the development of methods aiming at identifying the dyeing source in historical textiles, and the build-up of a suitable and wide database of native Japanese dyeing materials are fundamental to preserve such information.

In this work, the major and minor constituents of several selected Japanese colouring sources extracted from roots, bark, leaves, dried flower buds and fruits have been characterised by a combined analytical approach. A protocol based on surface-enhanced Raman spectroscopy (SERS), able to determine the wide variety of chemical species (naphthoquinones, alkaloids, polyhydroxyflavonoids, diarylheptanoids, allylbenzenes and tannins) contained in these vegetal materials, was developed, and the obtained data corroborated with the more conventional liquid chromatographic and mass spectrometric method (HPLC–MS). Pyrolysis coupled with gas chromatography–mass spectrometry (Py-GC–MS) and evolved gas analysis coupled with mass spectrometry (EGA–MS) have also been applied to investigate the potentialities of these fast and micro-destructive methods in the determination of dyeing constituents and in disclosing highly thermolabile compounds possibly present. Lastly, the dye content in an historical Japanese cloth was assessed using the different techniques.

The comparison of results collected with the presented analytical protocol aims at highlighting the strengths and limits of each technique, enabling us to provide a highly detailed description of the chemical content of the plants under study and contributing to the enrichment of the botanic sources database fundamental for Japanese colorants and dyestuffs determination.

Using HPLC-HRMS for the analysis of organic colourants in Japanese woodblock prints

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In this study, the application of high-pressure liquid chromatography-high resolution mass spectrometry (HPLC–HRMS) was explored for the detection and identification of organic dyes in Japanese woodblock prints from the Edo (1603–1868) and Meiji (1868–1912) periods. The presence of organic dyes, in particular yellow and red hues, has proven to be challenging to detect using non-invasive approaches, such as multispectral imaging (MSI) and fibre optic reflectance spectroscopy (FORS). This is due to intrinsic limitations of these techniques, but also to the sensitivity of organic dyes to environmental conditions, their disposition to fade as well as their use in mixtures and overprinting with other colourants.

Firstly, a series of reference mock-ups was prepared to study the feasibility of the technique and to identify a sampling protocol and preparation workflow. Plant-based red and yellow dyes from the palette of colourants used in the Edo period were chosen (Villafana and Edwards 2019). Turmeric (*Curcuma longa*), gamboge (*Garcinia hanburyi*), amur cork tree (*Phellodendron amurense*), pagoda tree (*Sophora japonica*), Japanese madder (*Rubia akane*) and safflower (*Carthamus tinctorius*) were extracted from their plant sources using traditional extraction methods and printed onto Japanese *hosho* paper. Samples removed from the mock-ups consisted of raised single paper fibres from the recto. HPLC analyses were performed on unaged and artificially photo-aged mock-ups, to evaluate detection limits of the instrument and determine the minimum sampling requirements (number of fibres) for each colourant under investigation.

The developed protocol and method of extraction were then successfully applied to the identification of turmeric and safflower on a facsimile reproduction of Hokusai's print *The dream of a fisherman's wife* and extended to the analysis of yellows, reds, blues and purples in two original prints of *Lion dancers* by Kunichika dating from 1867. When possible, sampling from the back of the prints was chosen.

Overall, the results of the dye analysis have highlighted the suitability of HPLC–HRMS to identify organic colourants through a minimally invasive and ethically acceptable sampling method, in addition to informing on the challenges and limitations of the method when faded and discoloured prints are analysed.

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Organic Colourants in Margarito d'Arezzo's The Virgin and Child Enthroned, with Scenes of the Nativity and the Lives of the Saints (probably 1263–4): Some unexpected discoveries using a multi-analytical approach

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The oldest painting in the National Gallery collection, *The Virgin and Child Enthroned* by Margarito d'Arezzo (NG564), dated to about 1263–4, is of considerable interest since the technique and materials of the Gallery's paintings of this period have not so far been studied in any depth. The panel shows the Virgin and Child in a mandorla, surrounded by scenes of the Nativity and lives of several saints, set within red and decorative black borders, against a gilded background.

Investigations using a combination of non-invasive techniques, such as macro X-ray fluorescence (MA-XRF) scanning and fibre optic reflectance spectroscopy (FORS), and the analysis of small paint samples by high- performance liquid chromatography (HPLC) and X-ray diffraction (XRD) have provided evidence for the use of a number of organic colourants, with indigo and both red and yellow lake pigments being identified.

While documentary evidence confirms that yellow lakes were being produced from an early date, there is very little direct evidence for their use in 13th-century panel paintings. This presentation will discuss the finding of an unusual compound, syngenite ($K_2Ca(SO_4)_2 \cdot H_2O$), as a potential yellow lake substrate and will consider how the recent scientific examination has revealed a greater complexity of the design elements than initially expected. This new evidence is leading to a reassessment of Margarito and the materials and techniques of painting at this period.

Finding madder reds in 19th- to early 20th-century oil paintings

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Since antiquity, the root of the madder plant (*Rubia tinctorum* L.) has been used to create dyes and pigments of rich and transparent colours, from the lightest yellows to the deepest purples (Cardon, 2007). Their main chromophore is alizarin, followed by purpurin and other anthraquinones as minor components, which have been found in the paintings and materials of the exceptional Portuguese painter Amadeo de Souza-Cardoso (1887–1918), Fig. 1 (Vilarigues *et al.*, 2008).

The identification of pigments in works of art is key to unlocking new solutions to conservation and restoration problems, but also for studies of dating, provenance, and authentication. To overcome this challenging objective it is essential to develop a database with historically accurate references.

For the last decade, we have been systematically studying the Winsor & Newton (W&N) 19th century Archive Database proving it to be a reliable source of recipes for pigment reconstructions. W&N was a leading company of the 19th century and was used by Amadeo (Vilarigues *et al.*, 2008; Otero *et al.*, 2017; Vitorino *et al.*, 2017; Veneno *et al.*, 2021).

We will investigate, for the first time, the W&N 19th-century manufacturing processes of madder lake pigments and reproduce them with as much historical accuracy as possible. The pigments will be characterised through a multi-analytical approach that will include high-performance liquid chromatography–diode array detector (HPLC–DAD), microspectrofluorimetry, and UV-Vis, infrared (FTIR) and surface-enhanced Raman (SERS) spectroscopies. The prepared pigment references will be further validated by comparison with samples from Amadeo`s paintings (Fig. 1). This will allow us to build a robust database and optimise our analytical methodology.

