Iron Gall Ink at the Agnes: Analysis of Iron Gall Ink in the Agnes Etherington Art Collection
ABSTRACT

The historic European art collection at the Agnes Etherington Art Centre is comprised of important 14th to 19th century pen and ink drawings. Given the time period of their creation, the media of a number of these drawings is likely to be iron gall ink which is known for its potential instability. This project surveys a selection of drawings from the collection to ascertain the presence of iron gall ink, characterize the ink recipe, assess the current condition of the drawings and provide long-term conservation recommendations. Studies have shown that copper ions contribute to a greater rate of oxidation than iron (II) ions. Despite this, most accepted conservation treatments for iron gall ink are targeted for use with ferrous ions. More data on the metallic components of iron gall ink in heritage objects is necessary in order for the conservation community to assess the need for developing alternate treatment methods. Analysis of the ink in the Agnes’ collection involved indicator papers to detect the presence and amount of iron (II) ions. Ultra-violet photography was used to help characterize the extent of degradation and X-ray fluorescence (XRF) was used to identify and establish relative amounts of component metals. Results of the survey indicated that a majority of the ink drawings contained iron gall ink. Iron was the most commonly found metal in the inks, but copper, lead, zinc, arsenic and manganese were also detected. When classified following the condition rating system outlined by the Netherlands Cultural Heritage Agency, the majority of the inks that tested positive for iron content were in good condition.
ACKNOWLEDGMENTS

A special thank you to the Agnes Etherington Art Centre for allowing me to work with their wonderful collection and for their enthusiasm with the project. In particular I would like to thank Jacquelyn Coutré and Jennifer Nicoll for all of their input and help.

Thank you as well to the faculty of the Art Conservation program for their endless support. Thank you Rosaleen Hill, Alison Murray and H.F. (Gus) Shurvell.
CONTENTS

Abstract .................................................................................................................................................. ii
Acknowledgments ................................................................................................................................... iii
Contents .................................................................................................................................................. iv
1. Introduction .......................................................................................................................................... 1
   1.1 Iron Gall Ink ...................................................................................................................................... 2
      1.1.1 Vitriol .......................................................................................................................................... 2
      1.1.2 Gall Nuts ...................................................................................................................................... 2
   1.2 Degradation ...................................................................................................................................... 3
      1.2.1 Hydrolysis .................................................................................................................................... 3
      1.2.2 Oxidation .................................................................................................................................... 4
      1.2.3 Oxidation and Iron Gall Ink Composition .................................................................................. 4
   1.3 Identification .................................................................................................................................... 5
2. Experimental .......................................................................................................................................... 6
   2.1 Selection of Drawings ...................................................................................................................... 6
   2.2 Methods of Analysis ....................................................................................................................... 6
      2.2.1 X-ray fluorescence .................................................................................................................... 6
      2.2.2 Bathophenanthroline ................................................................................................................ 8
   2.3 Condition Assessment ..................................................................................................................... 9
3. Results .................................................................................................................................................. 11
   3.1 XRF Analysis ................................................................................................................................... 11
   3.2 Bathophenanthroline Test Strips .................................................................................................... 12
   3.3 Condition Ratings .......................................................................................................................... 13
4. Discussion ............................................................................................................................................ 14
5. Conclusions ......................................................................................................................................... 16
6. Bibliography ......................................................................................................................................... 17
1. INTRODUCTION

The Agnes Etherington Art Center (AEAC) is located on Queen’s University’s campus in Kingston, Ontario. In addition to collecting Canadian contemporary and historic art, AEAC holds an extensive historic European collection (Agnes Etherington Art Centre 2015). Since the paintings within the collection have received the bulk of the exhibition and research attention, AEAC welcomed the opportunity for a closer look at their Renaissance and Mannerist drawings dating from 16th to 19th century Europe. Brown or black inks applied by pen or by brush were commonly used by artists of the time period; to create those inks, a range of materials were used. With age, many of these inks can change appearance making it difficult to differentiate them using visual examination alone. Commonly used inks include bistre, sepia, iron gall ink (Watrous 1957) and, less frequently by the 15th century, carbon black inks (Eusman 1998). Early use of iron gall ink as a writing ink can be dated back to fifth century and by the 14th century its use was common. By the end of the 15th century iron gall ink surpassed other inks in popularity due to its permanence on paper and its ease of manufacture (Eusman 1998). While it was primarily a writing ink, it also saw early use for artistic practices in illustrated manuscripts and later in renaissance drawings (Watrous 1957).

