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The Gothenburg Colourists

Analysis of selected works by Karin Parrow, Ivan Ivarsson and Ragnar Sandberg

Sebastian Karlsson

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ABSTRACT

Paintings from three selected Gothenburg colorists, Karin Parrow, Ivan Ivarsson and Ragnar Sandberg were analysed to gain insight into their use of colour. The Gothenburg colorists refers to a group of artists who were active in the Gothenburg area and west coast of Sweden, most of them had studied under Tor Bjurström (1888-1966) at the Valand Academy of art during the 20s. The eight selected artworks were investigated using X-ray fluorescence, Infrared false colour photography and Fourier transform infrared spectroscopy. Analysis results suggest that the artists overall used cadmium based yellows and reds, chromium based greens, ultramarine, Prussian and cobalt blues zinc and lead whites are predominant. Analysis also identified individual characteristics in the different artists' use of colour. In Ragnar Sandberg's Cyklister, indications of advanced photocatalytic degradation of cadmium yellow were observed.

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1. Introduction

1.1 The Gothenburg Colorists

The Gothenburg Colourists were a loosely bound group of artists working out of Gothenburg, the main defining characteristic of their works is their coloristic approach to painting. The group rose to prominence during the second quarter of the 20th century, Sundborg (1948) suggests that the movement had its beginnings during the immediate period following the end of the first world war. The real start was likely in 1920 when the artist Tor Bjurström (1888-1966) arrived in Gothenburg to work as a professor at the Valand academy of art. Bjurstöm was an accomplished artist in his own right, but he would become just as known for his teaching efforts at the academy in Gothenburg. The group of artists who would become known as the Gothenburg colourists are mainly students of Bjurström, some students who studied under Sigfrid Ullman (1886-1960) who took over Bjurstöms position at the academy in 1929 have also been associated with the Gothenburg colourist term.

The Gothenburg colourists were never a formal movement, and never presented themselves as such. Instead it is a term used to describe a group of artists who all more or less used a coloristic artistic expression with focus on vibrant colours and a shared image subject rooted in the Swedish west coast of Gothenburg and Bohuslän. The Gothenburg colourists who has historically received most attention are Åke Göransson (1902-1942), Ivan Ivarsson (1900-1939), Ragnar Sandberg (1902-1972) and Inge Schiöler (1908-1972), Several other artist has been associated with the group such as Folke Andreasson (1902-1948), Inga Englund-Kihlman (1905-1979), David Larsson (1898-1976), Alf Lindberg (1905-1920), Ragnvald Magnusson (1904-1984), Nils Nilsson (1901-1949), Karin Parrow (1900-1984), Olle Pettersson (1905-1990), Waldemar Sjölander 1908-1988), Maj Arnell (1910-2005), and Erling Ärlingsson (1904-1983) (Sundborg 1948).

During 2021 and 2022 the Gothenburg museum of art is developing an exhibition of the Gothenburg colorists planned for 2023. Early in the planning stages a gap in the knowledge of how these artists operated was identified, while researchers have explored how they painted there is a lack in research using analytical data aiming to identify the types of pigments used by these artists. This thesis was initiated with the purpose of Investigating a selected number of artists and artworks from the Gothenburg colorists with the aim of identifying pigments. The focus was set to investigate paintings from the 1930s. Two artworks were included by Karin Parrow, Skärgårdskväll and Hamnen i Vinterväder. Three artworks dated to the period were chosen for Ivan Ivarsson, Blommor och flicka, Badande Flicka and Älvstrand, Hjjärtum. Three artworks were also chosen from Ragnar Sandberg, Badande, Embarkering and Cyklister.

1.2 Summary of current research

The life and artistic output of Karin Parrow was the least documented out of the artists included in this thesis, books detailing the Gothenburg colorists such as *Göteborgskoloristerna* by Romdahl et al. (1948) only mentions her in passing, Hansson *Svenskt kvinnobiografiskt lexikon* notes that while Karin is now a well-known name in the Swedish art world, she was at the time overshadowed by her male peers and rarely represented in the written sources on the colorists. He suggests that a main reason is likely the focus on male artists which was prevalent during the period; it was men who arranged exhibitions, researched and critiqued art. Karin does not currently have any biographical work and what information can be obtained is mostly in the form of shorter articles and exhibition catalogues. The researcher Eva Zetterman is as of the time of writing working on a monograph on the subject of Karin Parrow, her article on Karin in *En ny frihet* (2018) named *Karin Parrows konstnärskap: med känsla för färg* was used as the primary basis for the chapter about Karin. Zetterberg provides information on how Karin approached painting and does give some suggestions on possible use of materials. Hanssons (2022) *Svenskt kvinnobiografiskt lexikon* article contained some biographical information.

There is therefore a comparatively more extensive research on the life and artistic output of Ivan Ivarsson and Ragnar sandberg. For Ragnar most of the information was drawn from Lindes book *Ragnar Sandberg* (1979) the book compiles several interviews conducted by the author with Ragnar which is interspersed with shorter biographical texts about Ragnar. The book provides detailed information on Ragnar's philosophical outlook on painting but contains few notes of how Ragnar chose his materials and paints . Ryndels article *Ragnar G L Sandberg* in Svenskt biografiskt lexikon was also used mostly for biographical information. The book *Dagboksanteckningar 1945-1972* (2002) by Sandberg, Krueger was also researched but did not end up being used as it detailed his life between 1945 to 1972 which falls mostly outside the scope of the thesis.

Out of the three artists, the life and artistic output of Ivan Ivarsson has been documented most comprehensively, most notably the biography written by his friend and colleague Arne Stubelius *Ivan Ivarsson* (1954). The book provides a comprehensive portrait of who Ivan was and as Stubelius was one of Ivan's friends it includes many first hand accounts on how Ivan approached painting and notably notes which colours Ivan prefered and how he chose his material. Furthermore the book *Göteborgskoloristerna* by Romdahl et al. (1948) has a chapter on Ivan written by Sundborg which was used as a compliment.

There are several studies on the subject of international artists and oil paint manufacturers, as Ripolin has been noted as a paint used by Ragnar a brief section on Ripolin is included but otherwise an in-depth literature study on the subject was not justified. As there is little concrete evidence of specific brands used by the artists. While Ivan is noted as having used international brands as well as domestic brands the possible international brands are far too numerous to be studied at length without any clear evidence. Instead the section is mainly focuses on the development of artist paints with a focus on sweden, the section is based on Johansson, (2001) *Med pigment och kopaler: svensk färgindustri under 200 år* which details the development of the swedish paint manufacturing industry from 1700 to 1900, this section is supplemented by Kumlien, (1954). *Oljemåleriet: material, metoder och mästare,* Kumlien was involved in the development of the artists paints at the Swedish company Beckers and lists several of their paints included in their range during the 30s.

Research on the properties and drying mechanisms of drying oils are an extensive subject, which has been studied by several researchers, the section on drying oils included in the thesis is aimed to give a general a basis for the understanding of following section detailing the properties and degradation pathways for pigments as these are often closely interconnected with the properties of the binding media.

Studies on chemical properties, manufacture and use of artist pigments are extensive, as are studies on degradation pathways deterioration and degradation of many of the more unstable pigments available during the 1930s. Historical information and basic information on chemical properties and permanence were obtained from the *Artist's pigments: a handbook of their history and characteristics. Vol. 1 to 3* series of books, supplemented by Eastaugh, et al. (2007). *Pigment compendium: a dictionary of historical pigments*. This section is used as a complement for the interpretation of analysis data and for discussing possible degradation pathways for the pigments.

1.3 Disposition

The main focus of the thesis concerns pigment identification in a series of works by the artists Karin Parrow, Ivan Ivarsson and Ragnar Sandberg. The first part is a brief overview of the paintings, this is based on condition reports obtained from the museum. A more detailed condition report is not within the scope of this thesis as the timeframe for work at the museum did not allow for this. The paintings were superficially examined in connection with the analysis, and as their condition is reported as overall stable (with the exception of one of the paintings) the allotted time was spent primarily focused on analysis. During analysis of possible advanced stages of degradation the paint layers were identified in Ragnar Sandberg's Cyklister which were examined in further detail in following chapters.

The second part of the thesis gives an overview of the artists included in the study, and a brief overview of the manufacturing of artist paints during the period. By knowing how the artist worked and historical information on artist paints during the 1930s, valuable information can be gained which can aid in the interpretation of the analysis data. The section also includes some tables of common pigments from the era. The enamel paint Ripolin is also examined in a smaller section as sources suggest that Ragnar would occasionally use this brand of paint. A shorter section on drying oils and barium sulphate, a common filler from the period which is expected to be observable in several of the paints, are included.

The third part details the methods and materials used in the study, namely X-ray fluorescence (XRF) and infrared false colour photography (IRFC).

The fourth part focuses on interpretation of analysis data collected from the artworks. Tables are presented with the pigments identified by the author. The data was collected using several analysis methods; X-ray fluorescence (XRF) and Infrared false colour photography (IRFC). The primary analysis method used was XRF, the data presented from this analysis is presented in the form of selected representative analysis points in all the selected artworks the artworks are grouped according to artist. All XRF spectrums are included in the appendix. Infrared false colour photography was conducted on all artworks.

In the last part of the thesis all the information is collected and discussed in context with the information gathered in the literature review, the conclusions from the analysis is summarised and connected with the information collected from the literature review. The pigments stability, possible degradation and mitigation of degradation is discussed in context to the paintings included in the thesis.

1.4 Aims and objective

Prior research about the Gothenburg colourists has been somewhat limited in scope, some artists have received more attention than others, and what exists is largely limited to the biographical aspects of the artists. Karin Parrow was chosen as the Gothenburg art museum has a vested interest in exploring artists which have previously been historically overlooked. Ivan Ivarsson and Ragnar Sandberg were chosen for the study partially as they are two of the most notable artists within the Gothenburg colourist group. To the authors knowledge no technical study on the materials used by the Gothenburg colourists has ever been conducted.

The aim of the study is to contribute to the general understanding of the Gothenburg colorists, specifically the artists Karin Parrow, Ivan Ivarsson and Ragnar Sandberg. Through chemical analysis of several of their works the thesis hopes to elucidate what kind of paints these artists might have employed in their artistic output during this period. For many of the colourists colour was central, and everything else was secondary, many of these artists explored the possibility of colour to its fullest to reach new levels of expression. Analytical information on how these artist painted will help the Gothenburg museum of art and researchers increase the understanding and interest in this group of artist, who are not only significant in the qualities of the artistic output but also for significant in the larger context for the city of Gothenburg and the neighbouring region of Bohuslän.

Several pigments used during this period are known to be prone to fading, discoloration and degradation. A in depth chemical analysis has the potential to further help the Gothenburg art museum in preserving these works as identification of pigments allows for a deeper understanding of possible degradation pathways of the pigments. This is especially relevant as the colour is integral to these artworks, any alterations in the colour of these paintings risks irreversible damage to these paintings' ability to work as a conduit for the artist's intentions.

The objectives of this thesis are therefore the following

- Using chemical analysis to get an understanding of the chemical composition of these artworks.

- Using literature review to try to pinpoint pigment makeup of these artworks.

- Apply the gathered information to form a better understanding of how these artists operated and how to preserve these artworks.

1.5 Research questions

1. What pigments did the Gothenburg colourist artists included in the study use?

2. How does the analytical data gathered relate to what is known about the artist's practice?

3. Some of the pigments used during this period are known to be prone to degradation, are any of these pigments present in the selected artworks? If that is the case , what are the possible pathways to degradation and how can they be mitigated?

1.6 Methods

The subject of the thesis is approached from several angles, the primary method is the use of chemical analysis to gather data. Literature review is then used to interpret the analytical data. For historical information on the artists Libris was used, Libris is a digital joint catalogue for a large number of Swedish libraries, primarily university libraries. Libris was used as there is overall very little digitised publications and information on the Gothenburg colorists, furthermore Libris allows for interlibrary loans.

The artists were selected by the Gothenburg museum of art and are Karin Parrow, Ivan Ivarsson and Ragnar Sandberg. All of the artworks included in the study were selected from the same decade i.e. the 1930s. Only two artworks were selected from Karin Parrow as those are the only artworks in the collection by Karin that are reliably dated to the 30s, Skärgårdskväll and Hamnen i Vinterväder. Three artworks dated to the period were chosen for Ivan Ivarsson, Blommor och flicka, Badande flicka and Älvstrand, Hjjärtum. Three artworks were chosen from Ragnar Sandberg, Badande, Embarkering and Cyklister. For a brief overview of the paintings based on condition reports obtained from the museum see chapter 2.

Analysis will be carried out using primarily non-invasive methods such as X-ray Fluorescence (XRF) and Infrared false colour imaging (IRFC), Xrf analysis is one of the primary methods for analysing pigment composition of artworks noninvasively. It allows for elemental analysis which can be used to determine the possible chemical makeup of the pigments. The analysis of paintings is complex, the use of XRF alone does not provide conclusive evidence in all cases, as it can not be used to determine organic pigments or chemical structure. IRFC is used as a complimenting method, it is a simple noninvasive method which can be used to identify some organic and inorganic pigments and can additionally be used to visualise the layout of the different pigments in the artworks. Further complementary micro-invasive sampling analysis was carried out using Fourier Transform Infrared Spectroscopy (FTIR) but the results were inconclusive and will not be featured in the study.

1.7 Limitations

The nature of the analysis carried out is closely linked to availability of equipment, highly advanced and accurate analysis equipment will not be available as they require both time, funding and often require more extensive sampling. Further as time is a limitation the study will only include a select number of artists and works from a specific period.

2. The Paintings

2.1 Skärgårdskväll

Figure 2.1: photography by Hossein Sehatlou

Artist: Karin Parrow

Size of canvas: 67 x 78 cm

Date: Unknown, gifted to the Gothenburg art museum by Ernst and Conny Colliander in 1937.

Material: Unvarnished oil painting on linen canvas with white ground. Mounted on a stretcher with a gilded ornamental frame. Surface coating of Céronis beeswax varnish applied in 1971.

Condition: Stable, older tear mending in the mid-left part of the painting.

2.2 Hamnen i Vinterväder, Karin Parrow

Figure 2.2: photography by Hossein Sehatlou

Artist: Karin Parrow

Date: signed 1939.

Size of canvas: 41,5 x 54,5 cm

Material: Unvarnished oil painting on linen canvas with white ground. Mounted on a stretcher with an ornamental frame. Surface coating of Céronis beeswax varnish applied in 1977.

Condition: Overall stable.

2.3 Blommor och Flicka

Figure 2.3: photography by Hossein Sehatlou

Artist: Ivan Ivarsson

Size of panel: 61 x 61 cm

Date: dated to 1934 purchased by the Gothenburg art museum in 1936

Material: Unvarnished oil painting on Masonite board with white ground. Mounted in a profiled painted frame.

Condition: The paint layer is overall stable; the Masonite board exhibits some mild convex deformity but which does not negatively affect the general stability. Older discoloured retouches

2.4 Badande Flicka

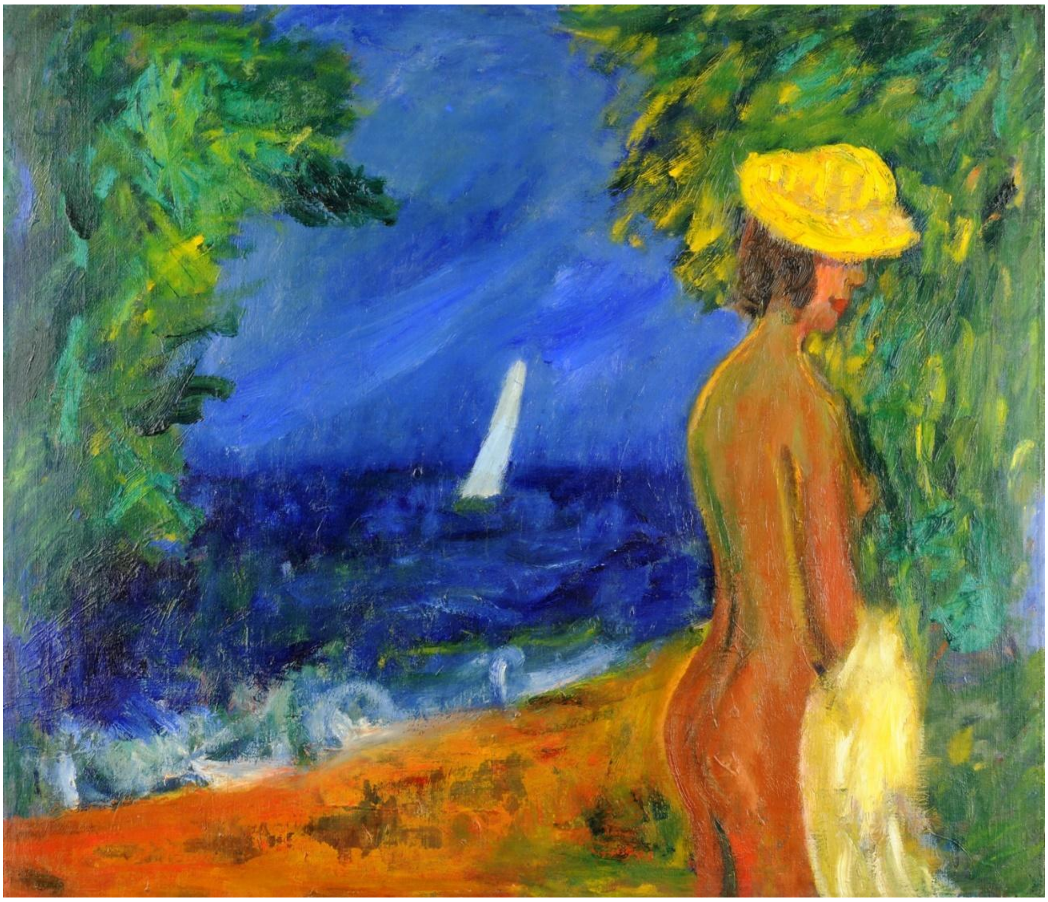


Figure 2.4: photography by Hossein Sehatlou

Artist: Ivan Ivarsson

Size of canvas: 100 x 114 cm

Date: Signed 1936

Material and description: Thickly applied impasto oil painting, painted alla prima on linen canvas. The painting has likely been overpainted, as older paint layers are partially visible. The edges of the painting are reinforced with stitched canvas, during a conservation treatment in 1991 it was concluded that the reinforcement of the canvas was likely done by the artist. The painting is mounted on a stretcher with a protective polyamide canvas. The varnish is likely to have been applied by the artist as paint residues from the pencil can be seen incorporated into the varnish; several lines on the back of the figure have been applied over the varnish. The varnish was suggested to likely be a damar/mastic/oil mixture.