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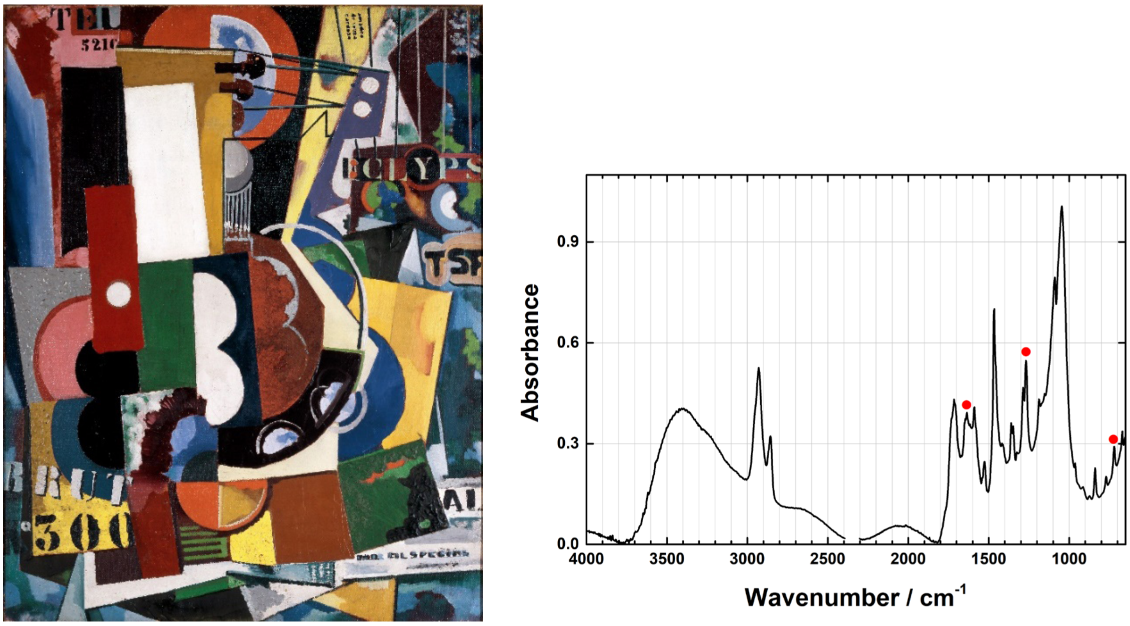

Fig. 1. Left: Amadeo de Souza-Cardoso, Untitled (BRUT 300 TSF), *c.* 1917, cat. no. 196. 85.8 x 66.2 cm; right, infrared spectrum of red area from BRUT painting: (•) alizarin.

Posters

Colours in the collection of medieval archaeological textiles at Lödöse museum

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Lödöse museum is situated on the west coast of Sweden, a few miles north of Gothenburg. During the 12th century Lödöse was the site of one of the first medieval towns in Sweden. Archaeologists have uncovered more than half a million objects during the past century, making Lödöse one of the richest sites in Sweden when it comes to medieval finds. Most of the artifacts are common items from everyday life, but after nearly a millennium in the muddy soil, they are not so common anymore. They now tell the story of the people who lived before us. Runic messages with warnings, promises of friendship and love, give life to the past. Names carved into tools tell us who once used and cherished the items a long time ago. Lödöse Museum also holds one of the largest medieval archaeological textile collections in Northern Europe, dating from 1050–1350 AD. The collection consists of 1700 fragments representing a large variation, from coarse packing textiles to delicate fragments of herringbone twill. Previous analyses show mainly textiles made of wool, but also flax, goat's hair, horsehair and silk. As is often the case with archaeological textiles, the fragments display many shades of brown. While it is possible to discern visually that that some were more brightly coloured, the dyes had not previously been investigated.

A renewal of the permanent exhibition opened in 2021 and textiles are now on display for the first time since the museum's opening in 1994. During the course of this renewal, the textile colourants and their stability to light exposure were investigated analytically using HPLC–DAD, XRF, SEM–EDS, technical photography and microfading on up to 50 sample threads from 29 textile fragments. The samples chosen consisted of textiles of different qualities, from various parts of medieval Lödöse. The results contained both the expected and the unexpected.

The organic colourants detected were tannins, madder, indigotin and luteolin-based dyes. In addition, one textile, fragments of a woollen tabby weave from a pleated fabric, had been dyed red with kermes. This is a clear indication that it concerns an important, high valuated textile.

Through technical photography, the natural UV luminescence of undyed wool fibres was visualised. However, none of the dyes produced any detectable light induced effects.

The XRF and EDS results show the presence of a range of inorganic elements possibly associated with colourants and dye auxiliaries. These include aluminium, chlorine, potassium, calcium, manganese, iron, copper and zinc. Brown and black colourants often contain higher levels of iron together with tannin, indicating the presence of the iron-tannin dye complex.

The microfading results showed that the colours of nearly all the analysed textiles are stable to light exposure with colour changes detected below that of the Blue Wool 3 standard. Only two samples, one dyed red with madder and one with kermes, showed higher sensitivity to light exposure with colour changes slightly higher than Blue Wool 3. These results may impact decisions in exhibition conditions for textiles at Lödöse museum.

Dyes of Lieto Ristinpelto textiles from 13th-century Finland

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The female burial from Lieto Ristinpelto, SW Finland, is from the 12 century CE, according to textile technical structures.

The visible colours of the textiles vary from different brownish shades to, blueish, greenish and reddish hues. The textiles are remains of a bronze spiral ornamented shawl, an apron, two tablet woven bands and a finger-woven band with plaited tassels. These textile structures are known from other Late Iron Age, but some of the Lieto Ristinpelto textiles are unique, like a rug-like textile and its bordering band, a red woollen tabby and yellowish twill. The colorants of thirty samples of fourteen different textile fragments are studied with HPLC-DAD. Red, yellow and blue dyes from plant origin have been preserved in several of the fragments. The results of this study will be discussed in the presentation and compared to Finnish textile finds from the same period.

Figure 1. Left, red tablet woven band and (right) apron corner with spirals and furs from female burial 86 from Lieto Ristinpelto

Non-invasive analysis of dyes used for the outer surface of the Honmaru Goten (Honmaru Palace, Nijo Castle, World Heritage Site) sliding door covers

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The Honmaru Palace of Nijo Castle, a World Heritage Site, in Kyoto is the area within the inner moat in the centre of the castle grounds.

The structure we see today was originally the Katsura-no-miya family residence, built in the northern section of the Kyoto Imperial Palace, just inside the Imadegawa Gate. The main parts of the Katsura-no-miya Palace, were moved to the present location in 1894 on the order of Emperor Meiji. At The Honmaru Palace, the feast for the accession of the Taisho Emperor was held.

The maintenance of the small sliding doors used as fittings in the Honmaru Palace was carried out in conjunction with the building repairs. These sliding doors have pictures of birds and/or plants attached to them, and are surrounded by double brocade borders as mounting textile. The dyes used for these brocades were analysed and the results are reported here.