Currently, the inks in the 14th to 19th century European drawing collection held at the AEAC have not been classified beyond a visual description. Media description involves categorizing the medium as ink and giving it a descriptive colour. Correctly differentiating iron gall ink from other brown and black inks not only provides an art historical context, it can also significantly inform how an object should be preserved. For this reason the project surveys the drawing collection to identify the presence of iron gall ink. Observation and analysis was carried out using a range of non-invasive and non-destructive tools which further characterized the inks by determining their metal components and degradation states. A condition assessment was made about the current state of the ink-bearing object using visual analysis as well as ultraviolet photography.

Knowing the individual components can help identify ingredients of the original recipe as well as help predict its physical stability. Ink components can be compared against recipes found in artist treatises which can give information on the manufacturing method and adds to the understanding of how these drawings were produced. Metal components will be identified by analysis using X-
ray fluorescence. Information gathered by this survey can be used to help provide recommendations for long-term preservation.

1.1 Iron Gall Ink

Given that iron gall ink was in use for around 900 years up until the end of the 19th century, it is not surprising that during that time production methods and recipes varied widely. The Netherlands Institute for Cultural Heritage (ICN) (since renamed The Netherlands Cultural Heritage Agency) was able to find examples of roughly 250 recipes for the making of iron gall ink. At its most basic, iron gall ink is a combination of iron and tannins or gallic acid. However, the source of these two ingredients will have a large effect on the final characteristics of the ink (Stijnman 2006, 25-26). The ink is usually further modified with additional ingredients such as a liquid, often water, wine or vinegar, a gumming agent or a colorant (Karnes 1998).

1.1.1 Vitriol

The iron component of the ink is historically known as vitriol and is usually iron(II) sulphate. Vitriol could be collected by distilling ground and rain water or by soaking vitriol-rich earth in water. A purer vitriol could also be created with further processing. The characteristics of the vitriol extracted by either of these methods are related to the mineral content found in the local ground. In historical texts, the vitriol is often described by its colour which can range from light yellow, to green, to sky blue. A blue colour, for example, likely indicates the use of copper salts in the form of copper sulphate which may have been mixed with iron sulphate. These colour descriptions give an indication of the original chemical used and show the possible variants involved in an iron gall ink recipe (Stijnman 2006).

1.1.2 Gall Nuts

Gallotannic acid was generally extracted from gall nuts found on trees. Galls nuts are a result of an insect or other outside contaminant piercing the outer skin of a tree, which then swells to form a growth. This growth, call the gall nut, is rich in tannins (Watrous 1957). Gall nuts can be found on trees in many parts of the world and were often imported to Europe. Very rarely was the source of the gall nuts described in ink recipes despite their importance for the final character of the ink. Gall nuts can vary in tannin concentration depending on their originating tree species; concentrations can range from 10-70% and have a direct correlation with the ink darkness (Stijnman 2006). Tannins were extracted from the gall nuts through soaking powdered gall nuts in
a liquid, by boiling or by fermentation. The fermentation process helps convert the gallotannic acid to tannic acid which results in a darker and richer ink (Karnes 1998).

Other ingredients such as vinegar, gum or colorants will change the properties of the ink. These additives were used to affect the viscosity, flow, colour stability and antibacterial properties (Karnes 1998).

1.2 Degradation

Many factors can contribute to iron gall ink-related degradation of cellulosic materials, but the two main attributed chemical pathways are acid-catalyzed hydrolysis of cellulose which leads to a decrease in the degree of polymerization and oxidation of cellulose catalyzed by metal ions (Banik 1997; Kolar and Strlič 2006). Storage and handling conditions also contribute to the accelerated deterioration of cellulosic material with iron gall ink.

These changes can be observed with the naked eye. When freshly penned, the ink usually has a cool black colour; it is only with age that it develops its characteristic warm brown colour making is difficult to distinguish visually from bistre and sepia (H. Neevel 2006; D. J. G. Neevel and Reissland 1997). As deterioration continues, brown discolouration can form around the ink lines; this is usually accompanied by a loss of flexibility and strength in the paper fibres which leads to cracking in the page (D. J. G. Neevel and Reissland 1997).