Condition: Before the conservation treatment in 1991 the painting exhibited deformities, and local flaking and losses of the paint layer which were consolidated using sturgeon glue. An additional edge reinforcement was done using a polyester canvas. A thin protective cyclohexane (Larpal-N) was applied. Areas exhibiting loss of adhesion of the paint layers with a tendency towards flaking was observed when examined during the project.

2.5 Älvlandskap, Hjärtum

Figure 2.5: photography by Hossein Sehatlou

Artist: Ivan Ivarsson

Size of canvas: 126 x 141 cm

Date: dated to the 1930s.

Material: Unvarnished oil painting on an edge reinforced linen canvas with white ground. Mounted on a stretcher with a gilded ornamental frame.

Condition: The paint layer is overall stable with smaller areas who exhibit a possible tendency towards flaking primarily concentrated in areas where the green paint has been thickly applied.

2.6 Badande

Figure 2.6: photography by Hossein Sehatlou

Artist: Ragnar Sandberg

Size of canvas: 63,7 x 83,3 cm

Date: dated to 1935 purchased by the Gothenburg art museum in 1936

Material: Unvarnished oil painting partially impasto application, linen canvas. Painted ornamental frame.

Condition: The paint layer is overall stable; cracks formed during drying, some tendency towards flaking in small areas.

2.7 Embarkering

Figure 2.7: photography by Hossein Sehatlou

Artist: Ragnar Sandberg

Size of canvas: 64,5 x 73,5 cm

Date: dated to 1938

Material: Unvarnished oil painting on linen canvas. Ornamental frame.

Condition: The paint layer is overall stable.

2.8 Cyklister, Ragnar Sandberg

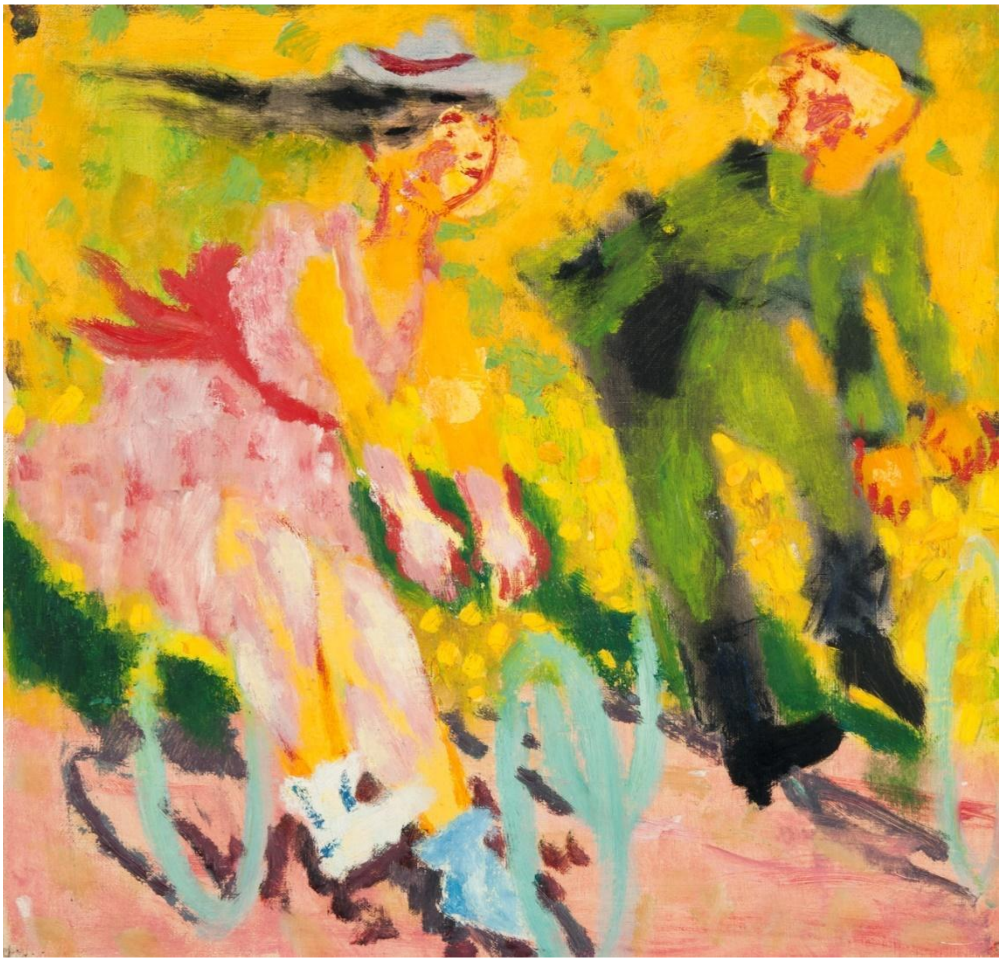


Figure 2.8: photography by Hossein Sehatlou

Artist: Ragnar Sandberg

Size of canvas: 46 x 44 cm

Date: dated to 1936 bought by the Gothenburg art museum in 1938

Material: unvarnished oil painting with impasto application, on a white grounded linen canvas. A protective undefined wax varnish has been applied. Mounted on a stretcher with a profiled painted frame.

Condition: loss of adhesion between mainly the yellow layers of paint, with some areas of severe degradation of the binding media, the most severely affected layers exhibit flaking, chalking and larger losses of paint. Possible loss of colour in some of these areas. These areas were consolidated using Plexisol P550, lager flakes were softened using a Klucel gel with iso-propanol and consolidated using Lascaux medium for consolidation.

2.8.1 Suspected degradation of cadmium yellow in Ragnar Sandberg's Cyklister.

Figure 2.8.1: Image showing the areas exhibiting signs of degradation of cadmium yellow paint.

During the analysis of Ragnar Sandberg's Cyklister some areas of concern were identified, three yellow areas of the paint exhibiting signs of advanced binding media degradation i.e. a chalky and desaturated appearance. Analysis found clear indications of the presence of Cadmium yellow in these areas. Cadmium is a pigment which is known to be prone to degradation.

Based on available photo documentation it does not appear like the degradation has increased substantially in the last decades. The areas where sampled, and prepared as cross sections for analysis, the analysis has as of the time of writing not been concluded so no clear answer can be given in this thesis. Initial examination has found that the samples are very fluorescent which would suggest that the pigment has been subject to degradation.

3. Historical background

3.1 Karin Parrow

1900-1982

2.1 Karin Parrow, Unknown author (Wikimedia Commons)

Karin Parrow was born in 1900 on the island Vinga in the Archipelago of Gothenburg. Artistic talent ran in the family, out of the thirteen children in the Taube family, three of them became artists ´Karin herself, her older sister Märta Taube-Ivarsson (1888-1974) a sculptor and painter and her older Brother Evert Taube (1890- 1976) was a notable author and the one of the foremost troubadours within the Swedish ballad tradition.

Karin started her artistic career during the mid-1920s when she studied at Valand academy of art in Gothenburg during the years 1926-1929. After Valand Karin studied abroad in France in 1930, where she studied Croquis for half a year, possibly at the Academie Grande Chaumièrer, or two months at the Scandinavian Academy (personal communication Eva Zetterman, November 5, 2021). During the 1930s Karin maintained a productive artistic output and participated in exhibitions almost every year. The critique was mixed and sometimes contradictory; one art critique is elated over her artworks while others regard her work as dependently following in the steps of Carl Kylberg, Ivan Ivarsson and Ragnar Sandberg. However statements from her time at Valand notes her as one of the earliest adopters of the elevated use of colour which came to characterise the Gothenburg Colorists, which therefore rather would suggest that she was a progenitor rather than a late adopter (Hansson 2022).

Karin maintained a productive artistic career for almost sixty years until her death in 1982 showing in galleries in Gothenburg, Stockholm and Malmö. While she produced an extensive amount of work only fourteen can be found in museum collections, among these are five paintings owned by the Gothenburg Museum of Art. One contributing factor was the destruction of 300 artworks in a flood in 1969; instead the majority of her surviving production is in private collections.

Zetterberg (2012) notes that Karin mostly painted with oil on canvas and panel, but also employed watercolour, pastel, pencil and charcoal sketches. Most of the paintings are signed with either her full name or initials but few are dated. Many of her undated paintings are hard to date. As her career progressed a successive development of her artistry can be seen. This change can be seen in the larger devotion and focus on the use of uniform, almost abstract paint fields and a decreased focus in capturing details. The subjects portrayed in the art are commonly landscapes, still life, people, portraits and self-portraits. Her landscape and tableau paintings often draw from her own life and immediate surroundings in the province of Bohuslän, an area encompassing the northern Swedish west coast.

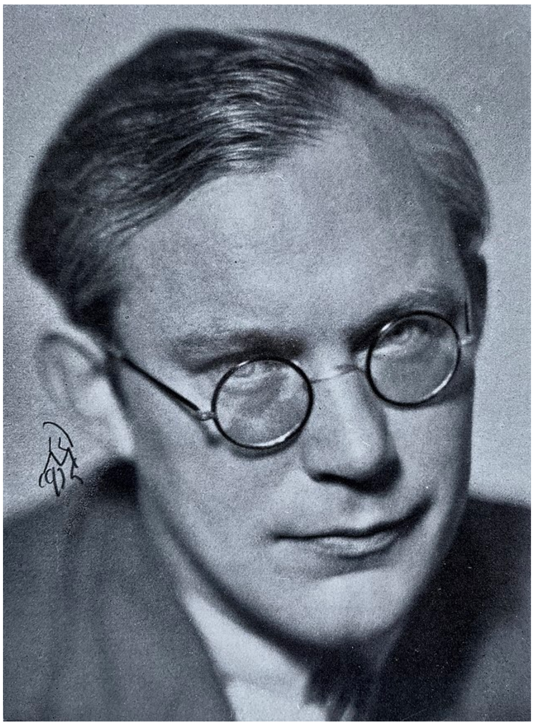
Karin’s art commonly depicts select motifs and themes which often recur in different variations and stages of development. In her landscapes Karin explored the seasonal changes, light shifts, the shifting moods of the ocean and the ocean’s reflections. In Parow’s still lifes it is also common to find glimpses of landscapes through windows or doorways. The sea was a constant presence in both her life and artworks. Evidence of this interest in the sea can be found in both her choice of motif and in choice of titles as words like archipelago, bathing and the ocean are common. Achieving harmonic balance in her motifs also seems to have been an important aspect for Karin as her work seems to have employed the golden ratio to create balance in the picture.

Karin was a self-acclaimed colorist and her work is known for its bold use of colour. She mainly used primary colours, red, blue and yellow, and commonly applied them directly out of the tube, unmixed. Zetterberg (2012) notes that Karin’s use of colour suggests that she demonstrates a great affinity for colour which can be seen in her highly skilled use of complementary colours: red is used with green, blue is used with orange and yellow with violet. Karin felt that the coast of Bohuslän possessed a unique shimmering light which when reflected in the water made the water appear like a living organism, and that capturing it on the canvas was her foremost interest. When painting blue Karin used several nuances of blue; often different blues were used to distinguish the sea and sky or shadows from each other. The blues she used included turquoise blues, ultramarine and cobalt blues. Other frequently used colours in Karin’s art are striking reds, deep oranges, violets and pinks.

Karin’s painting techniques made heavy use of impasto painting combined with thinner paint layers which allowed the canvas to shine through to create an illusion of light. Her brushwork is broad and hastily applied, and in some works she uses thick outlines to give shape to her figures and landscapes. Her figures are often featureless and anonymous. She summarised her career with “En handfull bilder tycker jag själv att jag har lyckats med. Att göra en bild är något av det svåraste som finns!” (Hansson, 2022) – I feel that only a handful of my pictures have been truly successful. To create a picture is one of the hardest things one could do!.

3.2 Ivan Ivarsson

1900-1939



2.2 Ivan Ivarsson, Unknown author (Wikimedia Commons)

Ivan Ivarsson was born in 1900. Throughout most of his life Ivan would struggle to come to terms with his own mortality and it would come to have a great effect on both his artistry and his struggles with his declining mental health. He endured many hardships during his formative years that would be a constant reminder throughout his life; Subelius (1954) suggests that his use of vibrant colours is partially a product of these hardships. He associated dark colours with the mud he used to play in in the graveyard opposite his childhood home, and he could sometimes ask his colleagues why they chose to paint with mud when there was so much vibrant colour.

His happiest periods during his childhood were the summers he spent with his family at his maternal grandfather's house. Ivan's maternal grandfather worked as a groundskeeper at Sollum in Hjärtum Bohuslän, years later Ivan would often return to Hjärtum to paint, often revisiting the same motif. Ivan was described as being thin and somewhat sickly throughout much of his life. When he became unemployed, he moved out to his parents' summerhouse. Where he paints his first of many flower bouquet still lifes, a subject which would come to characterise his artistry. Sometime during 1922 he decided to attend Valand Academy where he would study under the supervision of Tor Bjurström, Ivan studied with a large number of artists which would be characterised as the Gothenburg colourists such as Karin Parrow, Ragnar Sandberg and Märta Taube (Stubelius, 1954).

In 1927 he went on a longer european trip, with stops in Germany, Italy and France. During the summer of 1928 Ihe got married with Märta Taube while visiting Paris, and later that year their son Per-Ivan was born. Early in the marriage, the couple borrowed Carl Kylberg's atelier in Helsingør (Stubelius, 1954). According to Linde (1979) there were rumours that his economical situation got dire enough for Ivan to start painting over Kylbergs unfinished paintings which were left in the atelier. In the beginning of the 30s Ivan is once again forced to relocate home to Gothenburg due to destitution. He spent extended periods on Stenungsön just outside Stenungsund Bohuslän, during these periods he often painted his wife and child in nature.

His art did not sell well and they lived on assistance from Ivan's parents. All of Ivan's funds were spent on canvas and oil paints, and acquisition of oil paint was a constant problem throughout most of his life. When he had no paint, he became nervous and depressed. Those times he instead used ink, watercolour, crayons, pens and charcoal. If things were extremely dire he would empty out ballpoint pens to paint. Between 1932 and 1936, Ivan worked almost exclusively in Gothenburg. Ivan often painted his ateliers a brilliant ultramarine blue which Stubeliues (1954) calls his cardinal colour during the Gothenburg period. The Gothenburg period was his most productive period for exhibitions, and it is during one of these in 1936 that he sells his first artwork to the Gothenburg Museum of Art. The painting depicts a red rose bouquet in a yellow flower pot.

Ivan expressed that he painted only for himself and no one else, but if someone else saw something in his art, that was a nice bonus. Ivan's favourite artists were Renoir, Chagall, Bonnard, Vullilard, Osslund, Sandbeg, Bjurström, Isaksson and Kylberg. Ivan also supposably showed a strong aversion to being studied, as he would burn all his correspondence so no academics would be able to study him and come to wrong conclusions or make inaccurate statements on his character and art.

Stubelius (1954) notes that Ivan’s happiest moments were when he had just returned from buying new oil paint. He would often peruse the tubes he had just brought home and would often open the tubes and check their consistency and opacity of the paint between his fingers. Ivan had noticed that paints extended with oil or turpentine did not possess the same brilliance as pigment heavy paints. Ivan tested many domestic and international colour manufacturers for the most intensive and brilliant paints and avoided any paints he felt had too low pigment ratio. Stubelius mentioned that Ivan went through oil paint very fast, he saw Ivan regularly started 2-3 paintings a day.

Ivan’s main colours were cadmium based yellows, oranges and reds, chromium oxide greens and ultramarine. He also used ochres, English red and white, but more sparingly during his Gothenburg years. Black had supposedly been completely eliminated after his first visit to France. He had tested cobalt blue and green but thought that they lacked the brilliance he sought. He is known to mostly have painted with oil, but he also used tempera and aquarelle. He did one fresco early in his career, but the paints did not behave the way he had expected and he likely didn’t do another one. Stubelius also witnessed him doing primitive linoleum prints without a printing press. He is known to rarely have painted drafts for his paintings. In an interview leading up to his joint exhibition with Märta in 1932 he described his attitude toward painting as foremost to compose and reproduce colour, and if the colour is not foremost it can certainly be art but it is not painting.

In 1937 Ivan moved to France, his financial situation was still unsteady, and he relied on friends back home selling his art and sending money. Ivan had long predicted his own death, and often said that he did not predict that he would live to become old. His predictions came true, during the early summer of 1939 he fell ill and was admitted to hospital where he died on the 20th of June. His death is lamented by Bjurström as one of the biggest tragedies the new school of Swedish painting could suffer (p. 121 Sundborg, 1948).

During his career Ivar was sometimes accused of being too stereotypical in his painting as he often used repetitive motifs and colour choices. This was in part due to the fact that he often painted entire series of the same motifs to work through them and achieve the highest level of intensity. These works are the ones that received the highest exposure, but Stubelius notes that the paintings he did not exhibit show a much larger artistic breadth. He theorised that these paintings and the discarded paintings from his series were often painted over when canvas became scarce.

3.3 Ragnar Sandberg

1902-1972

Ragnar Sandberg was born in 1902 in Sanne Bohuslän. The family relocated to Stenungsund in 1915. As the family was reasonably well-off, Ragnar grew up in an upper middle-class household. In 1920 he would start attending the Valand Academy where he would study under Tor Bjurstrom. Bjurström did not have great confidence in Ragnars future as a painter but considered him quite the gifted

. During student exhibitions he partook in at Valand he received good critique from the press. Linde (1979) notes that during his years at the Academy he stood out as one of the few painters who dared to use light colours. Much of Ragnar's early production is suggested as having been lost or destroyed.

2.3 Ragnar Sandberg, Unknown author (Wikimedia Commons)

During his years at the academy, he greatly admired Munch, Sandels and Sager-Nelson and the French impressionists. By 1925 Ragnar was still studying at the Academy but had taken several breaks from his studies. travelling to parts of Asia and France, but he returns to Stenungsund after his studies. During this period Ragnar stops painting completely. He considers becoming an author, but these plans get upturned in 1929 when Ivan Ivarsson decides to settle in at Stenungsön, Stenungsund. The two rekindle their friendship with their rekindled friendship inspiring Ragnar to start to paint again, Linde theorised that this newfound inspiration helps Ragnar to lay his own personal difficulties aside and instead focus on his art (Linde, 1979).