In the past, we have carried out non-invasive spectroscopic analysis using FORS (fibre optic reflectance spectroscopy) for the dye analysis on cultural textiles (Sasaki and Sasaki (2007, 2017, 2021). In this study, the visible reflectance spectra and the fluorescence spectrum of dyes were measured using an Ocean Optics USB4000 fibre-optic multichannel spectrometer and analysed in comparison with standard samples.

The brocades analysed in this study were classified into six pairs of 12 different types of brocade based on preliminary visual examination. As this case was a non-invasive surface analysis, it was not possible to analyse extremely fine threads or threads that barely show on the textile surface. In addition, there is a possibility that information on the ground colour may be mixed in the brocading wefts. The results of the analysis of the ground colour and the brocading wefts of each brocade show that purple colour was dyed with gromwell, but in only one case was obtained by a blue dye and non-fluorescent red dyes (sappanwood). Green colour was dyed with a mixture of blue dye and a fluorescent yellow dye (amur cork tree) and yellow colour was dyed with a fluorescent dye (amur cork tree), or a non-fluorescent yellow dye. The pink colour was represented by a fluorescent red dye (safflower), and the orange colour by a mixture of non-fluorescent red dye (sappanwood) and non-fluorescent yellow dye. The blue dye peak was confirmed to be that of indigo by performing a second-order differentiation. This peak showed a significant collapse due to degradation effects over time, which could be misidentified as a synthetic dye. All dyes that could be analysed were natural dyes.

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Gamma radiation effect on early synthetic dyes

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Cultural Heritage's textile objects are constantly under the action of microorganisms, insects, climatic or physical factors. These assaults can determine dyes' discoloration and textile degradation which would definitely alter the object's preservation and affect its mission as a historical witness. Gamma irradiation's fungicide and bactericide effects are known and have been used for a very long time, being an exceptional disinfection method with very few drawbacks. Its efficiency and efficacy designates it for Cultural Heritage objects, but its application is limited to a maximum dose and dose rate effect on some biopolymers. Concerning the effect of ionising radiation on dyed textiles, until recently, there were almost no data in literature, references being limited to the mechanical properties of irradiated textiles

(Machnowski *et al.*, 2012).

If the effect of gamma radiation on natural dyes has already been studied and presented at the online DHA39 conference, Sibiu, 2020, the present survey takes into account the investigation of potential changes in early synthetic dyes caused by irradiation and describes its effect on experimental models of different dyed textiles, prepared according to traditional recipes. Such an approach comes as a necessity when considering the demands for gamma irradiation disinfection of 19th- to 20th century traditional textiles received at the IFIN-HH, IRASM Facility and the use of early synthetic dyes in these objects. Gamma irradiation experiments were carried out at about 2 kGy/h, having as target doses values from 10 to 25 kGy. This approach was tested on wool yarns dyed with early synthetic dyes chosen according to the literature (Ballard, 1991; Barnett, 2007). Dyes were extracted from the fibres by the classical acid hydrolysis method. Analysis was performed using reversed phase liquid chromatography with UV-Vis detection (RPLC–DAD), followed by a chemometric approach effected in order to have a better comprehension of the eventual changes induced by gamma irradiation decontamination processes on dyed historical textiles. Understanding the necessary and maximum degree of gamma sterilisation, by identifying and characterising irradiated synthetic dyes, will provide significant information on a suitable disinfection operation.

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James Morton and the anthraquinoid vat dyes: a revolution in synthetic dye fastness

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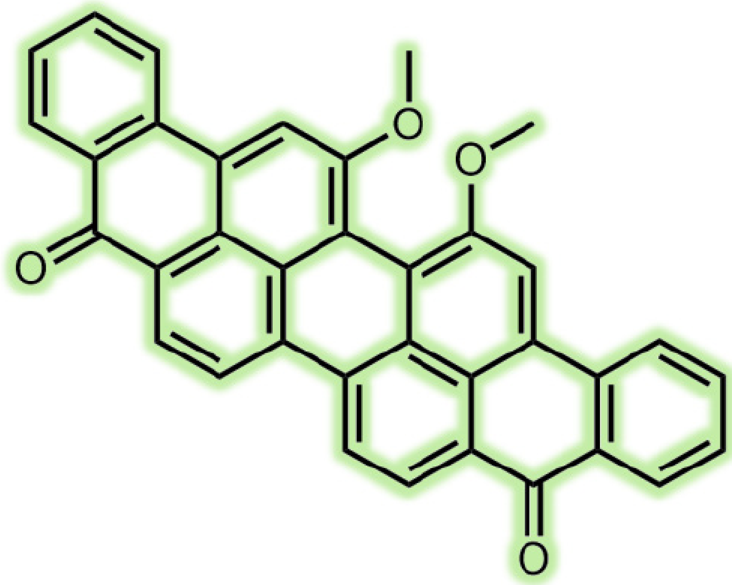
At the turn of the twentieth century, the poor colour fastness of synthetic dyes was becoming increasingly apparent. Sir James Morton, a Scottish weaver and business owner, was motivated to remedy this situation when his synthetically dyed tapestries were completely faded after a single week in the Liberty of London department store windows (Morton, 1929). A new class of vat dye – the anthraquinoids, discovered by René Bohn in 1901 – provided Morton with a solution. Morton developed a textile brand based on these new anthraquinoid vat dyes, producing 'unfadeable fabrics' with light- and wash-fastness



Vat Green 1, Caledon Jade Green

guaranteed. By the following decade, he and his head dyer, Rudolf Hübner, had re-created the complex methods of synthesising these dyes and were producing and developing them in-house under the brand name Caledon (Fox, 1987). Morton's recognition of the value of the anthraquinoid vat dyes and his marketing of the Caledon brand contributed to their status as one of the most important dye classes of the twentieth century (Venkataraman, 1952).

Over the following decades, anthraquinoid vat dye manufacture expanded from small-scale production for luxury decorative goods to bulk production for military apparel during the Second World War (Blackie, 2019). Today, such items are likely to be valued parts of heritage collections. The reported light-fastness of the dyes means that these objects may be well-suited to exhibition and display. However, despite this importance and potential, anthraquinoid vat dyes have been little studied in heritage contexts. This presentation outlines the scientific and cultural impact of the anthraquinoid vat dyes, discussing the role of Morton and his team in their popularisation and development. This work forms part of a wider heritage science project, looking toward developing methods for the identification and colour preservation of these culturally important dyes in collections.

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Giving a new status to a dyes collection: a contribution to the Chromotope project

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Chromotope – The 19th Century Chromatic Turn (Grant agreement No 818563) – is a multidisciplinary ERC research program that focuses on the 'chromatic turn' of the 1860s in France and England, following the invention of the first synthetic dyes. This project, based on a partnership between Sorbonne Université (PI: Charlotte Ribeyrol), Oxford University and the conservatoire national des Arts et Métiers in Paris (CNAM) investigates how this turn led to new ways of thinking about colour in art, literature, history and science throughout the second half of the 19th century. One of the key aims of this research is to reappraise the role played by the CNAM in the dissemination of knowledge about synthetic dyes, from the creation in 1852 of the first chair in dyeing and printing held by Jean-François Persoz to the leading figure of André Wahl during the Interwar period.