Not all iron gall ink will degrade to this extent; some may in fact deteriorate very little. The rate of degradation is linked to how environmental and material factors influence the two previously mentioned chemical degradation mechanisms: acid catalyzed hydrolysis and oxidation catalyzed by metal ions.

1.2.1 Hydrolysis

The polymer chain of cellulose is very susceptible to chain scission at its glucosidic bond, the bond that connects the repeating polysaccharide units that make up cellulose. In the presence of water and acid, the acid acts as a catalyst to the hydrolytic reaction which separates the original chain into two halves (Daniels 1996; Arnold 1997). As the cellulose chains are reduced in length, so are their strength.

The ferrous sulphate and tannic acid that are key parts of the iron gall ink manufacturing process are also contributing factors to its degradation due to their acidic nature. The rate of degradation
caused by acid-catalyzed hydrolysis is directly correlated to the pH of the paper, which can be affected by the papermaking ingredients, such as alum-rosin sizing, and the ink ingredients, such as the relative proportions of ferrous sulphate, tannic acid and other additives (Kolar and Strlič 2006).

1.2.2 Oxidation
Transition metals, such as iron and copper, contribute to the oxidation of cellulose through the Fenton reaction. In order to do so, they must be able to contribute a single electron. For example, Fe(II) is catalytically active while Fe(III) is not (Strlič, Selih, and Kolar 2006). In iron gall ink, both Fe(II) and Fe(III) can be found. In order to identify the presence of deleterious Fe(II) ions, bathophenanthroline test strips have been developed by ICN (J. G. Neveel and Reissland 2005).

1.2.3 Oxidation and Iron Gall Ink Composition
Of particular interest is the presence of copper elements in the ink. Recent studies have begun to investigate the copper to iron ratio of iron gall inks in order to develop more effective conservation treatments. A survey was conducted at Slovenia’s National and University Library and the Regional Archives of Maribor to identify the copper content of 99 iron gall ink documents. It was discovered that 32 of the 99 had ink with more than 10% copper, in some cases extending up to higher than 60% (Kolar et al. 2003). A similar survey was conducted in Mexico analyzing over 2000 inks on paper at the Archivo General de la Nacion (General Archive of the Nation) to help characterize the little studied iron gall ink found in Mexico. This extremely comprehensive study revealed that historic Mexican iron gall inks are chemically complex and often have high concentrations of copper and manganese in addition to iron. In several cases, traces of lead and arsenic were found. Because the survey included materials from all over the country with creation dates spanning from 1500 to 1900, some broad correlations could be made between geographic location, time period and metal content within the ink (Alcantara Garcia, Ruvalcaba Sil, and Vander Meeren 2013). With more data, copper content could perhaps be connected to geographic location or time period of manufacture.

From a conservation standpoint, there is an interest in knowing if a collection has a high content of copper-containing iron gall ink as this would confirm the need for a treatment where the efficiency is reliant on a particular metal content. Current treatments generally require the application of the chelating agent phytate, however studies suggest that other treatment methods
may be more effective when there is a high concentration of copper present in the ink (Kolar et al. 2003). Additionally, it is believed that copper may have an increased catalytic effect on oxidation of cellulosic materials (Kolar et al. 2003; Malesic, Kocar, and Balaziv Fabjan 2012).

Treatments, both experimental as well as those generally considered safe, exist to remediate both high acidity and free metal ions in historic papers. For papers nearing a state of advanced deterioration, it is recommended to address the likely contributing factors. Condition surveys, such as the one conducted for the AEAC European drawing collection, are important in highlighting which documents would benefit most from intervention.

1.3 Identification

There exists a number of techniques that can be used to identify the inorganic and organic components that are present in iron gall inks. Many of these require destructive or micro-destructive sampling or the displacement of the artifacts being studied (Strlič et al. 2006). Such techniques were inappropriate for use in the context of this survey. Of the in-situ methods developed for identifying iron gall inks (H. Neevel 2006), UV fluorescence, X-ray fluorescence (XRF) spectroscopy and bathophenanthroline test strips, discussed in detail later in this paper, were chosen due to availability to the researcher and relative ease of use. These techniques give information about the metals in the ink which can indicate the presence of the vitriol-containing iron gall ink. The presence of iron ions, however, does not conclusively identify iron gall ink. Iron or other metals can be present in inks from contamination from metal containers or writing implements. Other iron-containing pigments, such as ochre, could be present (H. Neevel 2006).