Linde (1979) theories that it is unlikely that Ragnar found the inspiration to take up painting again from Ivan's use of colour as he was familiar with Kylberg's use of colour (which Linde argues is very similar to Ivan's) before he quit painting. Instead, Linde believes that it was what Ivan captured in his art that inspired Ragnar. During the 30s Ragnar moved back to Gothenburg, spending his summers in Stenungsund, Orust and Tjörn. He is Inspired by the west coast summer light and water reflections. He also partakes in several exhibition both in Gothenburg and Stockholm, he has some success in Gothenburg as he sells his first painting "Embarkering" to the Gothenburg Museum of art in 1936.

During the war Ragnar was called into military service but remained active and was highly productive. By the closing years of the 40s Ragnar had broken through and become well established. Linde describes Ragnar artistry as going through a middle age crisis during the 40s, he believes that Ragnar tires of his old works, his artworks no longer evoke the same feelings within him. Some of his works during these years are studies from worker cafes and dinner scenes. He starts painting landscapes devoid of all coloristic qualities, Linde suggests that these paintings are created in the field as the paintings start to portray more subtlety in their colour shifts and portrayal of light. In contrast to these more naturalistic works, he also starts experimenting with reduction of form and elements, sometimes bordering on abstraction. Linde suggests that these works are a clear influence by his admiration of Joan Miró.

Towards the closing years of the 40 he starts to develop the style that would come to characterise his later years. He begins to use graphics, parallel and linear lines and elements to divide and specify the different spatial elements in the paintings. In 1947 Ragnar became a professor in draughtsmanship at the Royal Academy of art in Stockholm and two years later he became a professor in painting. His artistic output during his time at the Royal Academy is diminished, according to Linde this is not due to a step down in productivity but a product of his harsh self-criticism. He was said to be very withheld and mostly at his atelier where he was said to be studying and deconstructing reproductions of old works by the old masters.

During his later years Ragnar primarily engaged in portraying still lives and models. The geometrical frameworks become more complicated, he devotes much time towards composition principles such as spatial areas and perspective, he studies the golden ratio, renaissance and baroque painters works. He reduced his colours to nuances of grey and ochres with elements of blue and brown. He also reads a lot of classical French literature and listens to baroque music which Linde suggests is closely intertwined in his output during the period. In 1972 he had a retrospective exhibition combining his old works with his new, shortly after the end of the exhibition he passed away (Linde, 1979).

3.4 Artist paints during the early 20th century in Sweden.

3.4.1 Development of prepared oil paints.

During the 17th century paints were primarily prepared from pigments bought from specialist paint-markers. Most pigments used in Sweden were imported from the more technically advanced paint makers in Europe. During the 19th century the sale of artist materials became more profitable and many of the paint-makers expanded and their production became industrialised. During the 18th century the demand for prepared paints increased, this was partly due to a strengthened middle class with many amateur artists and the establishment of the free artist. Thus the practice of preparing paints from raw materials was mostly lost.

One of the largest of the new industrial paint makers was the Winsor & Newton company founded in 1832. The basis for the company was formed by the Reeves family which had been prominent paint makers in England for several generations. The initially small company expanded quickly and opened specialised factories for production of artists paints. Several of the early synthetic pigments were produced along with organic pigments and mineral based pigments such as genuine ultramarine.

During the second half of the 19th century several art academies opened which also increased the demand for prepared oil paints. Several French companies manufacturing prepared oil paints were also opened during this period such as the Lefranc and Bourgeois companies (Johansson 2001).

3.4.2 Artist oil paints manufacturing in Sweden.

According to Johansson (2001)Paint manufacturers in Sweden produced very little in the way of artist materials during the 18th century, it would take until the early 20th century before any larger manufacture of artist materials were initiated. One of the leading paint manufacturers and retailers in Sweden during the last quarter of the 19th century was Beckers. During the 1870s to the end of the century the artist materials sold by Beckers were largely produced by international paint makers. Oil paints from France, Germany, England, and the Netherlands seem to have made up most of the assortment of artist colours sold. Other artist materials such as fine brushes and canvases were imported. By the end of the 19th century Beckers had become the main Scandinavian dealer for Winsor & Newton.

Around the start of the 20th century artists' oil paints had started to be manufactured by Swedish companies as well. The main Swedish manufacturer of artist oil paints during this period was Beckers, who were among the first Swedish companies with their own production of artists materials. The ease of access created by the increased availability of prepared oil paints was not only a boon, it also led to a change in how artists painted. Old knowledge was lost, and artworks were created with paints which could severely lack compatibility. Pigments which could be stable by themselves could be mixed unsuitably creating highly unstable mixtures. Several new synthetic pigments were also produced which lacked long term stability. To combat this a set of criteria for artists pigments were created by the German colour scientist Keims in the 1880s, the criteria where technical purity, lightfastness, resistance to atmospheric pollutants, insolubility in oil, insolubility in water, chemical compatibility in mixtures, and resistance to alkaline environments (for use in fresco painting).Binding media and fillers where also sought to be regulated as they could also strongly influence the stability of the colours. Paints matching these criteria were to be considered a “normal” colour. To be classified as a normal colour every batch of pigment also needed to be checked to ensure the quality of synthesis or manufacture.

Yellows	Reds	Greens	Blues	Whites	Blacks	Browns
Cadmium yellow	Burnt and red ochres	Chromium oxide green	Cobalt blue and violet	Zinc white	Ivory black	Brown ochres
Indian yellow	Cinnabar	Green ochre	Ultramarine		Graphite	Asphalt
Yellow ochres	Madder lake (alizarin)	Cobalt green	Prussian Blue			Umbra

Table 1. Table of the selected pigments suggested by Anton Munkert in 1905 (Kumlien 1954).

The first producer of the "normal paints" in Sweden was Beckers "Normalfärger" introduced in 1912, which consisted of 24 colours largely based on the list of paints produced by Munkert. When the first world war commenced in 1914 importation of artist materials to Sweden largely ceased. Instead, Swedish artists had to make do with the domestic production of artist materials, this meant an increased use of Swedish paints. The 1920s saw intense testing of new colours at Becker and by the end of the 1930s the list of normal paints included over 40 different paints.

Yellows	Reds	Greens	Blues	Whites	Blacks	Browns
Two shades of Cadmium yellow.	Two shades of Cadmium Red	Chromium oxide green	Cobalt blue and violet	Zinc white	Ivory black	Brown ochres
Two shades of Naples yellow.	Cinnabar (replaced in the early 1940s)	Green ochre (burnt and Veronese)	Ultramarine	Titanium White		Umbra (burnt and unburnt
Yellow ochres	Madder lake (alizarin)	Cobalt green (two shades)	Prussian Blue	Mixing white (mixture of lead and zinc white)		
Indian yellow	Burnt and red ochres	Cerulean blue	Viridian	Lead White		
Terra di siena	Caput mortuum					
Yellow ochre						

Table 2. Table of the selected Beckers Normalfärger during the 1930s (Kumlien 1954).

3.4.3 Common Paints during the early 19th century

The following tables of pigments are based on the paints presented by Kumlien (1954) and paints listed by Douma (2008). The tables include the main elements found in each the pigments with common additives and fillers for some of the pigments, in those cases the information is derived from Artist Pigments, A Handbook of their History and Characteristics vol 1-3 (Feller, 1986, Feller, Roy 1993, FitzHugh, 1997). All of the listed elements are not observable in XRF spectras, lighter elements than silicate can not be accurately identified in the XRF spectrums collected in this study and any possible identification of these elements should therefore also be seen as speculative.

Yellow Pigment	Main Elements	Common Additives/fillers
Cadmium yellow/orange	Cd, S	Zn, Ba, S, Mg, Sr,Pb, Fe, O
Naples Yellow	Pb, Sb, O	
Chrome yellow	Cr, Pb	
Lemon yellow	Sr/Ba/Zn, Cr	
Cobalt yellow	Co, N, K	
Yellow Ochre	Fe, O, H	
Terra di Siena	Fe. O. H, Mn	
Mars yellow	Fe, O	

Table 3. Table of the common yellow pigments available during the early 20th century.

Red Pigments	Main Elements	Common Additives/fillers
Cadmium Red	Cd, S, Se	Zn, Ba, S, Mg, Sr,
Alizarin crimson/madder lake	Organic	Al, K, Fe, Ca, C, O, Sn, Cr
Vermilion/Cinnabar	Hg, S	
Venetian red/English Red	Fe, O	
Red Ochre	Fe, O	
Caput Mortuum	Fe, O	

Table 4. Table of the common red pigments available during the early 20th century.

Green Pigments	Main Elements	Common Additives/fillers
Chromium oxide green	Cr, O	
Hydrated chromium oxide /Viridian	Cr, O, H	
Green earth	Fe, O, K, Al, Mg, Si	
Cobalt green	Co, O	

Table 5. Table of the common green pigments available during the early 20th century.

Blue Pigments	Main Elements	Common Additives/fillers
Ultramarine	Na, Al, Si, O, S	
Prussian Blue	Fe, Cn, H, O	Na, K, NH^{4+}
Cobalt blue	Co, Al, O	
Cerulean blue	Co, Sn, O	

Table 6. Table of the common blue pigments available during the early 20th century.

White Pigments	Main Elements	Common Additives/fillers
Zinc White	Zn, O	
Lead White	Pb, C, O	
Titanium white	Ti, O	

Table 7. Table of the common white pigments available during the early 20th century.

Black pigments	Main Elements	Common Additives/fillers
Ivory Black	C, P, Ca, O	
Carbon black	C	
Mars Black	Fe, O	

Table 8. Table of the common black pigments available during the early 20th century.

3.4.3 Ripolin Paints

According to Linde (1979) Ragnar has been suggested to have used Ripolin paints on several occasions, notably he used blue ripolin paints in a series of paintings depicting blue buses.

Ripolin paints were the first commercially available enamel paints, first developed in the 1890s. The first Ripolin paint factory was located in France but due to an enormous success the company soon expanded to open paint factories in several countries. Ripolin paints were produced for a wide range of applications such as house paints, cars, bicycles, furniture and boats. Ripolin paints are known for their high quality, fluidity, fast drying and self levelling properties which made them appealing for many artists such as Kandinsky (1866-1944) Picasso (1881–1973) among others (Dredge et al., 2013).

The binding media used in ripolin paints was comprised of a combination of drying oils (e.g. tung oil), gums and resins (commonly fossil resins). Many enamel paints during the 30s were based on an admixture of tung oil, linseed oil, phenolic resins, fossil resins, rosin or ester gums. The exact formulations of the paints likely varied between batches and countries and due to economical conditions and the need to make paints suitable for different climates (Dredge, 2013). Metal carboxylates dryers such as organometallic salts of cobalt, manganese, lead, and possibly zinc were often used (Mcmillan et al., 2013).

Matte finishes could be achieved in several ways, either by increasing the pigment concentration and using pigment extenders, lithophone and varnishes with matting agents could also be used to increase the matteness of the final product.

Ripolin is suggested to have used the following pigments in their paints, chrome yellows and greens, toluidines (organic aryl-amines similar to aniline) for red, Prussian blue for blues, and carbon blacks (Dredge, 2013). Red lead, vermillion, hansa yellow, alizarin crimson are also noted to have been found, with the use of red lead and vermillion being noted as primarily used in highly specialised lines. Cadmium based pigments have not been found in any ripolin paints, nor have cobalt based blues, violets and emerald greens been found. (Mcmillan, 2013)

Most enamel paints are noted as being alkyd resin based (Enamel paint - Wikipedia, 2022), such paints were introduced during the 20s, but it would take until after the second world war until research and development of alkyd paints took off (Ploeger, Chiantore, 2013). It would therefore seem likely that any Ripolin paints which were used in the paintings included in this study were likely not alkyd based but instead enamel paints based on mixtures of oils and varnishes as implied by above mentioned research. There has to the authors knowledge not been any research carried out on the ageing or degradation of ripolin paints produced during the relevant period for this study. As the research has suggested that the formulation of the paint varied it could likely be concluded that the ageing process is highly dependent on the exact formulation of the paint, i.e the stability of the drying oils, resins and additives used and the ratios of these compounds.

3.4.4 Drying oils

Both fats and oils belong to the lipid group, lipids are mainly composed of triglycerides, with smaller quantities of di and monoglycerides, free fatty acids and glycerides. Different lipids contain different types of fatty acids, oils which exhibit a high degree of polyunsaturation are commonly referred to as drying oils due to their ability to "dry" and form a hardened film and are therefore used as binding media in oil paint. The most commonly used oils used as binding media are linseed oil, safflower, walnut, other nut and plant based oils. The different drying oils vary in their drying behaviour, flexibility, colour, and permanence due to their diverse composition.

Oil paints dry into different stages, the first stage occurs in a few days to weeks where it forms a flexible film which is dry to the touch. At this stage the second stage of drying begins which is a significantly slower process than the first not completed until no reactive unsaturated compounds are left which often takes several years. (Erhardt et al. 2000).

The "drying" process of oils is a process caused by autoxidation which begins readily once it has been spread out to create a film and is exposed to light and oxygen. Atmospheric oxygen is inserted into the carbon hydrogen bonds adjacent to the unsaturated double bonds, this reaction cannot happen spontaneously. For the reaction to occur, a catalyst or initiator is required, which can be found in metals added to the oil, light, heat, ozone, and free radicals found naturally in oil. Therefore metals are commonly added to drying oils to catalyse drying through the creation of free radicals by electron transfer. Common metal catalysts are cobalt, Iron, copper, manganese, magnesium and vanadium. Many metal-containing pigments have also been found to drive this reaction, and some have been found to delay these reactions. It has also been found that metal based pigments (commonly oxides) react with free fatty acids to form complexes, which might result in the formation of metal carboxylate soaps which are discussed in more detail on zinc white and lead white sections.(Alves 2015).

Some modern oil paints have been found to be water sensitive, a well-documented phenomenon found in many unvarnished 20th century paintings. It is generally theorised that factors such as the paint formulation (binding media, pigment additives as fillers), environmental conditions and the artists' use and or modification of the material affect its sensitivity to water.. One known factor for the water sensitivity of modern oils paints is the Winsor & Newtons use of magnesium carbonate as a filler, which reacts with sulphur-based gases in the air to form water soluble sulphur-based deterioration products on the painting. Paints containing cobalt green, lead, zinc and titanium white, are suggested to be consistently non-water sensitive (Lee et al. 2017).

3.4.5 Barium Sulphate

Three main types of barium sulphate are used in paint manufacturing, the barium sulphate based mineral barite, Synthetically prepared pure barium sulphate and lithopone. Paint industry has been used as an extender for lead white and as a base for lake pigments. Barium sulphate has also been known to be used as a white pigment, artists oils paints created using barium sulphate were commonly sold as process white and permanent white (note that zinc white has also been sold as permanent white). When used as a filler in paints it is commonly referred to as lithopone. Lithopone is a mixture of barium sulphate and zinc sulphide. Another use for barium sulphate is cadmopone paints which is a mixture of barium sulphate and cadmium sulphide.

Barium sulphate remains in use as a white pigment and as a base for lake pigments today. Both natural and synthetic barium sulphate are lightfast and considered to be chemically inert. Barium sulphate is somewhat transparent in oil, this transparency is known to increase with ageing of the medium. As when the oil ages the refractive index of the oil becomes more similar to barium sulphate. Oil paints with barium sulphate are also known to exhibit chalking more commonly than paints without, this is because the higher transparency allows the light to penetrate the paint deeper thus enabling more severe binding media degradation (Feller, 1997).

4. Methods and Materials

4.2 XRF Analysis

XRF is an elemental analysis method, which means that it aims to identify the atomic elements in a sample. It uses a short-wave x-ray or gamma ray which ionises atoms, when ionisation occurs within the atom a surplus of energy is created within. This causes one or more of the atoms electrons to become excited and leave the atoms electron shell, the loss of the electron causes the atom to become unstable and an electron from a higher energy orbital descends to fill the empty space and stabilise the atom. The energy which is released when the electron descends from a higher energy orbital is picked up by a detector and measured. This energy is characteristic for all elements. The method is commonly used within the field of conservation for a wide array of uses such as pigment identification.

XRF Analysis was carried out in pre-selected areas of the paintings, the XRF analysis was mainly focused on determining the used pigments. Spots for analysis were primarily chosen in areas with pure colours, as they have a higher chance to have been applied straight from the tube with little mixing. This was done with the reasoning that it would be easier to separate which elements might belong to which pigment. Analysis was also carried out in some areas which were deemed likely to be mixtures to determine if other paints were used additionally to the paints used "straight out of the tube".

The raw XRF data was processed using PyMCA which is a free program developed by the European Synchrotron Radiation Facility (ESRF). All used spectra and more detailed interpretation can be found in the appendix.

The analysis was carried out using a ELIO non-contact portable x-ray fluorescence spectrometer (Bruker) with a rhodium target and a silicon drift x-ray detector (SDD). Capable of acceleration voltage range of 10 – 50 kV and current range of 5 – 200 µA. Analysis conditions used were 40 kV, 20 µA with a real time of between 40-80 seconds.

1.5.1.1 Sampling.

The sample areas were largely limited to the primary colours, some of the secondary colours and white paints, areas of similar colour throughout all the artworks were selected to achieve comparable results. Certain areas were also selected based on the wishes of the museum. Black and grey colours were tested in Ragnar's works as Ragnar was one of the few colourists who used blacks and greys regularly. Several spectra were obtained in each area, all the spectra collected were interpreted in batches for each artwork based on colour and proximity in shade and location. These results have been compiled into tables included in chapter 5, as well as in depth interpretations of selected representative spectras. Full interpretation of XRF spectras are included in the appendix.

4.3 Infrared false colour photography

Infrared photography uses a film which is sensitive to IR light, the range used in IR photography this range is primarily 700 nm to 900 nm which is commonly referred to as the near-infrared.