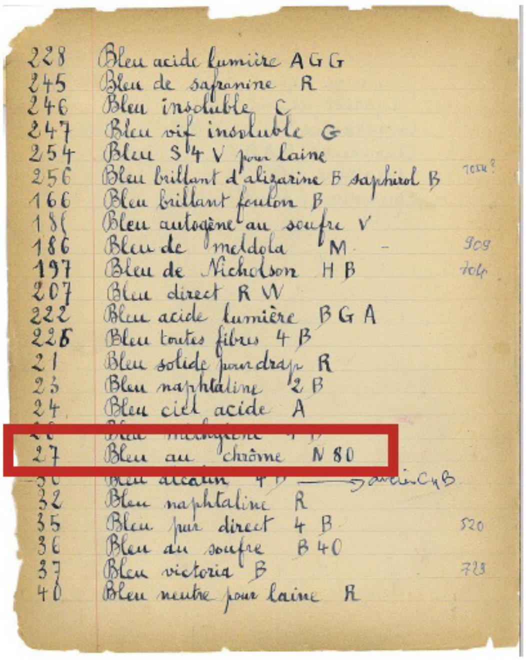
During this period, a collection of dyes including more than 2500 references, obtained from major French or foreign firms, was formed. It is now kept at the Musée des Arts et Métiers and its study is the subject of our poster. This research meets the inventory criteria of the museum›s database, but has been extended to consider all the specificities of these samples. A multidisciplinary method that combines historical research, chemical specificities of the dyes and detailed descriptions of each container has been carried out on this collection, enabling us to study it from different angles. For example, we paid extra attention to the careful description of the containers and their labels, the representativeness of each dye family or the alterations specific to certain chemical families.

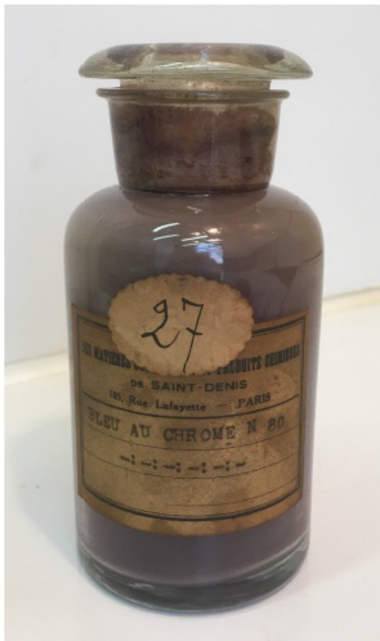
Analyses will also be carried out on samples manufactured by the German BAYER company.

Due to conservation problems, a number of containers have lost their labels but thanks to the dye repertoire and the remaining information from damaged labels, investigations into their possible composition will be undertaken for yellows, reds and blacks. Mass spectrometry and IR-Vis spectroscopic techniques will be used to this end.

All the data collected will be accessible through a new tool, the ChromoBase which will cross reference dyes together with 3D scans of textile samples and examples from contemporary scientific literature.

The CNAM collection of synthetic dyes is an important source of information on Europe's industrial heritage that deserves to be preserved. It represents additional interest insofar as these samples could also be used as chemical references in research applied to heritage objects. Links and collaborations have been established with TU Dresden and TU Niederrhein, to learn from the experience of the 'Weltbunt' project. A reflection on the status and accessibility of these objects is underway.





The dye repertoire and a glass container from the Société des Matières Colorantes et Produits Chimiques de Saint-Denis.

Investigation of dyeing materials used in Greece from the 18th century onwards

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Asphodelus microcarpus, *Berberis cretica* and *Cistus creticus* (Fig. 1). Smut, straws, *Roccella tinctoria* and *Rytiphlaea tinctoria*. All these plants and substances were used in the past for garment dyeing in Greece. Their use is described in old manuscripts such as Π.Α.Σ.Λ. Manuscript 3282 and Π.Α.Σ.Λ. Manuscript 249*, while others reached us through oral testimonies. The art of dyeing evolved and achieved a high standard already from antiquity (Bechtold and Mussak, 2009). Usually, the fibre dyeing process was a result of inquisitive experience of individuals. Nevertheless, existing documentation indicates that exactly the same materials and similar processing methodology was used in various areas of Greece. In the Island of Nisiros, for example, *Rytiphlaea tinctoria* (Fig. 2), a kind of algae, was used to achieve shades of red. In Cyprus, miles away, it was mentioned to be used for the same effect. The use of the same alga in Kefalonia is a matter of common knowledge even in the present time. In fact, there are many such examples as indicated by the doctoral research undertaken by the author during the last years. The aim of this project is to collect, compare and apply the recipes found during 'in the field' research and study of written sources, such as the documenting manuscripts of the National and Kapodistrian University of Athens. The data regarding the dyeing materials used since the 18th century as well as the application methods are of utmost importance for preserving this knowledge for future

Figure 1. Painting dated 1550BC. *Cistus creticus* is depicted.

Figure 2. *Rytiphlaea tinctoria*

generations and assist in the preservation of these objects.

An important step beyond documentation is the replication of the dyeing procedures. Most of the found recipes were used on woollen fabrics/yarns. Experienced dyers used varied temperatures, concentration of dyeing liquid, mordant and other additives in order to achieve the appropriate result. Each dyer possessed a set of secret methods and/or ingredients, which were used to make their coloured creations compete successfully in the open market. In the area of Ampelakia, for example, pig's blood was used as an additive to add extra brightness to the dyed material. This and many other secrets, undisclosed to the public ingredients and methodologies, made those dyers famous and gave wealth and recognition to the whole area (Portal Marie-Laure, 2007).

This is the preliminary phase of this research, which aims on one hand to preserve this knowledge and use it in a creative way for our modern needs, and on the other hand to provide useful information to conservators and researchers regarding the materials used for the decoration of textile objects during the above period in Greece.

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Blue and Yellow – A colourful approach to the dialectic between written sources and experimental archaeology

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The 'Blue' part of our poster will present new quantitative data on the different steps of woad production, based on a review of quantitative data found in historical documents, from mediaeval Italy to 18th-century Southern France, in the light of experimental archaeology. It will discuss results of recent experiments on woad growing and processing of woad leaves into woad balls and couched woad. Concentration of indigotin in these different forms will be assessed according to different methods.

The 'Yellow' part will be a complement to our oral presentation for DHA 41, 'Yellow Dyes of Historical importance. V', including colorimetric measurements and chromatic comparisons – expressed in the

CIEL*a*b* and CIE LCh° systems – of samples of yellow-dyed wool broadcloth in historical sources with samples resulting from reproductions of the historical recipes. It will focus on the colour variations resulting from different mordanting processes.