Logwood inks were also often combined with metal salts and can show similar degradation characteristics as iron gall ink. XRF analysis of iron-containing logwood inks have however shown that such inks have significantly less iron than iron gall inks (Bicchieri et al. 2008).

While many inks can have iron contaminants, few will show the high amounts of iron content that is commonly found in XRF analysis of iron gall ink. The presence of iron or other transition metals cannot conclusively point to iron gall ink, however the detection of more than trace amounts of metal in a drawing or writing ink strongly point towards iron gall ink given its historic prevalence.
2. EXPERIMENTAL

2.1 Selection of Drawings
The European historic art collection at the AEAC holds 370 drawings with various media and of that number, there are 177 ink drawings on paper. Amongst the ink drawings, a selection of 31 pieces was made. Individual drawings were chosen to include a diverse range of dates of and geographic regions of creation within Western Europe between the 16th to 19th centuries. Countries of creation include Belgium, Britain, Italy, Holland, Germany and France. All drawings are on paper and include brown or black ink. The drawings were examined in the state in which they were stored; this included unmounted, fully or partially adhered to a secondary support, in a notebook or hinged and matted.

2.2 Methods of Analysis

2.2.1 X-ray fluorescence
X-ray fluorescence (XRF) analyses were conducted with the Bruker Tracer III-SD handheld XRF unit to determine the inorganic components of the inks. In particular, presence of iron gall inks was confirmed by the presence of iron, with or without copper and other trace metals. XRF readings were taken with the drawings on a Plexiglas stand (figure 1). Two readings were taken of the paper support in areas free of drawing media and three readings of three separate areas with the highest density of ink. The apparatus had a tube voltage of 40 kV, current of 30 µA with a scan time of approximately 30 seconds. XRF spectra from each drawing were compared against one another. Signal intensity was adjusted to account for the live signal time and the eV per channel using Excel. Adjusted data can be compared against itself to qualitatively assess the metal
components in the ink while taking into account metal ions in the paper substrate as well as background signals.

Signal strength was determined qualitatively. For each drawing, the XRF spectra of the three ink readings were compared against the two paper readings. A peak was considered indicative of a major element when it differed by more than 200 counts from the paper background readings. A minor content was a difference of approximately 50 to 200 counts and a trace element is considered 50 counts or less.

Within the three separate XRF spectra of a given ink, readings were frequently inconsistent due to the variations in ink density. Single lines could be difficult to isolate and thin ink washes may have had little iron content. Since these factors had to be considered when analysing multiple readings of the same ink, the presence of an element was considered major or minor as long as it was present in one of the three spectra. Since the trace readings could easily be confused with background noise, they were only noted when all three ink spectra were consistent.
2.2.2 Bathophenanthroline

XRF analysis does not provide information as to the ionic state of the metals being analyzed. Test strips saturated with bathophenanthroline solution can be used to determine the state of oxidation of iron ions. For this project, the test strips used were the “Iron Gall Ink Test Paper” distributed by Preservation Equipment Ltd on behalf of ICN. When the colourless bathophenanthroline compound comes into contact with Fe(II), it forms a fuschia coloured chelate. To perform the test, the bathophenanthroline test strip is first dampened with distilled water and any excess liquid is removed. The strip is then pressed directly to the ink or paper area being tested for about thirty seconds. If Fe(II) ions are present in the sample, they form the fuschia chelate on the indicator paper. The chelate itself is not water soluble so there is no chance of it transferring to the artifact (J. G. Neevel and Reissland 2005). The Canadian Conservation Institute (CCI) has developed a colour-based rating system to estimate the amount of iron ions in the sample (Guild, Tse, and Trojan-Bedynski 2012) (Figure 2). The test was performed three times on different areas of each object. If the object appeared to have different types of ink, for example if it included a signature or a hand-drawn border, all possible inks were tested. The locations of both the XRF readings as well as the bathophenanthroline tests were recorded on an image of each work (figure 3).
2.3 Condition Assessment

Objects were classified using the ICN method of condition rating. This classification method is based on visual analysis of discolouration and mechanical damage of iron gall ink and has four ratings, ranking from Good to Bad condition (Reissland and Hofenk de Graaff 2001) (Table 1).