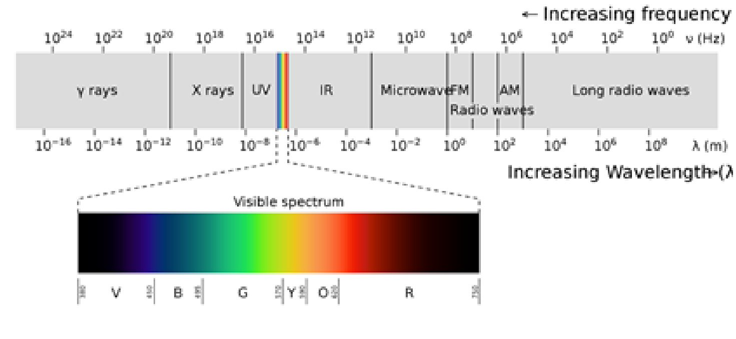


Figure 4.1: The electromagnetic spectrum, Philip Ronan (Wikimedia Commons).

Infrared false colour photography or IRFC is a photographic method which works by combining visible light photography and IR photography, the blue and green channels are taken from the visible spectrum while the red channel is represented by the IR imaging. The resulting image can then be used to document retouches and for tentative pigment identification. The use of IRFC for pigment identification is possible as different pigments absorb IR radiation differently, mixing the IR channels with visible light helps visualise this difference. Pigment analysis using IRFC alone is not an accurate method but it is a cheap and fast way for speculative pigment analysis which if combined with other methods, can be useful to map pigment distribution. It can be a useful tool for the identification of pigments which are hard to differentiate using purely elemental analysis. (Infrared False Color photography (IRFC) - Cultural Heritage Science Open Source, 2022) Interpretation of the IRFC photography was conducted using Cosentino, A. (2014) and a series of spectral imaging databases by Boust, C. (2017) Douma (2008) Images where taken using Artist camera by Art interaction technologies.

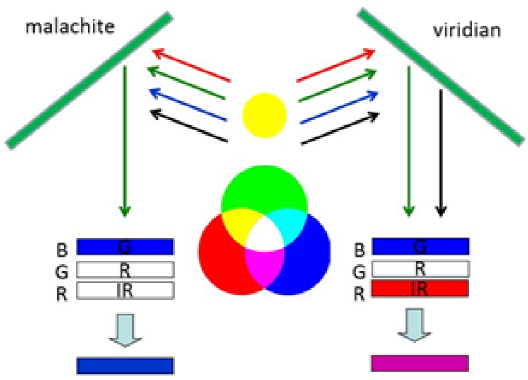


Figure 4.2: FCIR photography, differentiation between malachite and viridian. As viridian and malachite reflect light differently in IR the differentiation between the two using IRFC is possible , (CHSOS).

5.Analysis

5.2.1 Karin Parrow

Skärgårdskväll

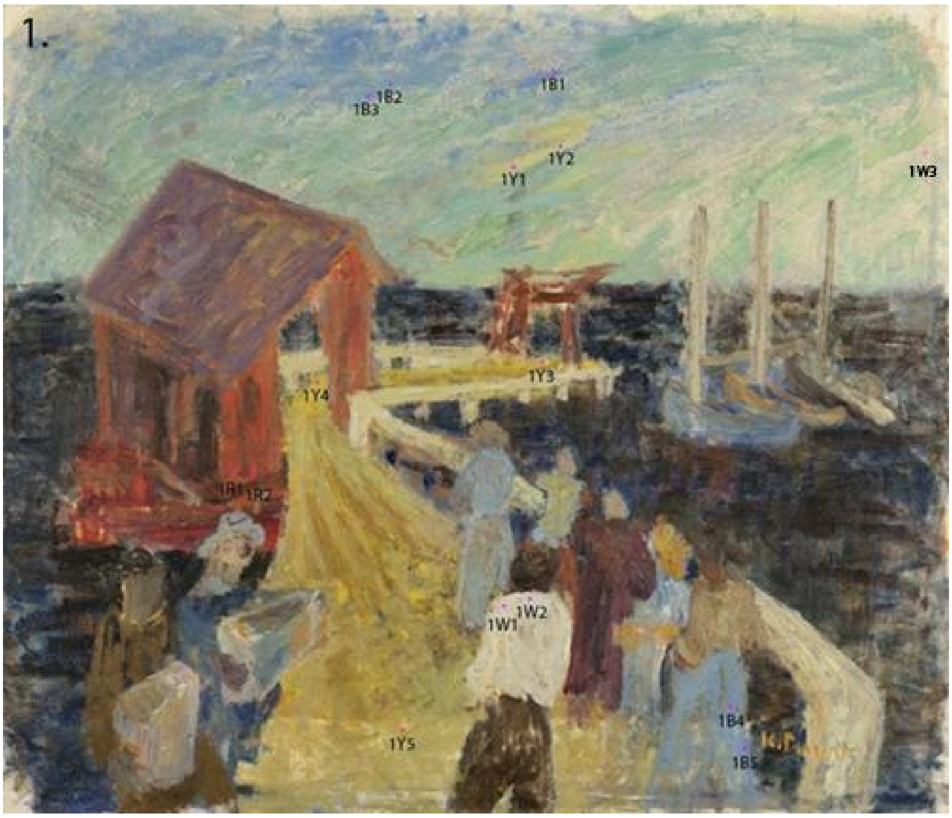


Figure 5.1: Image showing the points of analysis, photography by Hossein Sehatlou.

1Y1-2	1Y3-5	1R1-2	1R3	1G1-2	1B1-3	1B4-5	1B6-7	1W1-2	1W3
Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn
	Pb	Pb	Pb	Pb	Pb	Pb	Pb		Pb
Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl
Cd	Cd	Cd	Cd						
S	S	S	S		S	S	S		S
Fe	Fe	Fe	Fe		Fe	Fe	Fe	Fe	
Ni	Ni		Ni		Ni	Ni		Ni	
Cr	Cr				Cr	Cr		Cr	
Ba/TI	Ba/Ti	Ba/Ti		Ba/Ti	Ba/Ti	Ba/Ti	Ba/Ti		Ba/Ti
		Se							
		Co			Co			Co	
		Ca	Ca			Ca	Ca		
Cu				Cu	Cu				
				As	As				
	Mn					Mn			
							Si		
							K		

Table 9. XRF results Skärgårdskväll.

Hamnen i Vinterväder

Figure 5.2: Image showing the points of analysis, photography by Hossein Sehatlou.

2Y1-3	2Y4-6	2Y7-9	2Y10-12	2R1-3	2G1-3	2G4-5	2B1-3	2B4-5	2W1-2	2W3
Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn
Pb	Pb	Pb	Pb	Pb	Pb		Pb	Pb	Pb	Pb
Cl				Cl	Cl	Cl	Cl		Cl	Cl
Cd	Cd	Cd	Cd	Cd	Cd					
S	S	S	S	S	S	S	S	S	S	S
	Fe	Fe	Fe	Fe	Fe	Fe	Fe	Fe	Fe	
							Ti	Ti		
			Ni	Ni	Ni	Ni		Ni	Ni	
					Cr	Cr	Cr			
		Ba			Ba	Ba				Ba
				Se						
									Co	
			Ca	Ca	Ca	Ca	Ca	Ca		
					Cu	Cu				
					As	As				
							Si			
						K	K			

Table 10. XRF results Hamnen i Vinterväder.

Yellow

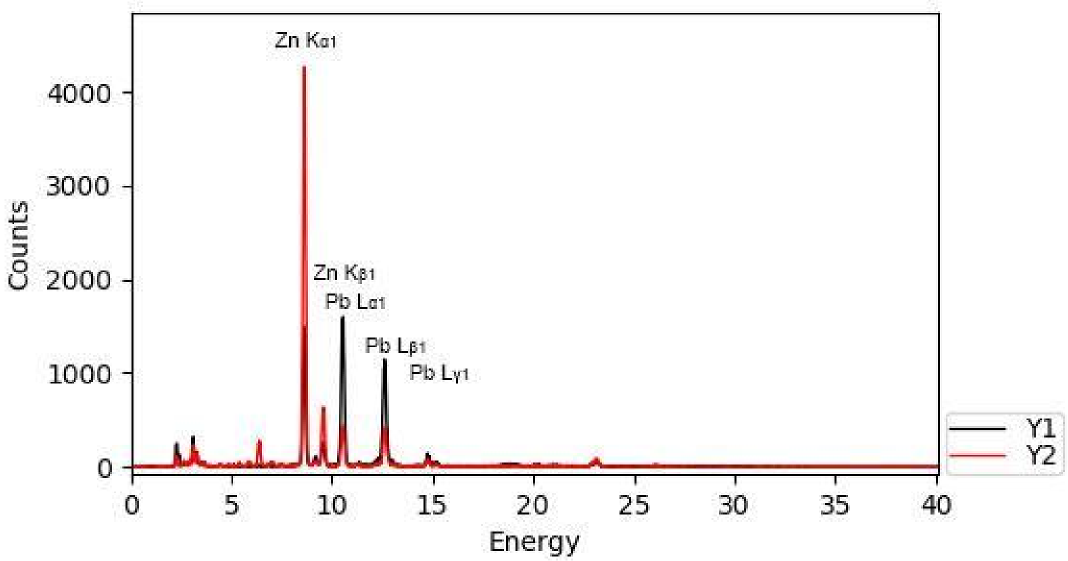


Figure 5.3: Image showing a comparison of the xrf analysis spots in the yellow areas of Karin Parrows artworks.

The XRF spectra obtained from the yellows found in the two paintings by Karin Parrow are quite similar. Spectras collected in the yellow all share strong peaks for Zinc and Lead, both can plausibly be traced to the ground layer of the painting which is likely a mixture of zinc white and lead white. Zinc is also commonly found in connection with cadmium paints, as cadmium pigments could be produced using mixtures of calcined cadmium sulphide, zinc sulphide and zinc or magnesium oxide. Zinc is also often incorporated in the crystal lattice during the simultaneous precipitation method used in the production of modern pigments, this can be done to lighten the resulting pigment. Lead white was sometimes also added to the cadmium paint mixture, but this practice had likely ceased by the 1930s due to the reportedly highly unstable nature of these paints, the lead could also have been added for its siccative properties.

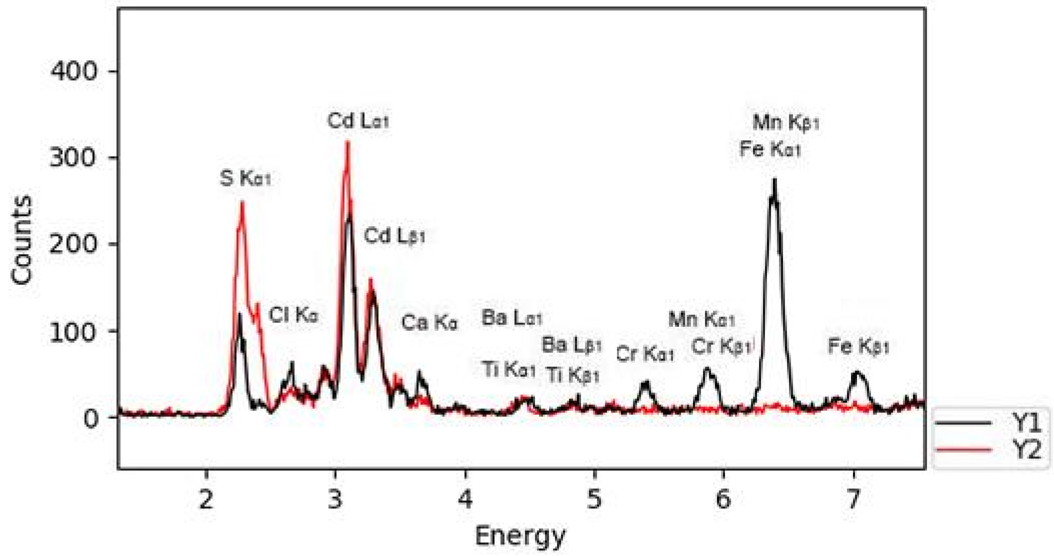


Figure 5.4: Image showing a comparison of the xrf analysis spots in the yellow areas of Karin Parrows artworks. Zoomed in on 1.5 keV to 7.5 keV

In Skärgårdskväll (Y1) there is evidence which suggests that tiger yellow pigments have also liklet been used. It is likely that these other yellows are earth pigment based colours as peaks for iron, calcium, and manganese can be seen, earth pigments are generally composed of iron oxides with varying amounts of clay and sand. The presence of manganese suggests the use of a terra di siena which is a darker yellow ochre, as it contains small amounts of manganese oxide. Manganese has also been known to be added as siccative, but since it is only found in yellow areas in proximity to the yellow jetty it is more likely to be a sienna paint than an additive to the cadmium yellow paint. Iron could also be an indication of a Mars yellow pigment which is a yellow based on a ferric hydroxide, described by Kumlien (1954) as being closer to chromium yellow than normal yellow ochre. Calcium could also indicate the use of chalk in the ground or as a filler in the paint. The presence of sulphur supports the idea that cadmium yellow was used as it is a component in cadmium yellow. The presence of a peak at 2.6 keV could indicate chloride, but it is also a peak associated with rhodium whose peaks $L_{\alpha1}$ and $L_{\beta1}$ are at 2.6 keV and 2.8 keV. As these peaks overlap it's hard to definitely conclude that it actually is chlorine that's present and not rhodium from the x-ray tube. The peak in Y1 is as strong as the argon peak at 2.9 which might indicate the presence of actual chlorine. If chlorine was present it could be traced to the cadmium yellow as it was sometimes used as a starting reagent in the production of cadmium yellow and can sometimes be found as a residue in poorly manufactured material. However, the general presence of cadmium in all spectra collected in these paintings would suggest that it comes from an external source such as aerosols (if not traceable to the x-ray tube). Karin lived and worked long periods by the sea so contamination by chlorine by atmospheric interference would be expected.

The presence of chromium in Skärgårdskväll (Y1) could possibly be explained as either a contamination of or an adjustment of hue using chromium oxide green. The weak peak suggesting the presence of titanium could be minute amounts of titanium white added to a mixture or the presence of titanium white in the ground. Titanium and zinc white were both available at the time and possess different qualities from each such as opacity which could warrant the use of both to achieve different effects. However, no clear use of a titanium white can be seen in any of Karin paintings and it is traditionally less commonly used for mixtures as it requires far more pigment to colour than zinc and lead white. titanium white can contain zinc white which could suggest that titanium white was used. The weak intensity of the peaks would correspond to the expected peaks of titanium. But it is hard to conclude with any greater certainty that it was used. Titanium's peak also potentially overlaps the peaks of barium which is also a possible candidate, but bariums K_α peaks cannot be seen, possibly due a sub optimal accelerating voltage. Using log scale no obvious peaks are visible which lowers the probability of it being barium. If barium is present that would indicate that the cadmium paint might have been prepared using lithophone (barium sulphate). The presence of titanium could possibly be traced to a yellow pigment as the weak tentative peak was identified at 7.5 keV in the spectra collected in the yellow areas could be indicative of nickel. Both titanium and nickel can be found in the several yellow pigments such as barium titanate yellow, and Titanium yellow which is a nickel titanium antimony pigment but no date for the introduction of this pigment could be found nor could any sources on how widely employed this pigment was.

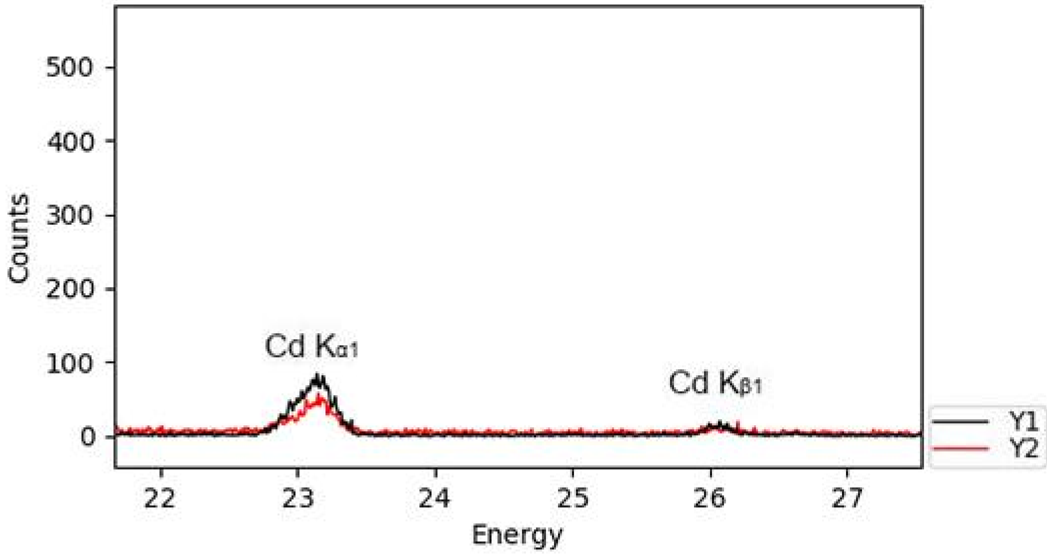


Figure 6.5: Image showing a comparison of the xrf analysis spots in the yellow areas of Karin Parrows artworks. Zoomed in on 21.8 keV to 27.5 keV

No peaks were attributed to antimony but peaks at 3.6 keV attributed to calcium, 3.8 keV, and 26 keV attributed to cadmium could correspond respectively to the $L_{\alpha1}$, $L_{\beta1}$ and $K_{\alpha1}$ peaks of antimony, no $K_{\beta1}$ peak can be seen at 29 keV. Both pigments are quite obscure, and no history of use could be found making the hypothesis that titanium either fully or partially responsible for the yellow colour deemed unlikely. If the tentative antimony peaks were present a more likely yellow would possibly be Naples's yellow. The peak for cadmium is quite weak compared to the intensity found in the peaks of the other examples of cadmium yellow in the study but it is still quite a clear cadmium peak compared to the titanium, nickel, possible barium peaks and tentative antimony peaks and it is therefore fair to assume that cadmium yellow with a possible additive of lithopone and yellow ochre and or a sienna are the yellows employed by Karin in these works.