Our choice of these two colours is not fortuitous, needless to say.

Fish skin dyeing tests with woad (Isatis tinctoria) and Japanese indigo (Persicaria tinctoria)

Dye tests: Adrienn Görgényi Andersdotter; Fish skin: Lotta Rahme

The focus of the tests was on dyeing with woad as it is Europe´s indigenous indigo-producing plant, even though new cultivating traditions are evolving in Europe and Japanese indigo cultivation is becoming more popular in temperate climates, even in the Northern regions, like Sweden. Many dyers prefer to plant Japanese indigo as it is easier to manage and can be grown in pots, unlike woad, which grows long taproots deep in the ground and is more suitable for field growing.

We know today that Japanese indigo (*Persicaria tinctoria*) and true indigo (*Indigofera tinctoria*) produce significantly more pigment than woad.

Since 2016 I´ve been growing woad and Japanese indigo in Malmö and I have been dyeing yarn, textiles and fibres. Fish skin has become more popular, and in 2021 for Lotta´s request I made dye tests with the fish skins that she tanned herself.

Two different dyeing techniques were used with the two different tanning processes. The focus was on the traditional woad, but for comparison and because of the increased popularity, Japanese indigo was added to the fresh leaf dyeing tests.

The samples

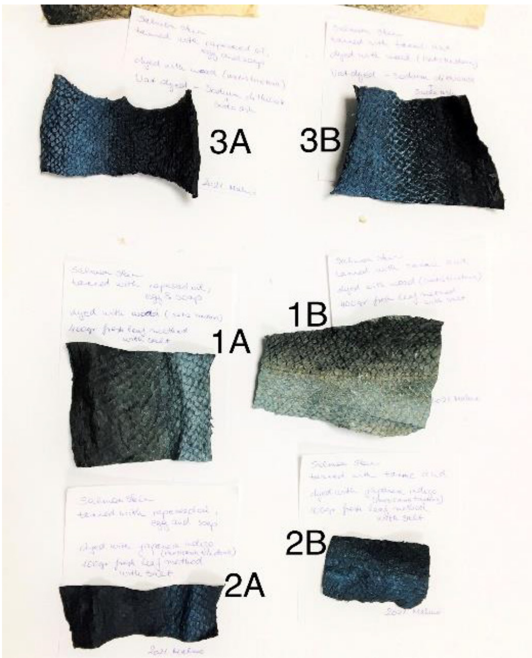
A. Farmed salmon skin tanned with rapeseed oil, egg yolk and soap
B. Farmed salmon skin tanned with gallnut

Methods:

- Method 1 – Fresh leaf dyeing with woad
- Method 2 – Fresh leaf dyeing with Japanese indigo
- Method 3 – Vat-dyeing with pigment extracted from woad

Conclusions

The test has shown us that Japanese indigo (2A., 2B.) has a lot more pigment in its leaves than woad (1A., 1B.). Woad-dyed fish skins were 2. 5 – 3.7 g in size; the Japanese indigo-dyed pieces were roughly half that size. 400 g woad leaves vs 100 g Japanese indigo leaves were used for the pieces and even if the pieces were not the same size this comparison shows the clear difference between them.



The rapeseed oil, egg yolk and soap-tanned skin (3A.) shrank somewhat during the vat-dyeing, which is likely the result of the temperature used to keep the vat active; the other piece (3B.) – tanned with gallnut – withstood the dyeing very well. Extracted pigment (3A., 3B.) gives a better control over the colour's shade than direct fresh leaf application (1A., 1B.).

Japanese indigo with the fresh leaf method (2A., 2B.) gave a similar colour shade result to the vat-dyed pieces (3A., 3B.). In this case the environmentally friendly and more sustainable method is the direct leaf application of Japanese indigo (2A., 2B.). There are no issues with chemical disposal after the dyeing and there is no prior pigment extraction needed. The leaf juice from the leftover mash can then be used to extract pigments left in it. As Japanese indigo has a higher pigment yield the amount of leaves used is lower.

The real challenge is the temperature and the pH during vat-dyeing, so the conclusion is that the fresh leaf dyeing with Japanese indigo is favourable rather than the vat dyeing with extracted pigment.

Probing the Thermochromicity of Fabric Dyed with 6-Bromoindigo and 6,6′-Dibromoindigo, Components of Tyrian Purple*

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Fabrics dyed with 6-bromoindigo turn noticeably blue when heated in water, while dyeings with 6,6′-dibromoindigo turn strikingly red under the same treatment. New data will be presented which probe the nature of these color changes.

Silk dyed with 6-bromoindigo (right column) and 6,6'dibromoindigo (left column)

*This presentation is dedicated to Professor Lou Massa on the occasion of his 80th birthday.

Degradation products and colouring components of shellfish purple identified by UHPLC-MS/MS

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Silk dyed with shellfish purple (*Hexaplex trunculus* (Linnaeus, 1758) = *Murex trunculus* Linnaeus, 1758) was left under artificially accelerated aging conditions (UV radiation) for 25 days and subsequently was treated with DMSO to extract the purple dye. Moreover, three solutions of indigotin (IND), 6-bromoindigotin (MBI) and shellfish purple in DMSO were left for 30 days under ambient conditions. Therefore, four solutions were produced in total and were analysed using a UHPLC–MS/MS method. The latter was developed to identify degradation products and the four analogues of brominated and unbrominated indirubins which have been rarely detected in *Hexaplex trunculus* extracts (Karapanagiotis, 2019). Chromatographic separation in UHPLC was carried out on an ACQUITY UPLC BEH C18 column (1.7 μm, 2.1 x 1.8 mm). MS was performed using a heated electrospray ion source (HESI). The (i) usual seven colouring components which are typically detected in shellfish extracts (Karapanagiotis, 2019), and (ii) the four minor components, which have been rarely reported (Surowiec, Nowik and Moritz, 2012), were identified in the shellfish purple samples (silk extract and shellfish purple solution) before and after aging. Moreover, isatin, isatoic anhydride and other degradation products were detected in any of the four investigated solutions.

Acknowledgements: This research has been financially supported by the General Secretariat for Research and Technology (GSRT) and the Hellenic Foundation for Research and Innovation (HFRI), Scholarship Code: 1514 (16th).