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition rating 1</td>
<td>Good condition - no or light brown discolouration at the inked areas</td>
</tr>
<tr>
<td>Condition rating 2</td>
<td>Fair condition - dark brown discolouration at the inked areas, no mechanical damage</td>
</tr>
<tr>
<td>Condition rating 3</td>
<td>Poor condition - mechanical damage (cracks) at the inked areas</td>
</tr>
<tr>
<td>Condition rating 4</td>
<td>Bad condition - serious loss of substance</td>
</tr>
</tbody>
</table>

Table 1 – ICN condition rating system for iron gall ink based on discolouration and mechanical damage.
By using a standardized rating system, useful comparisons can be made about the condition of iron gall ink containing objects with other similar collections.

Examination under UV light can give additional data to supplement the condition rating. Iron gall ink corrosion has different fluorescence characteristics depending on its state of degradation. Ultraviolet fluorescence appears around the outside of the ink lines and is visible on the verso as well as the recto. This has been observed in artificially aged samples just before brown discoulouration halos became visible (Baker 1985). Since degradation can occur unevenly across an object, it is difficult to assign an overall ranking based on these observations, however UV fluorescence can be an early indicator of future corrosion (Neevel and Reissland 1997, 42). In this study, objects were only observed on the verso due of the range of secondary supports. In many cases it was impossible to examine the reverse side of the page because the drawing was adhered to a secondary support or the manner in which the drawings were hinged made it difficult to examine the back of the page without risking damage. In order to keep the condition ratings consistent, all drawings were examined from the front. Ultraviolet light observation was conducted using fluorescent Black Light Blue (BLB) and was digitally photographed. This examination did not show the characteristic fluorescence described by Baker on any of the drawings regardless of their condition. Consequently, these results will not be discussed further in this paper.
3. RESULTS
In total, 24 inks (77%) showed iron content. Some drawings only tested positive in one or the other method of analysis.

3.1 XRF Analysis
While major peaks of alkali and alkaline earth metals were recorded, this survey was primarily interested in the metal content of iron, copper, lead, zinc, arsenic and manganese. In these results, only peaks for elements of interest were identified on the spectra (see Appendix – Selected Results).

Using the guidelines previously outlined, XRF analysis showed a major metal component in 23 inks (74%), all of which included iron. Copper was an additional major component in one drawing (3%) as was lead in another separate drawing. Minor elements found were lead and zinc as well as trace amounts of lead, zinc, arsenic and manganese. In three drawings with no major transition metal component, a minor amount of iron appeared on the spectra. Lead was included for the sake

![XRF Results](image_url)

Table 2 – XRF results of analysis of ink on 31 drawings. Shows the number of drawings with major, minor and trace amounts of iron, copper, lead, zinc, arsenic and manganese. The majority of major metal content was iron, with one drawing with a major copper content and one with lead.
of completeness however it is very likely that the XRF was detecting traces of nearby washes of lead white pigment (Table 2).

### 3.2 Bathophenanthroline Test Strips

Bathophenanthroline test strips indicated positive results for 19 out of 31 drawings (61%). Results were considered positive when any colour change was observed on the strips. In most cases, all three of the tests on a given drawing were consistent in whether or not they were positive. In the few cases where all three tests were inconsistent, the drawing was considered to have tested positive as long as one test strip showed a colour change.

All three test results were compared against the CCI colour indicator scale. Since the three tests were a record of three separate locations on the drawing which varying ink densities, they usually exhibited colour results that differed from each other. Usually, the colour results on each of the three strips were a range between two or three points on the colour scale. This range of results was
noted for each drawing (see Appendix – Selected Results). Of all 31 drawings, six are a 1 on the scale (19%), six are a 10 (19%) and seven are a 25 (22%) (Table 3). None of the drawings tested were a 50+ on the colour scale. The rating was based on the darkest colour result for all the test strips on a given drawing.

3.3 Condition Ratings
According to the ICN guidelines, a condition rating is assigned based on evidence of the most advanced level of degradation of iron gall ink. Only drawings that indicated the presence of iron with either bathophenanthroline or XRF tests were assigned a condition rating. Within these guidelines, most drawings were given a condition rating 1 with the exception of The Trojans, Tragedy of Euripides, Act V, Sc 1 with a condition rating 2 and Ecce Homo with a condition rating 3 (see Appendix – Selected Results). It is worth mentioning that these condition ratings only describe the condition of iron-containing inks and is not necessarily indicative of the condition of the drawing as a whole. Other signs of degradation or damage were also noted during observation. While they will not be discussed in depth in this study, frequent condition issues not related to ink included surface soiling, tears and losses, foxing, creases, local yellowing and discoloured white highlights. Overall, the drawings were in good to fair condition.
4. DISCUSSION

The sample size of this survey, 31 drawings, is too small to make generalizations about iron gall ink as a medium. It is much more useful to consider it as representative of the AEAC ink drawing collection. While the drawings chosen for the study span multiple centuries and countries of creation, they are all of western European origin and may suggest some general trends about artwork on paper from the geographic region.