Red

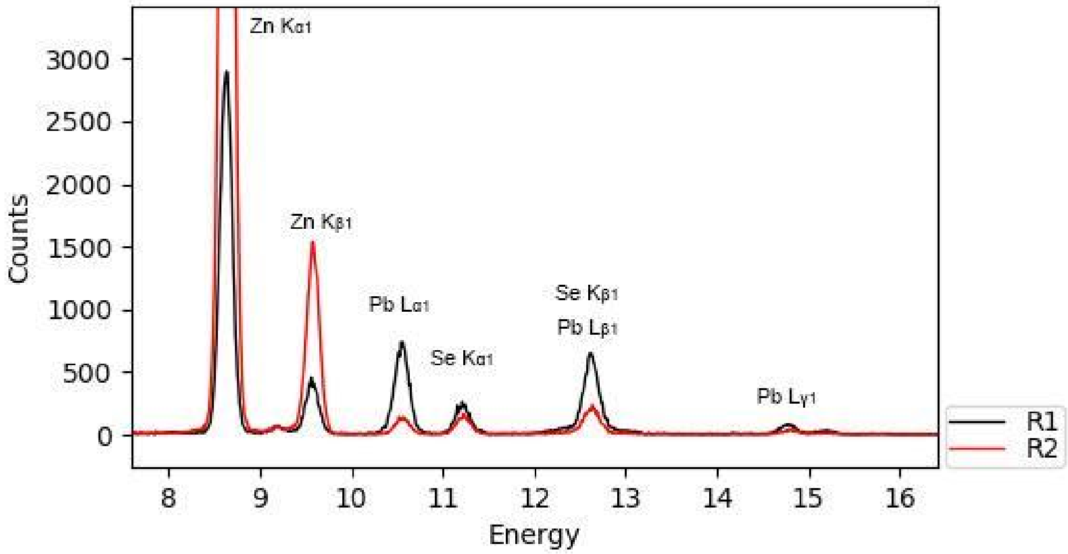


Figure 5.6: Image showing a comparison of the xrf analysis spots in the red areas of Karin Parrows artworks. Zoomed in on 7.8 keV to 16.2 keV

XRF spectra obtained from two of the Reds found in the two paintings by Karin are quite similar in nature. Both lead and Zinc can be seen in the spectra's, which is likely traced to the ground or additives in the paint. A peak can also be seen for selenium, sulphoselenides are found in cadmium reds therefore the presence of Selenium in a red paint is a strong indication of cadmium red.

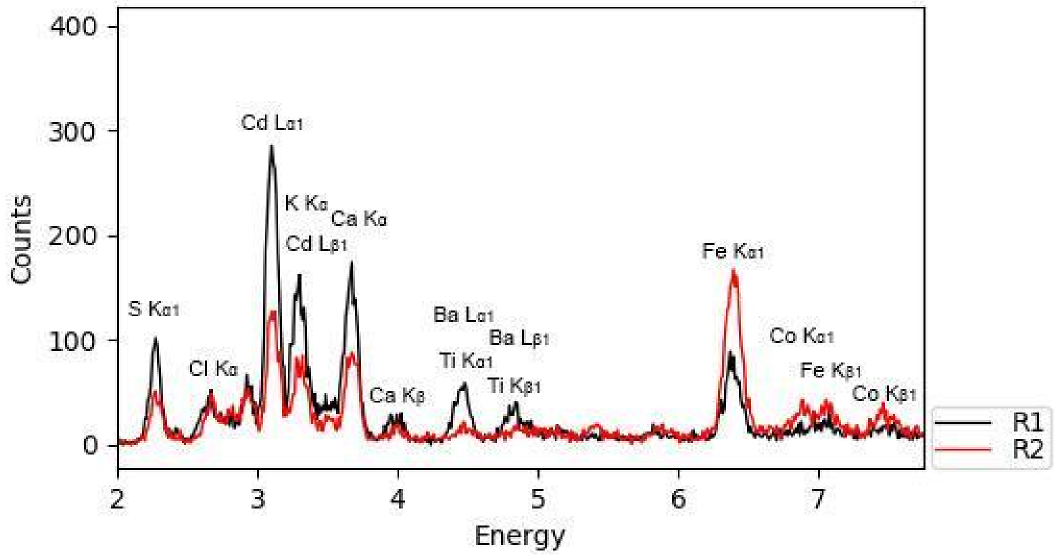


Figure 5.7: Image showing a comparison of the xrf analysis spots in the red areas of Karin Parrows artworks. Zoomed in on 2 keV to 7.8 keV

Strong cadmium, and sulphur peaks can be seen which also supports the notion that cadmium red is one of the reds used by Karin. The weak presence of a calcium peak could either suggest either the presence of chalk or the use of a iron oxide based red which is a plausible explanation to the presence of iron, but iron could also have been added as a siccative to any of the paints. Iron and calcium can also be loosely connected to the manufacture of madder lake based paints. Cobalt could be present due to contamination from a cobalt blue paint or as a commonly used siccative. Titanium peaks can be seen in the reds as well, which as mentioned previously overlap the peaks of barium.

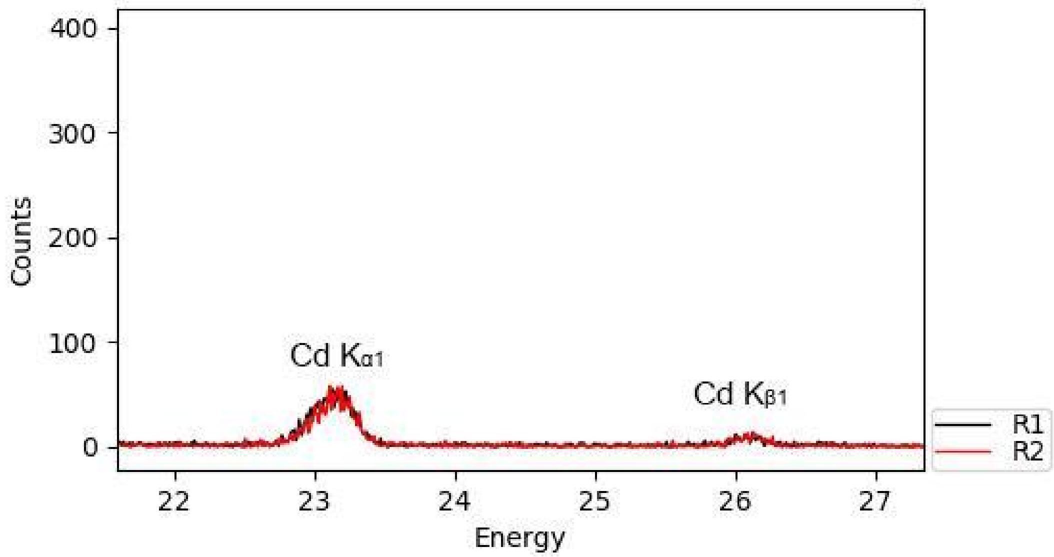


Figure 5.8: Image showing a comparison of the xrf analysis spots in the red areas of Karin Parrows artworks. Zoomed in on 21.6 keV to 27.2 keV

Moderately weak cadmium $K_{\alpha1}$, $K_{\beta1}$ peaks can be seen which has been in keeping with the cadmium yellow used by Karin, this might indicate that a quite low quality paint was used or could suggests that the cadmium paints were used in a mixture rather than straight out of the tube which could account for the lower cadmium content seen in Karin work. The presence of both selenium and cadmium would strongly suggest the use of cadmium red, and the strong iron peak might suggest the use of a red ochre.

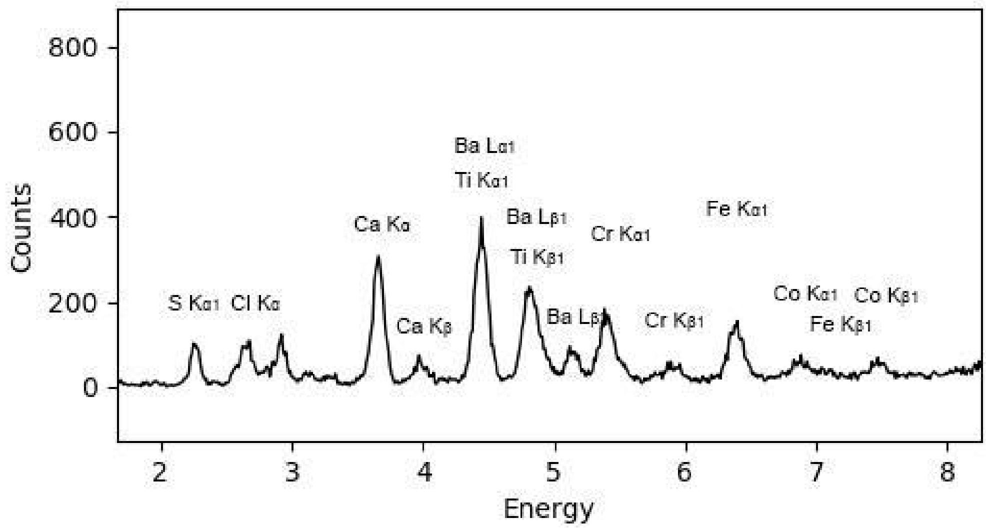


Figure 5.9: Image showing a comparison of the xrf analysis spots in the darker violett red area of Karin Parrows Skärgårdskväll. Zoomed in on 1.8 keV to 8.2 keV

Spectra collected in red areas of Skärgårdskväll suggest the use of an additional red paint as no clear cadmium peaks can be observed. calcium, chromium, iron, sulphur have all been suggested as possible elements possibly encountered in the organic dye madder lake, barium sulphate and clays are listed as common mordants for the dye when used in oil. (Schweppe, 2012). Calcium is a common mordant for precipitation of azo lake pigments (Eastaugh, 2008). Carmine is also a possible organic red similar in colour to madder lake. The iron peak could also suggest the use of an iron oxide red. Carmine is specifically stated as being prepared using an iron free alum which would suggest that unless a red ochre was used carmine is unlikely to have been used unless the iron peaks might originate from an underlying paint layer.

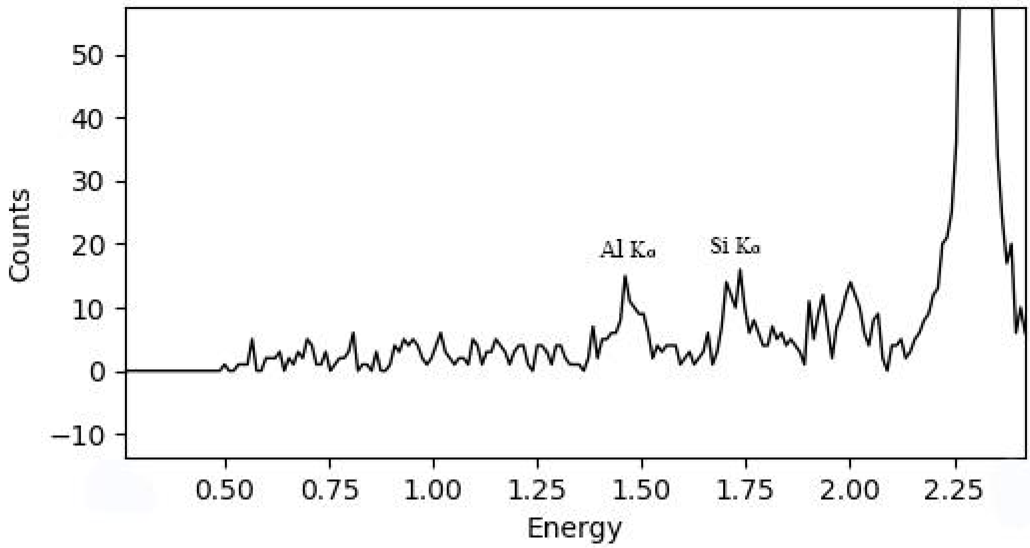


Figure 5.10: Image showing a comparison of the xrf analysis spots in the darker violett red area of Karin Parrows Skärgårdskväll. Zoomed in on 0 keV to 2.4 keV

There is a possible small peak in the region where Aluminiums K_{α} would be expected but this area is outside the area of accurate detection for the XRF model used, this could be from an alum salt mordant but might as likely also be noise. Both carmine and alizarin are commonly prepared using alum salt which is a potassium aluminium salt, while there is a possible aluminium peak there is no clear potassium peak which makes it unlikely that an alum mordant is present.

To conclude the analysis of Karin's reds found clear evidence of use of cadmium red, possible use of a iron oxide red, with/or a lake pigment such as alizarin.

Green

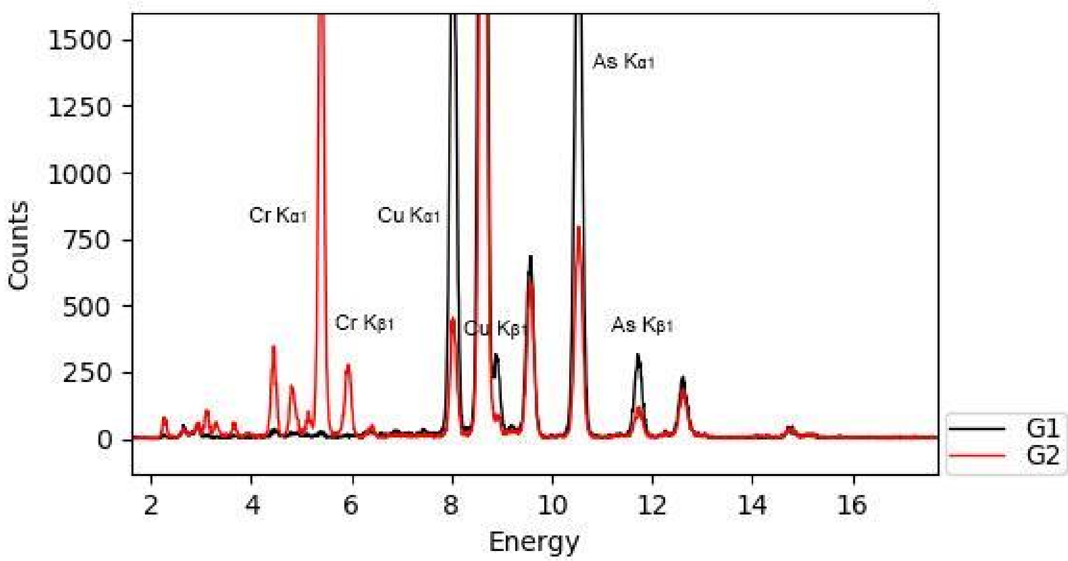


Figure 5.11: Image showing a comparison of the xrf analysis spots in the Green areas of Karin Parrows artworks. Zoomed in on 1.8 keV to 16.8 keV

The spectra in the green areas showed peaks for copper and arsenic. Such clear peaks strongly point to the use of an arsenic green, the two main arsenic green pigments in use are Schweinfurtner green or Scheele's Green. Schweinfurtner green is a copper(II) acetate tri arsenite or copper(II)acetoarsenite while Scheele's Green is a cupric hydrogen arsenite. To tell them apart further analysis of the molecular composition is required as their elemental composition is identical. Both pigments are unstable, Schweinfurtner green was seen as an improvement of Scheele's green and is comparatively less unstable.

In Hamnen I Vinterväder (G2) the arsenic green is clearly mixed with another green namely a chromium based green colour, this can be seen in the intensive chromium peak. There are two main chromium based green pigments chromium oxide and hydrated chromium oxide commonly known as viridian. While there is a quite noticeable difference in hue with viridian being more on the blue side it is hard to visually judge as the painting could likely be a mixture with arsenic green, unless the arsenic green was used in an underlying layer. Since the only substantial chemical difference is that one of the pigments is hydrated, analysis of the molecular structure of the paint layer would be needed to determine with certainty which chromium green pigment Karin used.

Peaks for zinc and lead from the ground can be found along with peaks for sulphur, chloride, barium, (or possibly titanium) iron, and calcium. Barium sulphate is likely present in the paint possibly also chalk as fillers, iron or lead based siccative could also be present. Analysis results conclusively show that both chromium oxide greens and arsenic green pigment-based paints were present on Karin's palette of colours.

Blue

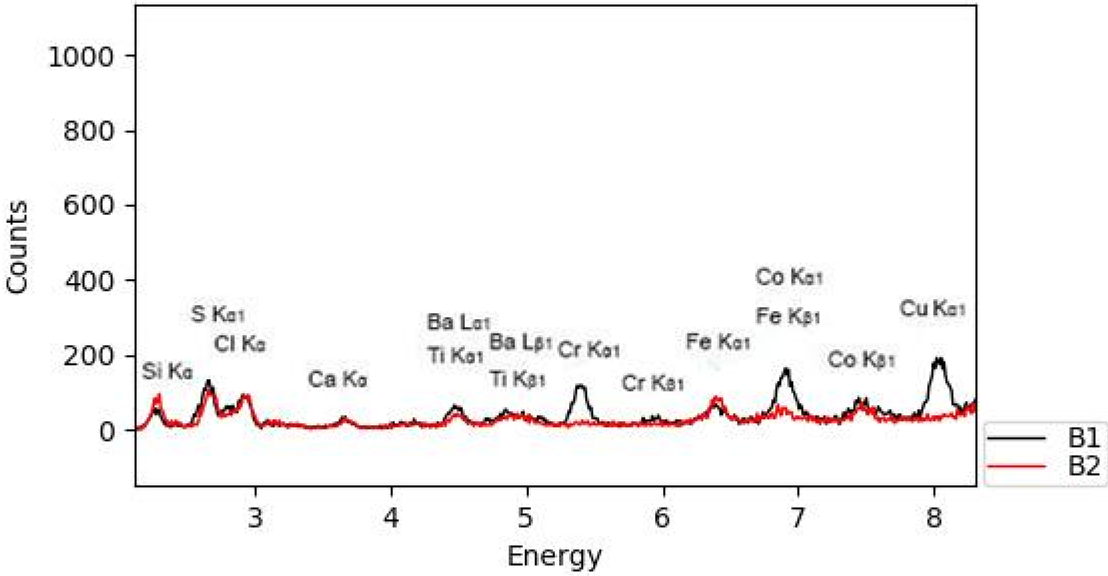


Figure 5.12: Image showing a comparison of the xrf analysis spots in the areas of blue used for skies in the Karin Parrow artworks. Zoomed in on 2 keV to 8.2 keV

Spectra obtained in the areas of blue used for skies in Karin's works and blue clothes of the figures in hamnen i vinterväder (B2) they are similar to those used in the water, silica, sulphur and small amounts of calcium is indicative of ultramarine but could also be cobalt blue as possible peaks for cobalt can also be seen. In Skärgårdskväll (B1) clear peaks for cobalt are present, if compared to reference xrf spectrums for cobalt blue (obtained from Chsopensource.org) the intensity of the peak matches well with what is expected of a cobalt blue. Chromium is also present which is likely a mixture due to a mixture. Copper is also present likely due to mixture with a copper arsenic green. Peaks for zinc and lead from the ground can be found along with peaks for sulphur, chloride and iron.