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Identification of organic dyes in the assemblage of women's garments from the early 17th century discovered at the Benedictine Church of Sopron

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In 2010, during the reconstruction of the Benedictine Church in Sopron (Hungary), a wooden coffin was discovered under the stairs of the crypt of Family Viczay. The location of the grave and the richness of the woman's attire with metal threads found in it suggest that the person buried here was a member of a prominent family. The special nature of the artwork is that it is not possible to find clothes of this age and style, only those of the highest layer of the aristocracy that were found in Hungarian collections. Only pictorial representations and estate inventories have proven their existence. The inventory of 27 items consists of several larger units:

- the overgown worn by the buried lady

- the bodice of the overgown
- cape which was placed folded on the deceased in the coffin
- golden plated silver belt
- remains of embroidery, the base fabric of which was broken down and presumably used to decorate the deceased's shroud
- several pieces of garment fragments found under the corpse, but not matching in style of their original clothing (fur)

In-situ removing and disassembly of the find (Ráduly and Újvári, 2013), material analysis (Járó and Tóth, 2013), analysis of manufacturing techniques (Nagy and Várfalvi, 2012), state/condition assesment and conservation (Nagy and Várfalvi, 2013), involving several museums and research institutes, has been achieved through extensive collaboration. There were two reconstructions of the garments in different colours (traditional reconstruction in black, digital artwork 'archeological brown'). Despite the examinations carried out, however, the original colour of the subject remained questionable. In 2016, it was possible to further investigate the object, aiming to prepare the colour of the suit on the basis of the results of dye analysis.

The uniformly brown fabrics were dirty, incomplete, mouldy, torn, extremely fragile and deformed. Samples of the colouring tests have been taken from 17 sites so far, which were first tested with SEM-EDX for the determination of the fibres in question and the inorganic components. Based on our results, on the wool and silk fabric, copper sulphate or potassium aluminium sulphate were used as mordants. After the extraction of the samples available, HPLC–MS/MS was used to identify the organic dyes, which resulted in the determination of plant dyes. A small amount of the sample (0.1 mg) and the degree of degradation of some parts didn't make our work easier; in such cases, the solution had to be concentrated.

During our work, we managed to identify alizarin, purpurin, xanthopurpurin and munjistin among the various pieces. In comparison to the results of the material tests carried out, we made an attempt to prepare the colour reconstruction of a unique find in Hungary, with the results of the measurements of the reference sample compiled in parallel with the examination of the artwork and cultural history descriptions.

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On the trail of colour: the garments of Cardinal-Infant Henry, a prince at the head of the Church

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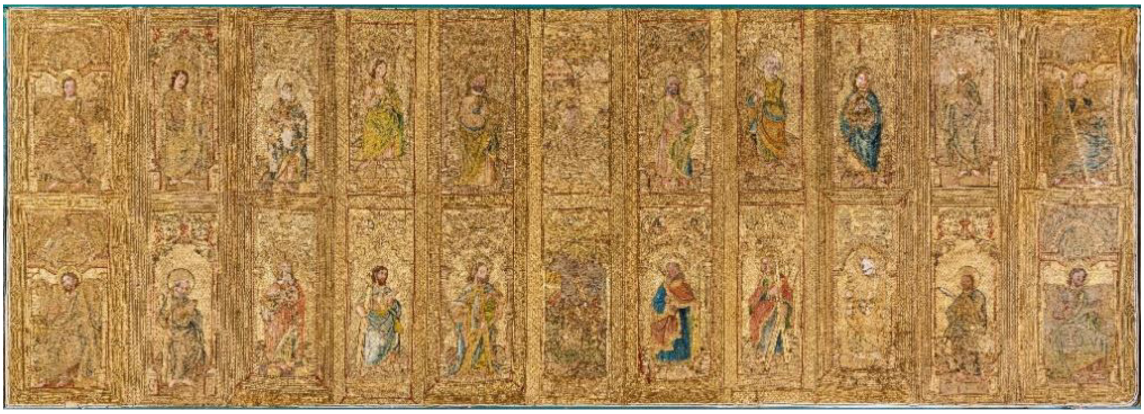
From an early age we have been used to seeing man attach symbolic, cultural, and religious meanings to colours. Their use is inherent to all civilisations at any part of the globe. Coloured textiles, especially in the religious world, are one of the main testimonies of the relationship between man and colour, and the significance of this relationship. In the early days of Christianity there was no known canon of colours, which was only determined in the 12th century by Pope

Innocent III, who established the use of five colours according to the liturgical calendar: white, red, black, purple (a variant of black) and green. As well as defining a hierarchy within Catholic groups, the colours of the vestments also express a mystical sense, through the mysteries of faith.

We know how textiles are objects of great structural specificity, of fragile supports and complex manufacturing processes, which makes their physical preservation difficult. In addition, as they age, colour alterations can also take place.

But what is colour? Can we take a journey through warps and wefts in search of the original dyes and pigments? From a 16th-century pluviale and an altar frontal found in the inventory of liturgical objects of Cardinal-Infant Henry (1512–1580), son of King Manuel I of Portugal, we reveal the result of a material and historical analysis through the world of colour. Using a combination of chromatographic techniques, mass spectrometry, spectroscopic techniques, and microscopy, it was possible to obtain information on the materials used in the production of this object (dyed fibres and metal threads).



Figures 1 and 2. 16th-century pluviale and altar frontal, from the inventory of Cardinal-Infant Henry (Church of Santo Antão, Évora, Portugal, ©Inventário Artístico da Arquidiocese de Évora)

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'La peinture en bois' – Reconstructing a colourful past based on the faded present*

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In 2020 a remarkable table from the furniture collection of the Royal Museum of Art & History of Brussels evidencing 'peinture en bois' was discovered. The preliminary research showed that this small, spiral-leg table was a spolium; a reassembled piece using recuperated old and newly made parts in the 19th century. Macro-XRF imaging analysis was performed by scanning the right half of the marquetry's surface to identify the distribution of inorganic elements across its surface. The imaging revealed the distribution of numerous inorganic elements that are associated with the usage of wood dyes and colourants, such as calcium, potassium, copper, iron, and manganese, pointing towards a once vibrantly coloured marquetry. Most particular are the macro-XRF images of areas where green colourants are to be expected, such as the flower stems and its foliage. Within these areas, local and well defined areas of potassium onto a copper ground were observed. An art technical source research indicated that potassium was related to the use of sap green, whereas the copper was associated with green-staining the wood with verdigris. Given that all colourants on the marquetry are faded due to photodegradation, we question what early 18th-century historical materials and techniques were used to 'paint' these green areas? What was the original appearance of these areas? And what was the visual impact of the use of sap green on top of the green-stained marquetry. Through the accurate reconstruction of historical recipes to make sap green and by staining and 'painting' a reconstructed marquetry of the table, we were able to observe that 'peinture en bois' was indeed an added value to create a more lively and convincing three-dimensional marquetry.

Fig. 1. Detail of the table top showing the early 18th- century marquetry (before cleaning). © Royal Museum of Art & History, Brussels.