First, most of the surveyed drawings in the historic European art collection contain iron gall ink, or at the very least, inks with a high iron content. Though no quantitative measurements were taken of the ink colours, it could be subjectively observed that there exists no correlation between ink colour and iron gall ink content. Black inks proved to be the only exception where most black inks showed no sign of iron content. In cases where multiple inks of different colours were used in a single drawing, it was difficult if not impossible to analyze one ink separately from the other.

In some cases, drawings had ink signatures or decorative borders. These other inks were tested, however, in order to accurately and consistently discuss the drawing media only, secondary inks were not included in any of the total results. It is however worth mentioning that frequently these inks contained different metal content from the drawing media suggesting that they were from a different ink altogether. This may indicate that it was not uncommon for an artist to use separate drawing and writing inks, preferring to sign their name with a writing ink.

Compared to studies which showed high instances of transition metals other than iron (Kolar et al. 2003; Alcantara Garcia, Ruvalcaba Sil, and Vander Meeren 2013), metal content in ink drawings in the AEAC collection was very consistent. In all inks that showed a high transition metal content, a major source of iron was present. In only one drawing was there an additional major source of copper (See Appendix – Selected Results, accession no. 43-012). In this drawing, the copper content was however significant: XRF spectra showed a stronger peak for copper than for iron. While the rate of occurrences of copper-containing ink in the AEAC collection is much lower than in the studies conducted in Slovenia and Mexico, these findings confirm their presence in historical western European collections. Higher rates of copper-containing iron gall ink might be linked to regional geography outside of Western Europe; further study is needed to make definitive correlations. Additionally, as previously discussed, high levels of copper in iron gall ink may affect potential treatment options.
The ICN condition ratings showed that most of the drawings are in good condition (condition rating 1), or, more specifically, that the presence of iron gall ink has not yet adversely affected their condition. Free metal ion content in these ink samples, according to the bathophenanthroline tests, varied from 0 to 25 using the CCI colour chart, suggesting little correlation between the quantity of iron(II) in the ink and its degradation within this collection. In the single example of poor condition (condition rating 3), the bathophenanthroline test strips showed results varying from 10 to 25 which are amounts that do not in and of themselves suggest the need for interventive treatment (Guild, Tse, and Trojan-Bedynski 2012). The relative good condition of the drawing likely speaks more to the conditions in which they have been kept than to the content of the media. As artwork on paper in a well-established collecting institution, the drawings are housed in environmental conditions conducive to slowing potential iron gall ink-related degradation. It is also the bias of an art gallery collection to collect primarily objects that are in good condition. Additionally, all of the drawings were produced by artists experienced in their craft; it is possible that as a result their inks were of a higher quality.

Not all XRF results corresponded with bathophenanthroline tests. Thin lines in particular were difficult to detect with XRF whereas bathophenanthroline test strips could be applied with more precision. In one case a drawing was lined with a page that contained other inks which made XRF analysis of the desired ink impossible. In that case bathophenanthroline was more effective as it only tested the surface of a page. Conversely, bathophenanthroline test strips only change colour in the presence of iron(II) ions and will not detect other metals. While an adaptation to the test exists to detect iron(III), the author has found this test to be more difficult to interpret and cumbersome to perform in the context of a survey of many works.
5. CONCLUSIONS

Due to the nature of iron gall ink, the first step in its conservation is its identification. Visual analysis alone cannot identify historic iron gall ink as is evidenced in this study, where there was little correlation between ink colour and iron gall ink content. A combination of analytical methods using both handheld XRF and bathophenanthroline indicator papers shows that the majority of the ink-containing drawings in the AEAC’s historic European art collection contain iron gall ink. As the two techniques can detect iron in different situations, they should be considered complementary.