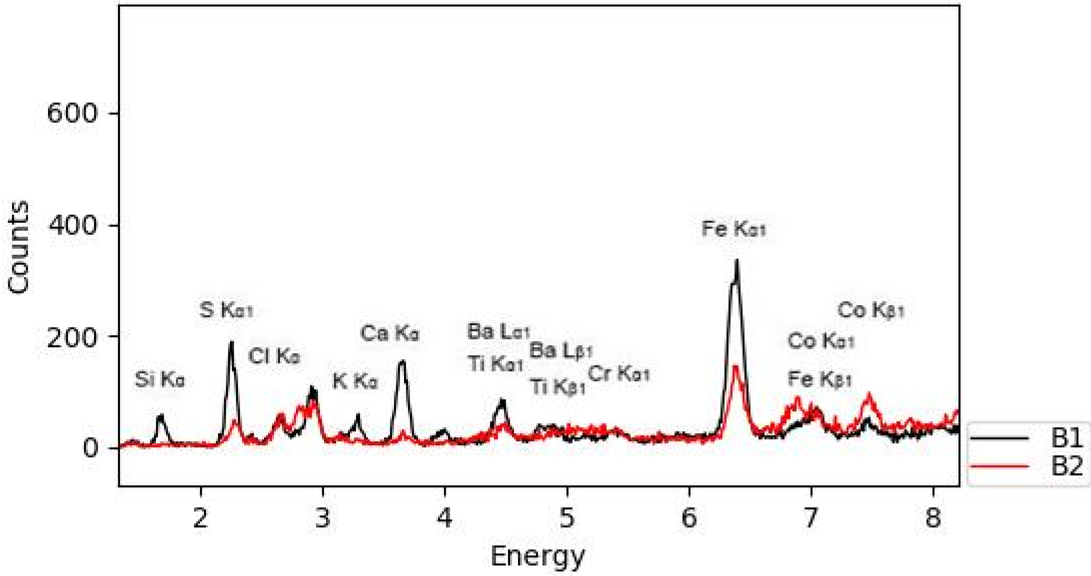


Figure 5.13: Image showing a comparison of the xrf analysis spots in the areas of blue used for the water in the Karin Parrow artworks. Zoomed in on 1 keV to 8 keV

Spectra collected in blue areas of the paintings suggests a use of a wide array of blues, in blue paints used for water showed peaks associated with potassium, iron with a possible weak peak aluminium. Potassium is associated with the manufacture of Prussian blue which is an Iron-hexacyanoferrate. Prussian blue is likely used in Skärgårdskväll (B2) which has a clear potassium K_α peak. Prussian blue is a quite dark blue and it is possible that the iron peak in Hamnen i vinterväder (B2) could be an iron based black such as Mars black or a dark brown ochre mixed with a blue. The silica K_α peak seen in Skärgårdskväll (B1) along with calcium and sulphur would suggest the presence of Ultramarine, which is a sulphur containing sodium aluminosilicate, aluminium is a light element. Peaks for cobalt could suggest the use of cobalt blue (cobalt aluminate) which is a commonly used blue or possibly a siccative in the oil paints.

Silica, potassium, and cobalt is also indicative of Smalt which is a cobalt containing glass pigment. The use of smalt fell out of favour with the introduction of other cheap blue pigments such as Prussian blue and cobalt blue as it is quite a poor pigment. The use of Smalt is deemed to be quite unlikely even if it is technically possible as it has been documented to have been produced up until the 1950s (p.122 Mühlethaler, Thissen, 1993). Barium is likely indicative of Barium Sulphate or titanium white, Chromium is likely either present as chromium oxide as a part of a mixture or a possible contaminant.

Analysis results suggest that Karin likely used Cobalt blue, Prussian blue and Ultramarine blue, the use of only one blue seems unlikely in the investigated artworks, instead different more complex mixtures seem to have been favoured by Karin. None of the blue paints found in the paintings seem identical; instead Karin likely used fine mixtures to create the unique hues of blues which is in accordance with what has been observed by other researchers.

White

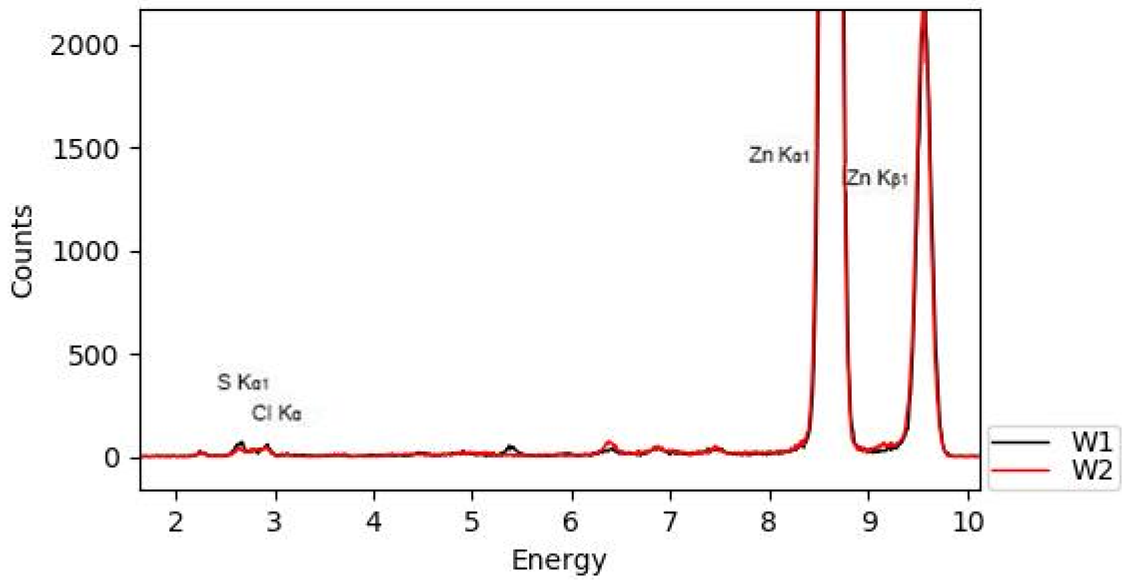


Figure 5.14: Image showing a comparison of the xrf analysis spots in the white areas of Karin Parrows artworks. Zoomed in on 1.5 keV to 10 keV

White areas show clear peaks for zinc and lead which suggests the use of lead white and zinc white.

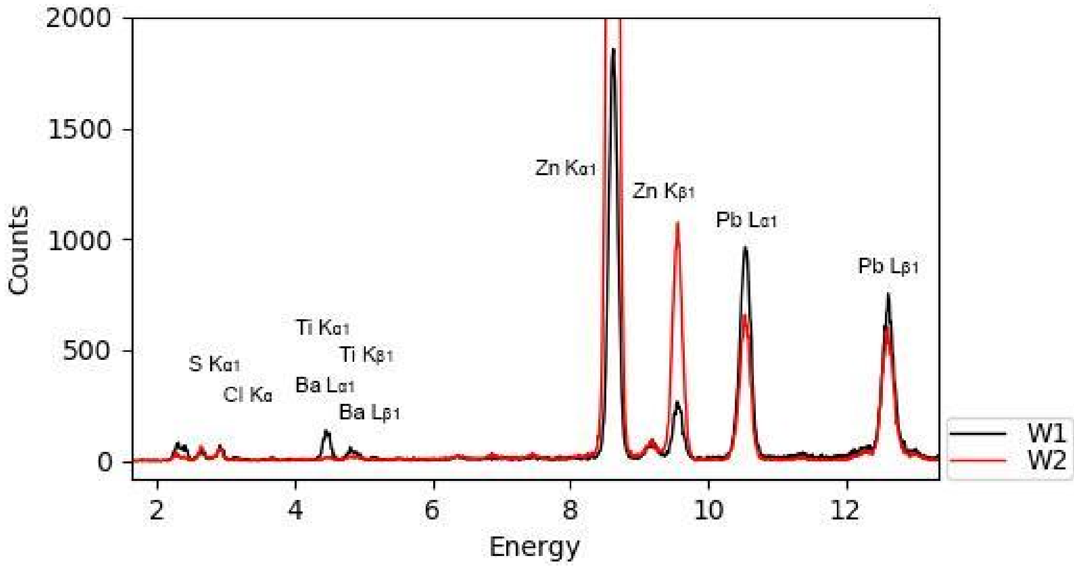


Figure 5.15: Image showing a comparison of the xrf analysis spots in the Ground of Karin Parrows artworks. Zoomed in on 1.8 keV to 13 keV

Spectra collected in the exposed areas of the ground show clear peaks for zinc, lead and barium or titanium, sulphur and chloride. The ground is likely a mixture of zinc white and lead white. Analysis results suggest that Karin likely used zinc white and lead white, a mixture of lead white and zinc white is used as a ground with a barium sulphate filler or titanium white. It is possible that this white also contains lead white and/or titanium white, and likely has a chalk filler.

5.2.2 Ivan Ivarsson

Blommor och Flicka

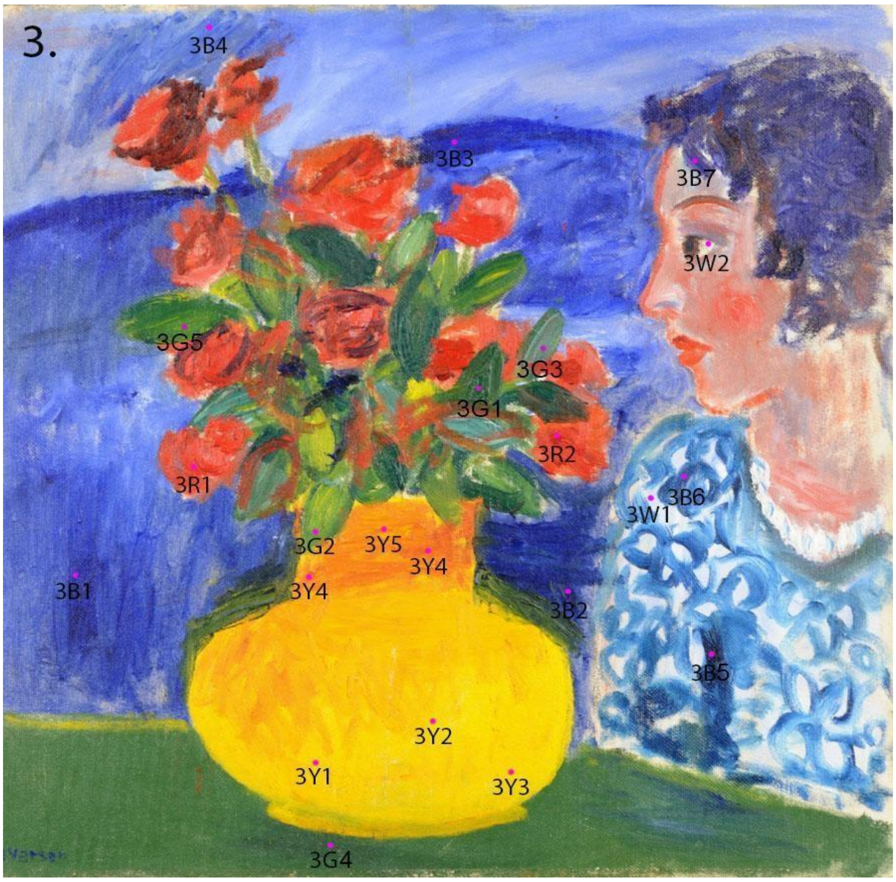


Figure 5.16: Image showing the points of analysis, photography by Hossein Sehatlou.

3Y1-3	3Y4-5	3R1-2	3G1-3,5	3G4	3B1-4	1B4-6	3B7	3W1	3W2
Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn
					Pb	Pb	Pb		
			Cl	Cl			Cl	Cl	Cl
Cd	Cd	Cd	Cd	Cd					
S	S	S	S	S	S	S	S	S	S
					Fe	Fe			
Cr	Cr			Cr	Cr				
Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba
Se	Se	Se							
			Co	Co				Co	Co
			Ca	Ca	Ca	Ca	Ca	Ca	Ca
					Si	Si	Si		
K			K	K	K	K			
Sr	Sr	Sr	Sr	Sr	Sr	Sr	Sr	Sr	Sr
			Sn	Sn					

Table 11. XRF results Blommor och Flicka.

Badande Flicka

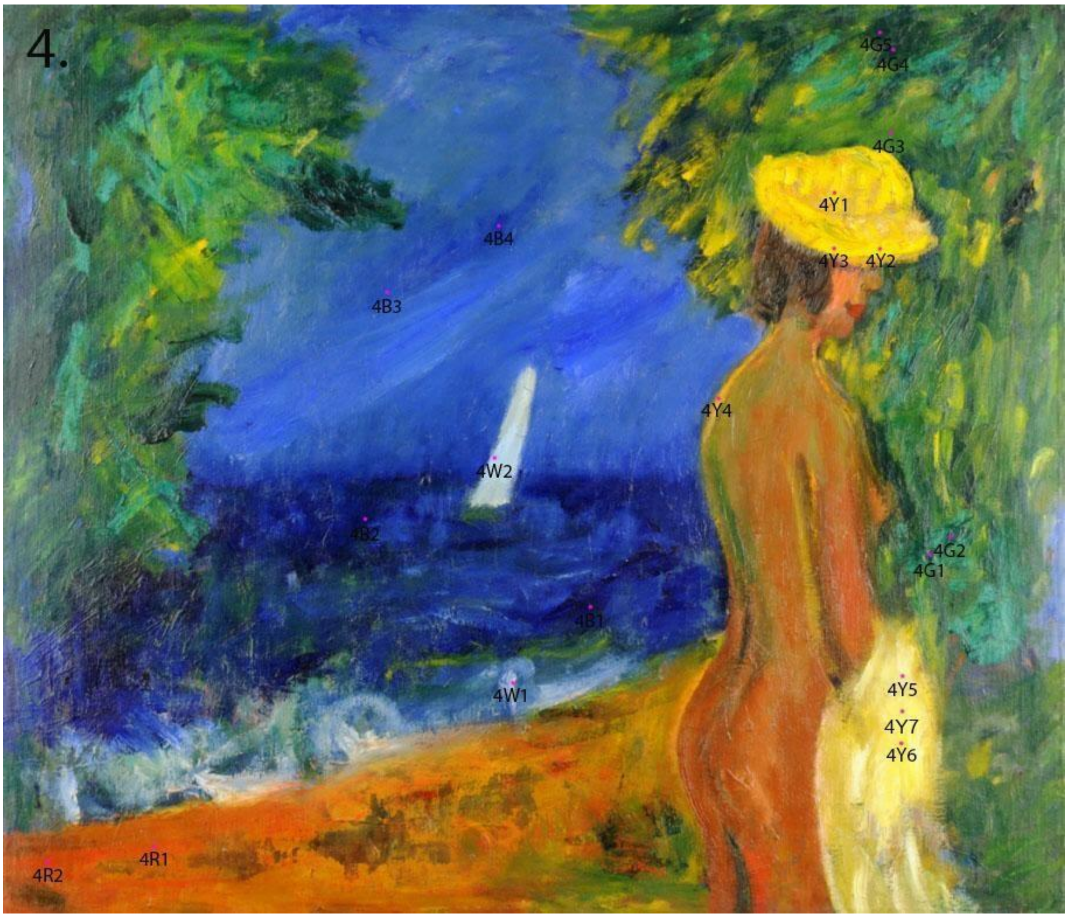


Figure 5. 17: Image showing the points of analysis, photography by Hossein Sehatlou.

4Y1-3	4Y4	4Y5-7	4R1-2	4G1-2	4G3	4G4-5	4B1-2	4B3-4	4W1-2
Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn
Pb	Pb	Pb		Pb	Pb	Pb	Pb		
Cl	Cl	Cl		Cl	Cl	Cl	Cl	Cl	Cl
Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	
S	S	S	S	S	S	S	S	S	S
			Fe			Fe	Fe		
			Ti						
		Ni							
	Cr		Cr	Cr	Cr	Cr	Cr		
Ba	Ba						Ba		
Se	Se		Se		Se				
		Co						Co	
Ca	Ca	Ca	Ca	Ca	Ca	Ca		Ca	Ca
	Cu								
			As						
	Sr			Sr					
			Hg						

Table 12. XRF results Badande Flicka.

Älvlandskap, Hjärtum

Figure 5. 18: Image showing the points of analysis, photography by Hossein Sehatlou.

5Y1-2	5Y3-4	4Y5-6	5R1-2	5G1-2	5G3-4	5G5	5B1-4	5B5-6	5W1	5W2
Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn
Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb
Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl
Cd	Cd	Cd	Cd	Cd	Cd	Cd		Cd		
S	S		S	S	S	S	S	S	S	S
Fe	Fe		Fe	Fe	Fe	Fe	Fe	Fe	Fe	
				Cr	Cr	Cr	Cr	Cr	Cr	Cr
				Ba	Ba	Ba				
Se	Se	Se	Se		Se					
							Co	Co		
Ca		Ca	Ca				Ca	Ca	Ca	Ca
			As							
							K			
							Si			

Table 13. XRF results Älvlandskap, Hjärtum.