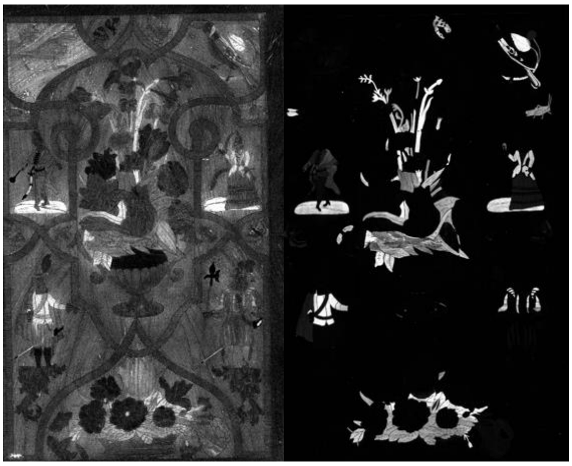

Fig. 2. Macro-XRF images of the elemental distribution of the marquetry's right part. On the left, the distribution of the copper elements, on the right, the distribution of the element potassium. © Royal Museum of Art & History, Brussels.

* This research is conducted under the research project 'HOME-AGE: Historical Materials and Techniques of the South Netherlandish Home in the MRAH-KMKG Collections', funded by the Belgian research programme FED-tWIN BELSPO BRAIN-BE 2.0 (Grant number: Prf-2020-011).

Database of Artistic Materials of National Gallery Prague

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One of the most important points in the complex process of collection items care is to understand the material composition and identify the components. For this purpose – apart from the availability of suitable analytical methods – it is necessary to have high-quality reference sources and comparative data files, which are also easily accessible to the general professional public (especially thanks to their online format). To this date, several online material databases dealing with art materials (pigments, dyes, binders, etc) and their instrumental analysis already exist. However, despite all benefits, these databases also may have several limits arising from their specific focus. In this work, we are introducing the current project of the National Gallery Prague (NGP): a completely new online database of around 200 standards of pigments and dyes used through the whole history of art. This Database of Artistic Materials (DatUM – *Databáze Uměleckých Materiálů*) is going to combine nomenclature (Czech, English and trade names) and basic information (colour, manufacturer and serial number, CAS and C.I. identificators, chemical composition) about each item with its analytical information from instrumental methods available in National Gallery Prague: microscopic images (from optical and scanning electron microscopes), elemental spectra (EDS and XRF) and molecular spectra (Raman and infrared, measured with different techniques) in one place. In addition, the use of each item in colour layers of works of art from NGP collections is going to be presented where possible. This reference material, unique in the number and variability of included materials as well as the scope of presented analytical information, is going to come out in 2023 on the NGP website.

Antimicrobial properties of natural dyes and pigments

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The number of different plant species that have been associated with creating decorative colouring for textiles, pots and other objects is exceeded only by those used for food and medicine. Yet plants known to produce dyes and pigments also happen to have edible and medicinally used parts and many have featured in traditional medicine systems. Dyes and pigments used by ancient cultures not only gave colour to the objects, but also protected the dyed materials and people wearing them against microorganisms. Nowadays, the constant emergence of antibiotic- resistant organisms and failure of chemotherapy requires application of improved treatment methods and new drug sources. The poster discusses antimicrobial potential of eight dyes and pigments that were used in dyeing objects of historic value, tattooing and mummification processes. Among them are indigo (*Indigofera tinctoria*), henna (*Lawsonia inermis*), neem (*Azadirachta indica*) and red sandalwood (*Pterocarpus santalinus*). The dyestuff-yielding plants have been screened for their antimicrobial activity against common human skin pathogens including gram positive bacteria *Streptococcus pyogenes*, gram negative bacteria *Pseudomonas aeruginosa* and fungus *Candida albicans*. The obtained results prove that various secondary metabolites present in dye plants that man has exploited for their colour have a potential to serve as valuable and sought-after antimicrobial agents. Humankind is in pressing need of suitable pathogen control alternatives that are effective, safe and easy to apply. Multiple properties of dyes and pigments can be employed not only in pharmaceutical industry, but also in the production of new cosmeceutical products or functional innovative materials with health-promoting characteristics. Bringing together the traditional knowledge and achievements with discoveries of modern science gives us the opportunity to use this wealth of knowledge in discovery and commercialisation of valuable new remedies.

Changes in the production of Burmese textiles in the long 19th century – a focus on dye and fibre characterisation of Karen garments from the British Museum's collection

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The 19th century is a complex period in Myanmar's history, marked by transition from the Konbaung dynasty (Myanmar's last royal house) to the early phase of complete British colonial rule (1885–1914). Tremendous innovations occurred in this time period and evidence exists that the scientific advances and technological developments taking place in Europe impacted Myanmar's traditional forms of crafts. Synthetic dyes represent one of the most important categories of new materials created in this period, and their introduction from Europe to Asia is an understudied topic (Chen *et al.*, 2016; Liu *et al.*, 2016; Cesaratto *et al.*, 2018; Tamburini *et al.*, 2020). Moreover, little in-depth scientific work on Myanmar minority textiles has been undertaken (Chen *et al.*, 2021).

For these reasons, a pilot study has been conducted at the British Museum focusing on the dye analysis and fibre characterisation of six Karen textiles with the aim to investigate how the fibres and dyes of such textiles changed over the course of the 19th century and how the changes related to local and colonial trade networks. The textiles span chronologically from the 1830s to the early 1900s according to their attribution dates, and include traditional garments such as tunics and skirts, in addition to representing a broad colour palette and different weaving techniques (plain weave and ikats). The investigation was conducted non-invasively by using broadband multispectral imaging (MSI) and fibre optic reflectance spectroscopy (FORS). The results obtained guided a sampling campaign during which samples were taken and investigated by optical microscopy (OM), scanning electron microscopy energy dispersive X-ray spectrometry (SEM–EDX) and high-performance liquid chromatography coupled to diode array detector and tandem mass spectrometry (HPLC–DAD–MS/MS). Natural dyes were found on the older textiles, supporting their attribution dates, whereas mixtures of natural and synthetic dyes were identified in the later textiles. Observations on mordants and fibre processing were also obtained, thus drawing an interesting picture on the introduction on new dyeing materials and techniques in Myanmar over this time period. The light sensitivity of the identified dyes will also inform the correct display of these delicate objects, which are planned to be exhibited at the end of 2023 in a major BM exhibition focusing on Myanmar art and history.

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Dyes of traditional clothing of Suiti in the 19th–20th century

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The *Suiti* are an ethnic group in the western part of Latvia and are renowned for their colourful traditional clothing (folk costumes). The costumes, particularly *villaines* (plaid woollen shawls) and colourful floral headscarves, stand out with bright colours (red, pink and orange). Studies of historical textile dyes are very closely related to history of the clothing in the territory of Latvia. In the past, various local and foreign plant-based and imported natural dyes were used for dyeing until the mid-nineteenth century when the earliest synthetic chemical dyes began to be used.