Nearly all of the drawing media with iron gall ink content was considered in good condition according to the ICN method of condition rating. The good condition of iron gall ink in this fine art collection is contrasted by the notoriously poor state of iron gall ink media that is often found in archival collections. Possible explanations for the relative good condition of the drawing media could be related to the higher quality of ink produced in an artist studio, the greater care placed over time in storing fine art materials over archival ones over or simply the collecting bias of a fine art institution that prefers to accession objects that are already in good condition.

Surveys in Mexico and Slovenia have shown high instances of copper content in iron gall ink-containing archival documents created in those regions. Those results differed from those obtained in the survey at the AEAC where the overwhelming majority of the metals detected in this were iron only infrequent or minor contents of other metals, including copper, lead, zinc, arsenic and manganese. While the study conducted at the AEAC was small in scale, the consistency of its results in contrast with results from Mexico and Slovenia shows the potential variety of iron gall ink metal content.

The presence of metal in ink alone cannot conclusively point to iron gall ink; in high enough quantities however, given the historical context, they make the presence of iron gall ink very likely. This study adds to the body of knowledge relating to the prevalence and metal content of iron gall ink in historic European ink drawing collections.
6. BIBLIOGRAPHY


## APPENDIX – SELECTED RESULTS

![XRF Spectra](image-url)

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<th>Accession No.</th>
<th>Title</th>
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<th>Place Made</th>
<th>Date Made</th>
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<td>11-053</td>
<td>The Judgement of Paris</td>
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<td>Britain?</td>
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<th>Ink Colour</th>
<th>Media Description</th>
<th>Overall Condition</th>
<th>Other Damage</th>
<th>Secondary Support</th>
<th>Barathophenanthrolone Indicator Test</th>
<th>XRF of Inks</th>
<th>Iron Gall Ink Condition Rating</th>
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</thead>
<tbody>
<tr>
<td>medium brown, light brown</td>
<td>ink line drawing, ink wash</td>
<td>good</td>
<td>surface soiling less filled</td>
<td>backed with papers, hinged and matted</td>
<td>yes1</td>
<td>iron</td>
<td>-</td>
</tr>
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</table>

Fe(II) Major Minor Trace
### Accession No. 12-047.008

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<th>Title</th>
<th>Artist</th>
<th>Place Made</th>
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<tbody>
<tr>
<td>The Trojans, Tragedy of Kurnpedes, Act V, Sc 1</td>
<td>Brue, Matthieu Ignace van</td>
<td>Belgium</td>
<td></td>
</tr>
</tbody>
</table>

### Ink Colour

- Light gray, medium gray, dark gray, opaque white

### Media Description

- Inkline drawing, ink wash, opaque white highlights

### Overall Condition

- Fair

### Other Damage

- Tears, loss, foxing, darkening of white highlights

### Secondary Support

- Hinged and matted

### Rathophenanthroline Indicator Test

- Yes 10 (only inscription)

### XRF of Inks

- Fe [II]: -
- Major: lead
- Minor: -
- Trace: -

### Iron Gall Ink Condition Rating

- Condition rating: 2
**Drawing adhered to page with print. Printing ink interfered with XRF readings making the results inaccurate.**

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<th>Secondary Support</th>
<th>Bathophenanthroline Indicator Test</th>
<th>XRF of Inks</th>
<th>Iron Gall Ink Condition Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>dark brown</td>
<td>ink line drawing, ink wash, opaque white highlights</td>
<td>fair</td>
<td>cockling, tears, highlights darkening and turning transparent</td>
<td>bluish paper, partially lined</td>
<td>yes 10 to 25</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Accession No.</td>
<td>Title</td>
<td>Artist</td>
<td>Place Made</td>
<td>Date Made</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>43-012</td>
<td>Adoration of the Christ Child</td>
<td>Borremans, Guglielmo (attributed to)</td>
<td>Italy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ink Colour</th>
<th>Media Description</th>
<th>Overall Condition</th>
<th>Other Damage</th>
<th>Secondary Support</th>
<th>Pathophenanthroline Indicator Test</th>
<th>XRF of Inks</th>
<th>Iron Gall Ink Condition Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>medium brown, dark brown, light underdrawing</td>
<td>ink line drawing, ink wash</td>
<td>good</td>
<td>repaired tears, heavy accretion on verso</td>
<td>hinged to paper which is hinged and matted</td>
<td>no</td>
<td>copper, iron, zinc, lead</td>
<td>Condition rating 1</td>
</tr>
</tbody>
</table>