Yellow

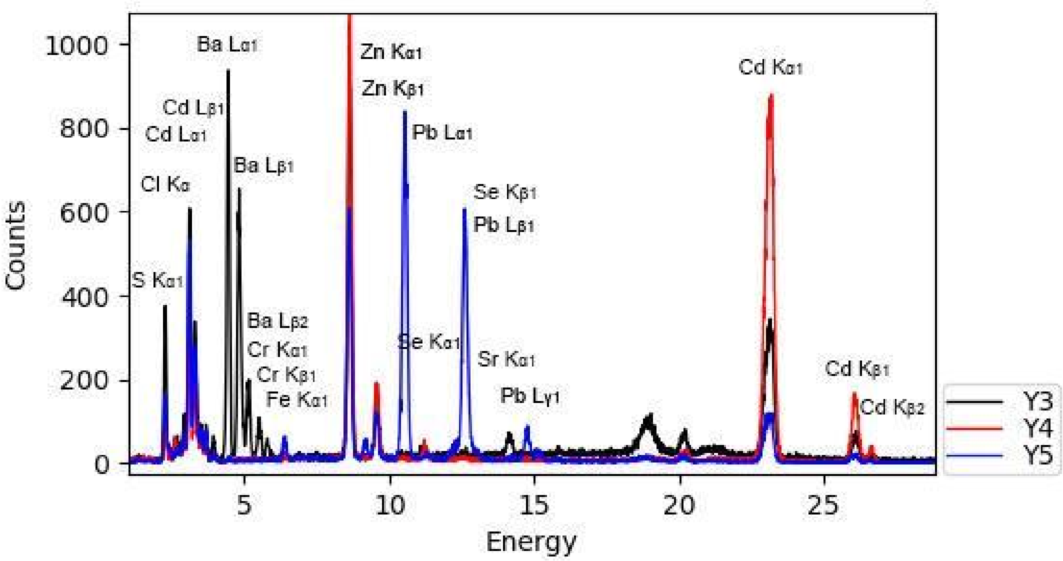


Figure 5.19: Image showing a comparison of the xrf analysis spots in the yellow areas of Ivan Ivarssons artworks.

The XRF spectra obtained from the yellow areas found in the three paintings by Ivan Ivarsson have some clear similarities, as all the spectra show clear peaks for sulphur, cadmium and zinc making it likely that cadmium yellow was used. intense barium peaks in Blommor och Flicka (Y3) would suggest a pigment with a large quantity of barium sulphate filler with a smaller proportion of pigment. Peaks can be seen at 32 keV using log y scale function which supports the identification of barium instead of titanium. The intense barium peaks in combination with chromium peaks could also suggest the use of a barium chromate yellow. The presence of strontium has been reported to be found in cadmium sulfoselenide (Eastaugh, 2006) which could suggest the use of a cadmium red to mix the orange shading on the flowerpot or a possible contaminant. However spectra in orange areas of the flowerpot show no selenium peaks, weak selenium peaks are only observable in the yellow areas. Selenium sulphate has been theorised as a possible filler used in cadmium manufacturing. Strontium is also used in strontium chromate yellow which along with zinc chromate is a yellow pigment used during the period. Possible peaks for chlorine can also be seen (again it is doubtful if this is the case as the peaks could just as well be from the x ray tube), If chlorine is actually present in any of the paintings it is most likely present as an aerosol as the peaks are consistent throughout.

Yellows found in Badande Flicka (Y4) show intense peaks for cadmium with weak peaks for fillers which points to the use of a highly pigmented cadmium yellow paint with small quantities of fillers such barium sulphate or chalk, the more intensive zinc peak might suggest the presence of a zinc lithopone but is also likely from the ground layer as zinc peaks of similar intensity are found in most colours. The spectra collected in Älvlandskap, Hjärtum (Y5) also show intense cadmium peaks in the L orbital peaks. Some of cadmiums L orbital peaks overlap with potassiums K orbital peaks but Cadmiums $L_{\alpha 1}$ at 3.1 which is the strongest of the L orbital peaks cadmium does not overlap. The high intensity of the L peaks compared to the lower intensity of the K peaks is unusual and not comparative of reference spectra of Cadmium. The addition of lead peaks is likely an indication of a lead containing ground.

Clear peaks of cadmium were found in all yellow areas of the analysed areas, it is therefore possible to conclude that Ivan used predominantly cadmium yellows in these paintings. Cadmium yellows and oranges are suggested as one of Ivan's favoured colours which reinforces the findings. All the cadmium paints show small inconsistencies in their chemical makeup suggesting that they are different cadmium yellows which could be explained by the speed at which Ivan is reported to have consumed paint. The high concentration of cadmium yellows compared to the findings in Karin's works is in keeping with the sources suggesting Ivan aversion for paints with low pigmentation and large quantities of fillers. The use of a Lemon yellow paint mixed with the cadmium yellow is possible, but it is perhaps more likely that the chromium is traceable to the chromium green table, and the barium and strontium is simply explained by the use of a cadmium with high quantities of barium sulphate. While it is cited that Ivan preferred highly pigmented paints with low quantities of fillers it is also suggested that subpar materials would be used in periods of financial difficulty as it was preferable to not painting at all.

Red

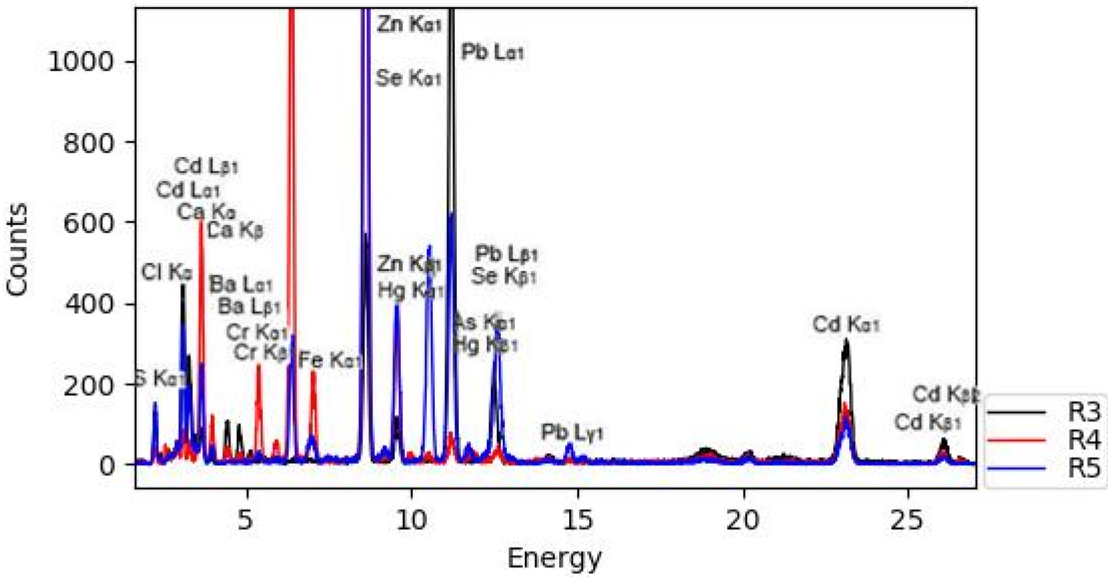


Figure 5.20: Image showing a comparison of the xrf analysis spots in the red areas of Ivan Ivarssons artworks.

Cadmium, selenium, and sulphur was found in all the XRF spectra obtained from the red areas of paint which is a clear indication of the use of a cadmium sulfoselenide pigment based pigment, as spectra show clear peaks for cadmium, selenium and sulphur in all works. Spectra collected in Badande Flicka (R4) indicate the presence of small amounts of mercury. As weak peaks at 10 keV and 11.82 keV correspond to the $L_{\alpha1}$ and the $L_{\beta1}$ peaks of mercury. There has been a documented use of mercury in cadmium paints with the mercury used as a substitute for sulphur. This alternative method for production is suggested as having been developed due to a shortage of selenium around 1948 (Fielder, 1986). The presence of mercury in the paint is thus not likely due to the use of mercury containing cadmium paint. Mercury was also used in vermillion/cinnober, a mercury sulphide based pigment. With the introduction of cadmium red vermillion was largely phased out by the 20th century but according to Kumlien (1954) beckers produced vermillion until 1940 which makes it possible that vermillion was used. The presence of mercury could therefore be explained as a mixture of cadmium yellow or orange with a vermillion paint, the peaks for mercury are weak and it is unlikely that a large amount was used. But It might also be that the mercury peaks could originate from an underlying layer of vermilion. The presence of lead and chrome could indicate the presence of a chrome orange or yellow.

Certain localised red areas in Älvlandskap, Hjärtum (R5) displays a clear peak at 11.72 keV which aligns with the $L_{\beta 1}$ peak of arsenic, the $K_{\alpha 1}$ peak of arsenic overlaps with the $L_{\alpha 1}$ peak of lead. The arsenic peaks were visible in several spots but localised around a certain area (see 5R1 in the appendixes). Arsenic is found in the yellow to orange to red pigment realgar which is based on a arsenic sulphide mineral. Until the invention of chrome orange the pigment was the only known pure orange pigment. Evidence of the use of realgar in European art has been established up until the late 19th century (Fitzhugh ,2012). However the use of Realgar by Ivan is unlikely as there is no documented use in early 20th century European art. All areas show clear peaks for cadmium red and it is unlikely that realgar was added to the mixture in just one small area, permitting of course that the pigment was even available. Arsenic has been historically used for pest management in museum collections, but the localised nature makes that unlikely. A more likely explanation would be the presence of a arsenic green layer behind the cadmium red layer. The arsenic containing area was sampled, the sample was microscopically examined and determined to not contain any other visible layers than the red layer. The sample was then analysed using xrf, as the arsenic peaks were still present the arsenic is likely incorporated into the paint.

The XRF data strongly suggests the use of different types of cadmium reds, with different types of additives. Sources cite cadmium red as Ivan's preferred red which reinforces the conclusions of the RF analysis. It has been suggested that Ivan had a habit of overpainting his old paintings and possibly works left by other artists in the studios he borrowed, Badande Flicka (R4) has been suggested as being one of these paintings. The relatively high chrome peaks in the red area R4 could either be a chrome yellow containing red mixture or orange but could also be from an underpainting.

Green

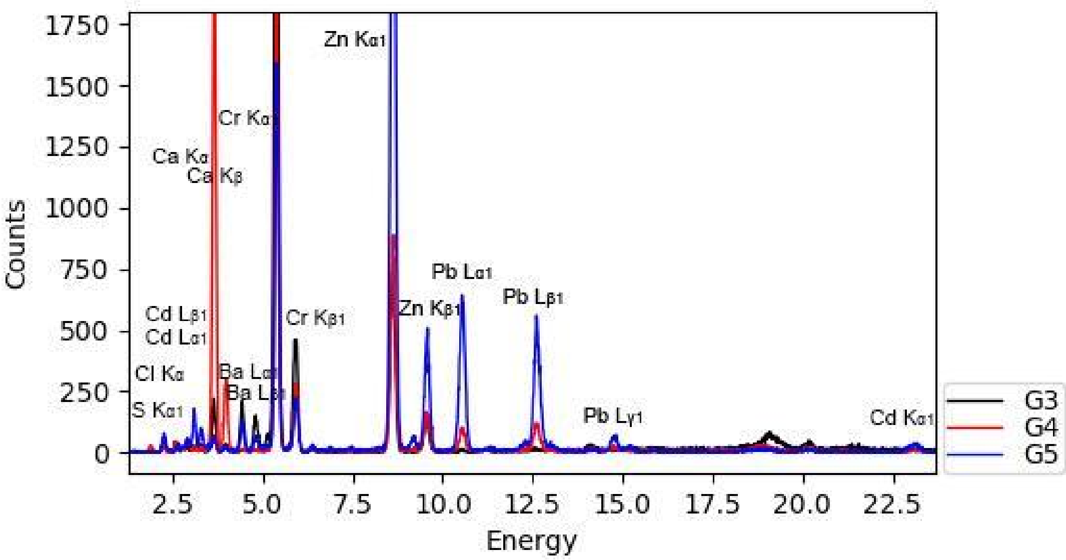


Figure 5.21: Image showing a comparison of the xrf analysis spots in the Green areas of Ivan Ivarssons artworks.

Spectra collected in the green areas suggest the use of chromium oxide green in all paintings, peaks for cadmium suggest the use of cadmium based pigments for mixing and adjusting the hue of the chromium green can be seen. Intense calcium peaks suggest the use of a chalk based ground of a high amount of fillers in Badande Flicka (G4).

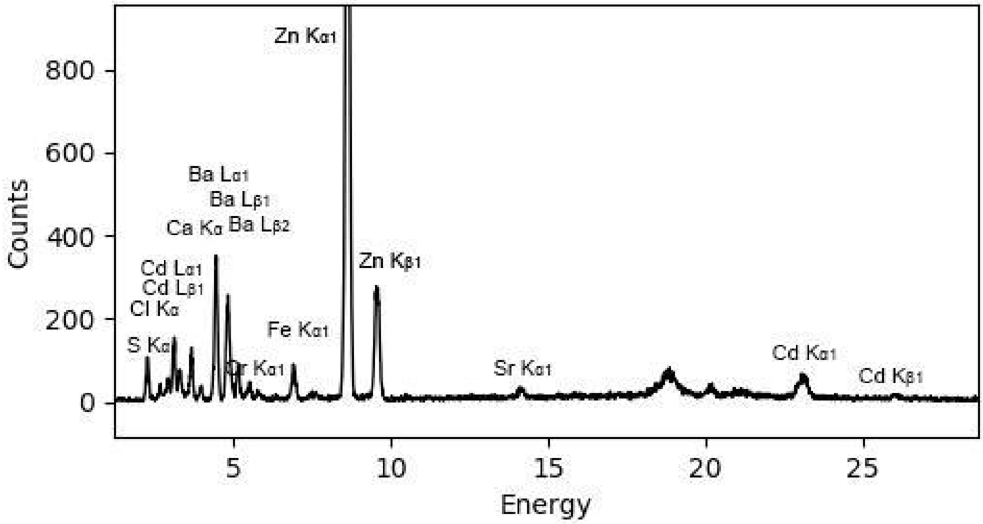


Figure 5.22: Image showing a representative analysis spot in the Green areas of the bouquet found in Ivan Ivarssons Blommor och flicka.

Spectra collected in Blommor och Flicka in the green leaves and stalks of the flower did not display a clear peak for chromium. No obvious peaks for any green pigment which might suggest the use of a mixed green or an organic green. Clear cadmium peaks were found throughout with more intense peaks in the more yellowish parts of the bouquet. Peaks for iron can be observed and possible peaks for potassium which overlaps with cadmium yellow might suggest that Prussian blue was used in the green mixture. Weak peaks for cobalt were identified which could suggest the use of cobalt blue, or aureolin yellow which is a potassium cobaltinitrite or the zinc containing cobalt green. But the cobalt peaks are overall too weak to suggest that a cobalt based pigment is the main green pigment. A Cadmium green might have been used which is a mixed green colour, often a mixture of cadmium yellow with Prussian blue or ultramarine blue.

Data collected during analysis show evidence of the use of chromium oxide green often in mixture with cadmium green. Chromium green is noted as one of Ivar's favoured colours, as for the non-chromium based green Ivan is cited as having tried both cobalt blue and green but found them lacking in intensity. Unless Blommor och Flicka is one of the paintings he painted when he tried them it is unlikely that they were used, especially considering the low intensity of cobalt peak.

Blue

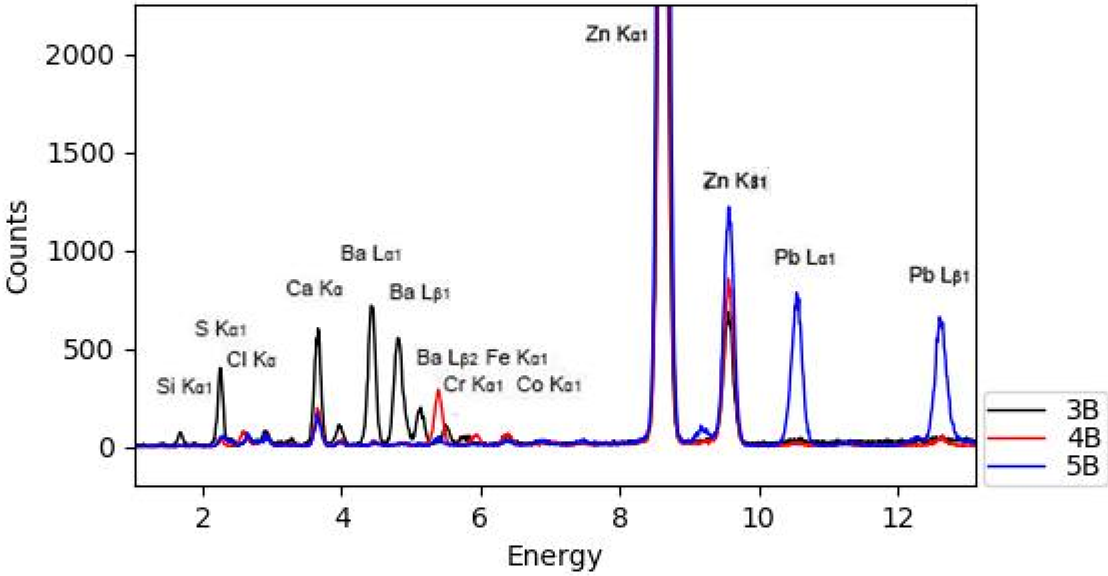


Figure 5.23: Image showing a comparison of the xrf analysis spots in the Blue areas of Ivan Ivarssons artworks.

Spectras collected in blue areas of Blommor och Flicka (B3) and Älvlandskap, Hjärtum (B5) all display peaks for silica, sulphur and calcium which would suggest the use of ultramarine with a faint peaks for aluminium. Small peaks of cobalt and iron can be seen in all paintings which could suggest the use of cobalt blue. Blue spectras collected in Badande Flicka (B4) do not display any silica peaks, no other clear peaks which point toward a blue are present. Barium peaks in Blommor och Flicka (B3) suggest the presence of a barium sulphate filler.

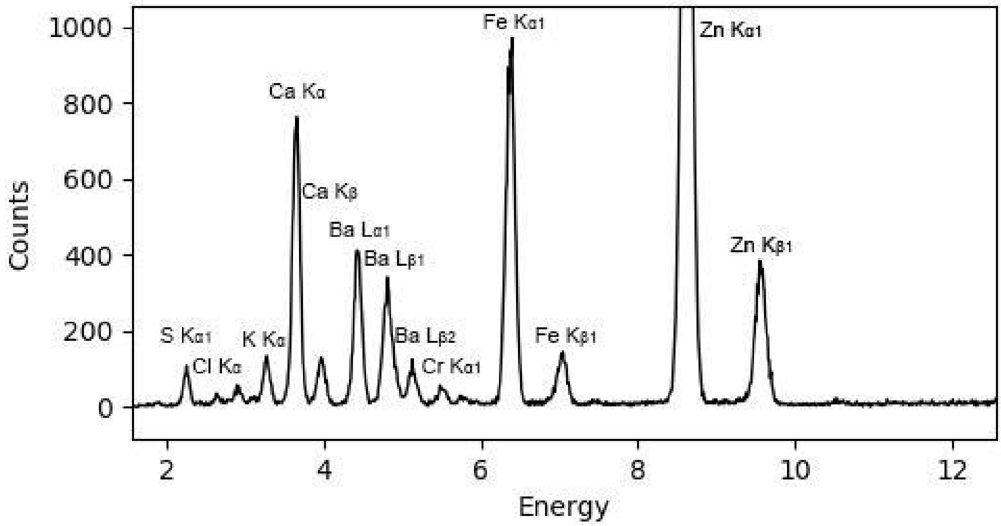


Figure 5.24: Image showing a representative analysis spot in the Darker blue areas of the dress found in Ivan Ivarssons Blommor och flicka.