In the present study, small threads from different parts of the folk costumes were analysed by *X-ray fluorescence (XRF) spectroscopy, fibre optic reflectance spectroscopy and* ultra high-performance liquid chromatography coupled with diode array detector and mass spectrometry (UHPLC–DAD–MS).

Obtained data from dyestuff extracts allow conclusions about the

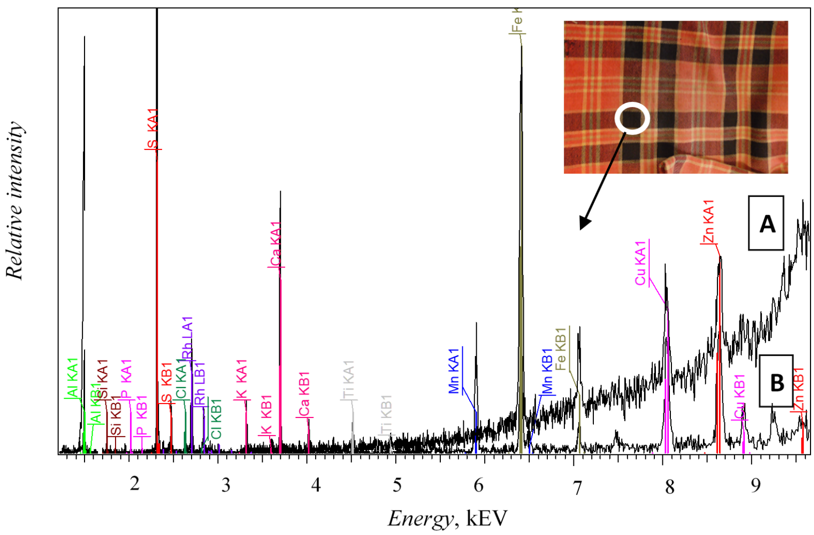

Figure 1. X-ray spectra (A – sample; B – sample holder) of yarn of the Suiti folk costume trakā drāna – 'the crazy clothing'.

origins of dyes and trade relations. The results of the chemical analysis confirmed that yarn was dyed with natural (local and foreign) and synthetic dyes. A high diversity of mordants of metal salts was not observed among the analysed samples: mainly Al, K or Fe, which is likely to correspond to potassium alum and iron(II) sulfate (Fig. 1).

Acknowledgments

I would like to express my deep gratitude to Dr.hist. Anete Karlsone and the Director of the ethnic culture centre "*Suiti*" Dace Martinova for their support, the chance to analyse historical samples and use descriptions and photos of samples in the study.

Discovering the ink murals: multi-analytical approach for the study of Wall Drawing #736 by Sol LeWitt

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Sol (Solomon) LeWitt (1928-2007) was an American artist exponent of conceptual art (Lovatt, 2012), known for his intense production of *wall drawing*, artworks created directly on the wall by overlapping different layers of coloured inks (Haxthausen, 2014). The *Wall Drawing # 736*, commissioned from Sol LeWitt by the Pecci museum in Prato and created in 1993 by Andrea Marescalchi and Anthony Sansotta, consists of a grid of coloured rectangles that covers the walls of the room and reflects the artist's eccentric tendency to use inks for the creation of murals.

In the present work we applied a multi analytical approach based

Figure 1. Sol LeWitt, Wall Drawing #736 – Rectangles of Color, 1993, Coloured inks on circular wall, site-specific work executed by Andrea Marescalchi and Anthony Sansotta. Collezione del Centro Pecci e della Città di Prato, Inv. 0074.

on non destructive and micro-destructive techniques, such as high-performance liquid chromatography with diode array and mass spectrometric detectors (HPLC–DAD–MS^2), pyrolysis coupled with gas chromatography–MS (Py-GC/MS) and Raman spectroscopy to characterise the materials used by Sol LeWitt in his 'wall drawings'. To better understand the procedure used in painting the ink murals, both samples taken from *Wall Drawing #736* and the inks used for its production (Marescalchi archive) were analysed. The combination of spectroscopic and mass-spectrometric techniques provided us with the exhaustive characterisation of the binder, dyes/pigments, and additives used by the artist.

The research, partially funded by Fondazione per le Arti Contemporanee in Toscana (Prato, Italy), led to a deeper understanding of the ink murals techniques. The acquired knowledge on the paint technique and palette of the artist will be relevant not only for supporting conservators in restoration and consolidation interventions, but also for collecting information on this unique technique used by Sol LeWitt.

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To be or not to be an iron gall ink: a multi-analytical methodology for the study of iron-polyphenol complexes

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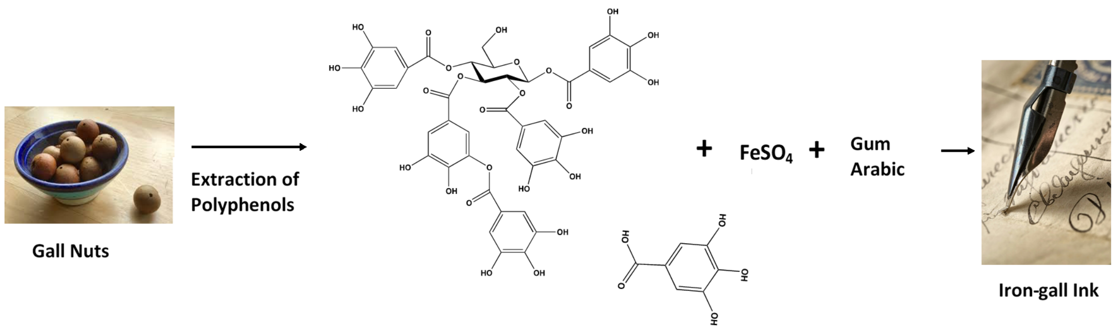
Until the beginning of the 20th century, a significant part of our cultural heritage was recorded using iron gall inks (Kolar 2006) [1]. Unfortunately, many historical documents are at risk of total loss due to degradation of the writing support caused by the corrosion of these inks (Neevel, Kolar and Strlič, 2006).

Medieval iron gall ink recipes typically contain three basic ingredients: a phenolic extract (*Quercus infectoria* galls), $FeSO_4$, and gum arabic (Díaz Hidalgo 2018; Teixeira 2021)., [3, 4]. Our knowledge on the molecular structures of the chemical compounds present in these inks is very limited and this gap prevents us to devise informed strategies for preserving the world written heritage.

The goal of this work is to characterize iron-polyphenol complexes present in iron gall inks. This will be accomplished through studies on isolated tannins from galls by preparative HPLC-DAD. The iron-complexes will be prepared using distilled water and sodium acetate-acetic acid buffers and analyzed through UV-Vis spectroscopy (Lu, Li and Lu, 2009). [5].

MALDI-MS and ESI-MS will be used to study the nature of iron complexes in aqueous solution. Structural characterization will be further complemented with SEM, FTIR, Raman microscopy and X-ray analysis.



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