In Blommor och Flicka a different blue was used for the dress of the figure, clear peaks for iron, and potassium suggests the use of Prussian blue. Barium peaks suggest the presence of a barium sulphate filler.

White

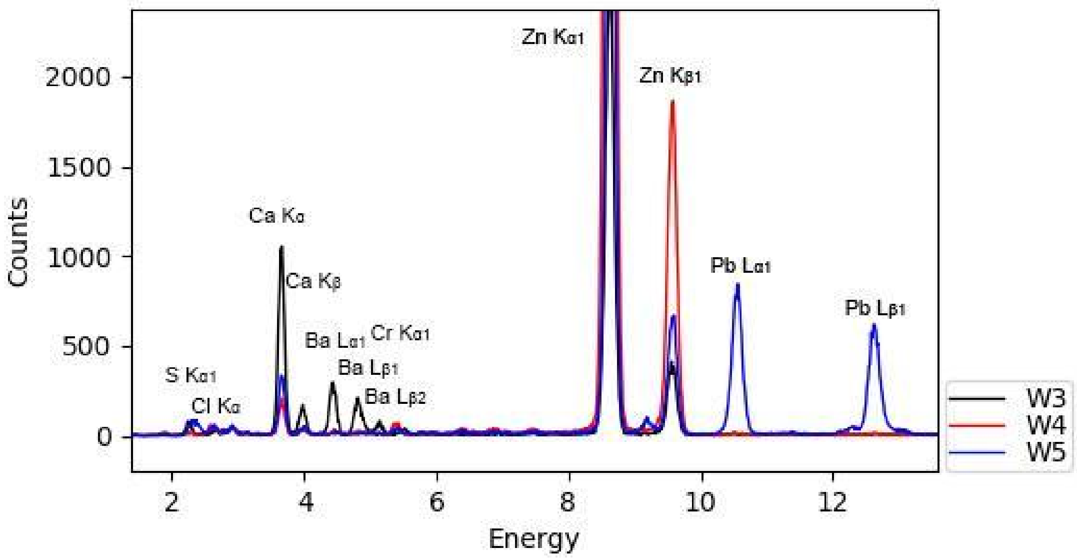


Figure 5.25: Image showing a comparison of the xrf analysis spots in the white areas of Ivan Ivarssons artworks.

Whites used in Ivan's work seem to primarily be based on a zinc with a lead mix in Älvlandskap, Hjärtum (W5). Barium peaks in Blommor och Flicka (W3) suggest the presence of barium sulphate.

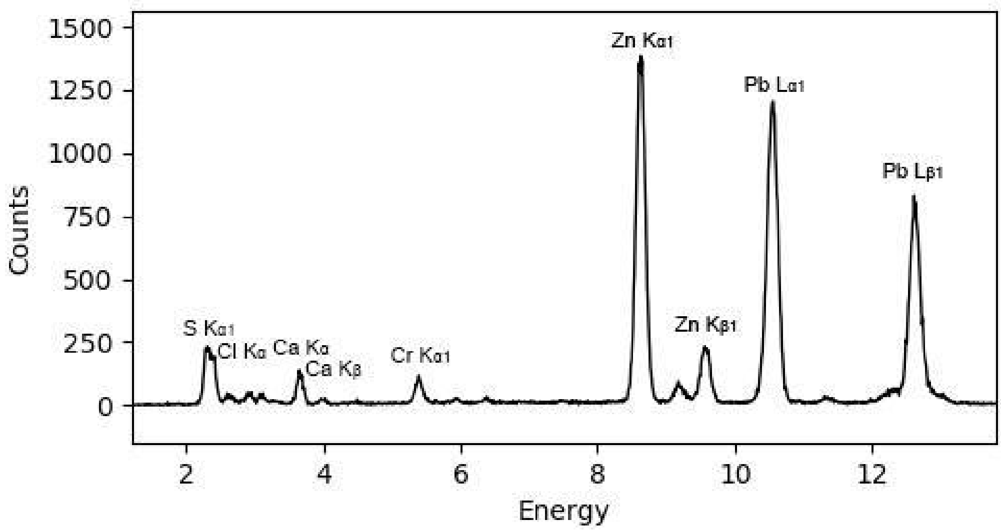


Figure 5.26: Image showing a representative analysis spot of the ground in Ivan Ivarssons Blommor och flicka.

Only one of the three works by Ivan had exposed ground in a location which could be surveyed. In Blommor och flicka the ground is exposed in the eye of the figure and could therefore be analysed. A zinc and lead based paint had been used with a small amount of chalk, no barium peaks can be seen thus suggesting that barium peaks seen in this painting can be traced to the paint and not ground.

5.2.3 Ragnar Sandberg

Badande

Figure 5.27: Image showing the points of analysis, photography by Hossein Sehatlou.

6Y1-2	2R1	6R2	6R3-4	6G1-2	6Gr1	6B1-2	6W1-2	6W3-4
Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn
Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb
Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl
Cd	Cd		Cd	Cd				
S	S	S	S	S	S	S	S	S
Fe		Fe	Fe	Fe	Fe	Fe	Fe	Fe
							Ni	
Cr		Cr						
Ba			Ba	Ba				
			Se					
Co	Co				Co	Co	Co	Co
	Ca	Ca	Ca	Ca	Ca	Ca		Ca

Table 14. XRF results Badande.

Embarkering

Figure 5.28: Image showing the points of analysis, photography by Hossein Sehatlou.

7Y1-3	7Y4-6	7R1	7R2-3	7B1-3	7B4-5	7W1-2
Zn	Zn	Zn	Zn	Zn	Zn	Zn
Pb	Pb	Pb		Pb	Pb	Pb
Cl	Cl	Cl	Cl	Cl	Cl	Cl
Cd	Cd	Cd	Cd	Cd		
S	S	S	S	S	S	S
Fe	Fe	Fe	Fe	Fe	Fe	
	Ti					Ti
				Ni	Ni	Ni
	Cr		Cr		Cr	
Ba	Ba		Ba			
Co	Co				Co	Co
		Ca	Ca	Ca	Ca	
				Si		
		K		K		

Table 15. XRF results Embarking .

Cyklister

Figure 5.29: Image showing the points of analysis, photography by Hossein Sehatlou.

8Y1-3	8Y4-6	8Y7	8Y8, 8y10	8Y9	8Y11	8Y12-13	8Y14-15	8R1-2	8G1-2	8G3-5	8B1-3	8W1-2	8W3	8Bl1-2
Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn	Zn
Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb	Pb		Pb	Pb
Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl
Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd			
S	S	S	S	S	S	S	S	S	S	S	S		S	S
Fe	Fe					Fe	Fe		Fe	Fe	Fe			Fe
												Ti	Ti	
Ni	Ni					Ni	Ni		Ni		Ni			
					Cr				Cr	Cr				Cr
		Ba			Ba	Ba	Ba		Ba	Ba				
								Se						
Co	Co					Co	Co			Co	Co	Co		
											Ca			Ca
		Sr		Sr	Sr				Sr					
														P

Table 16. XRF results Cyklister.

Yellows

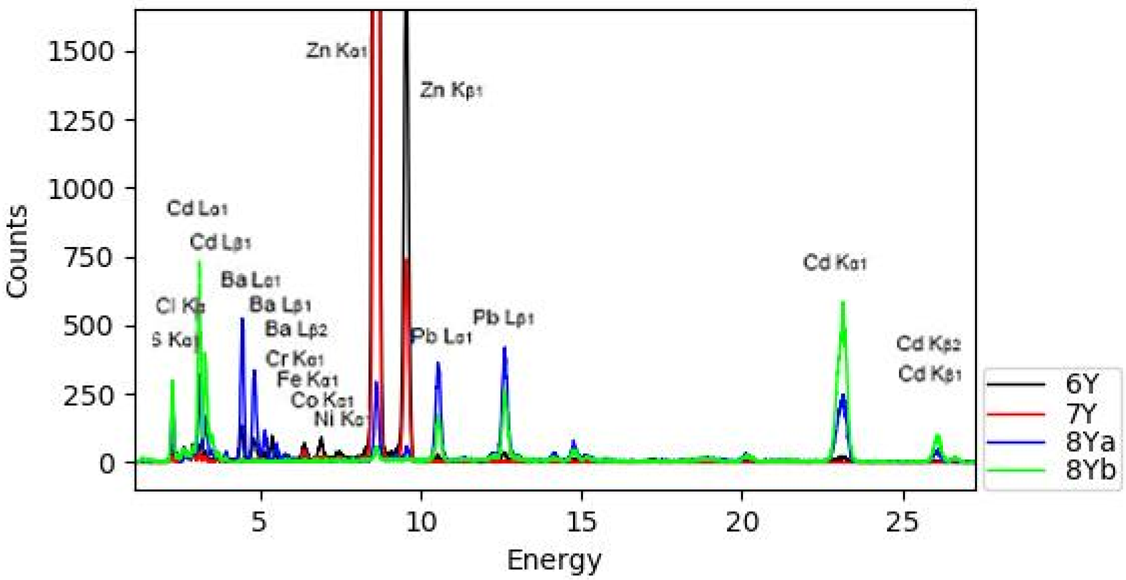


Figure 5.30: Image showing a comparison of the xrf analysis spots in the yellow areas of Ragnar Sandberg artworks.

Spectra collected in yellow areas all contained sulphur, zinc and cadmium. The cadmium peaks found in the yellow areas in Badande (Y6) Embarkering (Y7) were weak but present in all the yellowish areas. The most likely pigment used in these two works is cadmium yellow. As clear chromium peaks are only present in one sample of Embarkering making the use of a chromium based yellow such as chrome yellow or zinc yellow is unlikely. Organic yellows such as hansa yellow is possible but the presence of cadmium is a strong indicator of cadmium yellow. Possible peaks for Chlorine (which also overlaps with rhodium) were found in all works and if present are most likely to be traceable to aerosols rather than chlorine containing pigments.

Yellows used in Cyklister all contained clear cadmium peaks, yellow spectra collected in these areas varied, it would seem that at least two different cadmium based paints where likely used, Y8a is a cadmium based paint with a barium sulphate filler with a low zinc content, Y8b is a cadmium based paint with low zinc content and no fillers. Strontium was present in small areas throughout the paint layer, this is most likely a contaminant rather than a strontium yellow but it is possible small amounts of strontium yellow was used in yellow areas. Zinc peaks vary greatly in intensity in the different areas which is an indication that some of the cadmium yellows is likely a mixture. The small amounts of zinc found in some areas suggests that the underlying layer is more likely a lead ground. Peaks in the chalky whitish possibly degraded areas of cadmium yellow (see appendix 8Y4-6), contain peaks of zinc with lower intensity than surrounding areas which indicates that the whiteness of the area is not likely to be a mixture of zinc white.

Reds

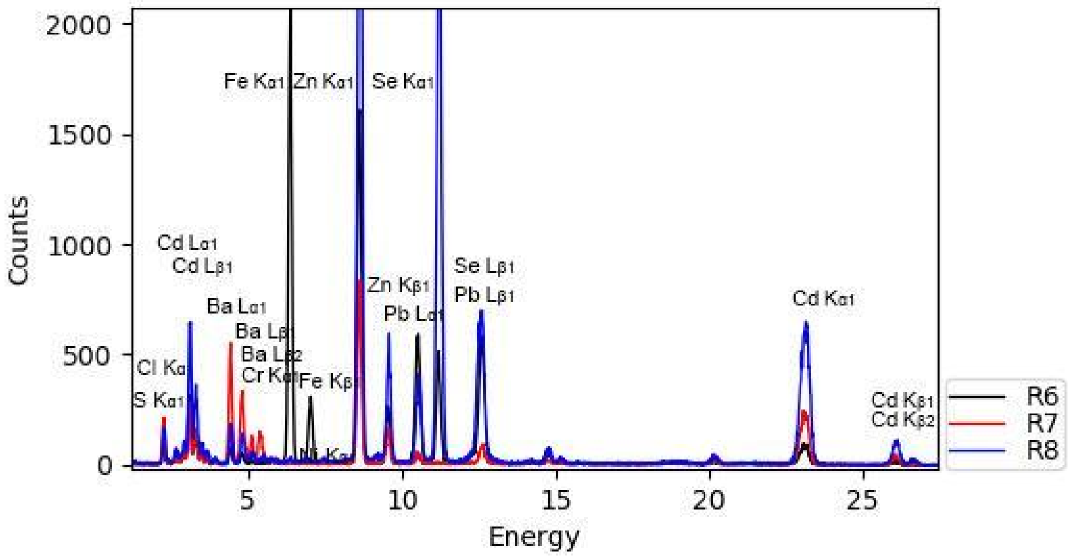


Figure 5.31: Image showing a comparison of the xrf analysis spots in the red areas of Ragnar Sandberg artworks.

Cadmium, sulphur and selenium were found in spectra collected, which is a clear indication that cadmium red was used. Barium was found in all the reds which is likely traceable to a barium sulphate filler. In Badande (R6) clear iron peaks suggest the use of a red ochre (or possibly another ochre) in mixture with the cadmium red.

Greens

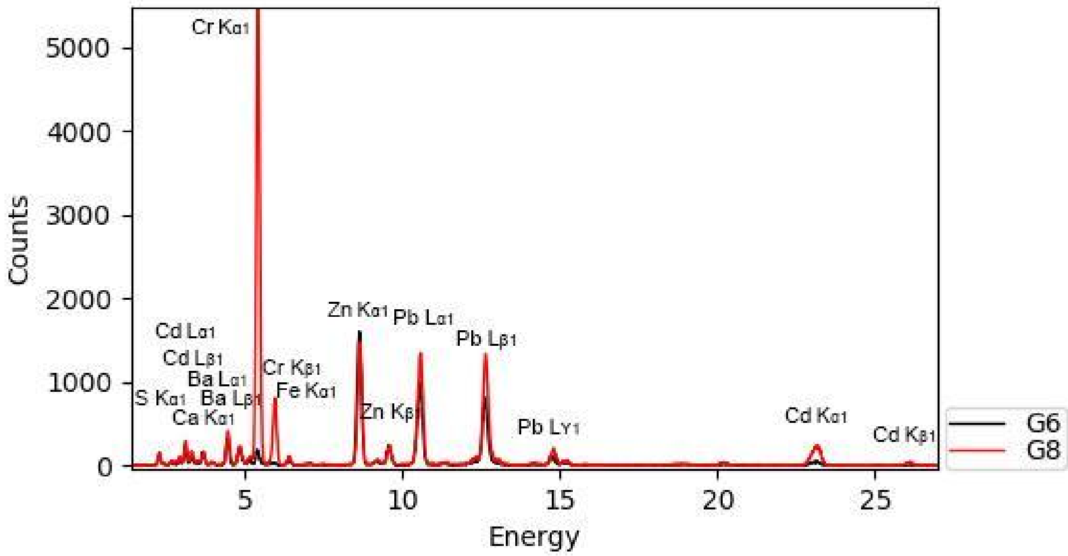


Figure 5.32: Image showing a comparison of the xrf analysis spots in the Green areas of Ragnar Sandberg artworks.

Greens were only found in Badande (G6) which is a greenish yellow and Cyklister (G8). In badande only weak chromium and cadmium peaks were found which suggests a mixture of chromium oxide green and cadmium yellow. In Cyklister clear peaks for chromium and cadmium are found suggesting the use of chromium green in mixture with cadmium yellow. peaks for barium in both colours suggests a barium sulphate filler. Presence of lead and zinc is likely traceable to a zinc and lead white ground.

Blue

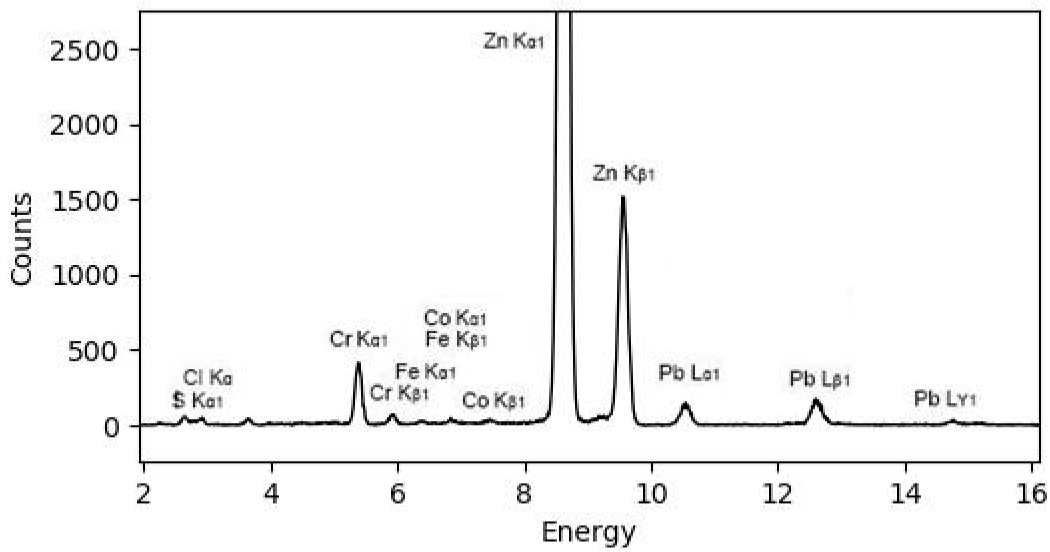


Figure 5.33: Image showing a comparison of the xrf analysis spots in the blue sky of Ragnar Sandberg's Embarkering. Zoomed in on 2 keV to 16 keV

Spectra collected in the background of Embarkering (B7b) has a clear peak for chromium, which indicates the use of a chromium based pigment instead of a blue colour. The most likely candidate is a hydrated chromium oxide which is a blueish green, possibly mixed with small quantities of a blue such as cobalt.

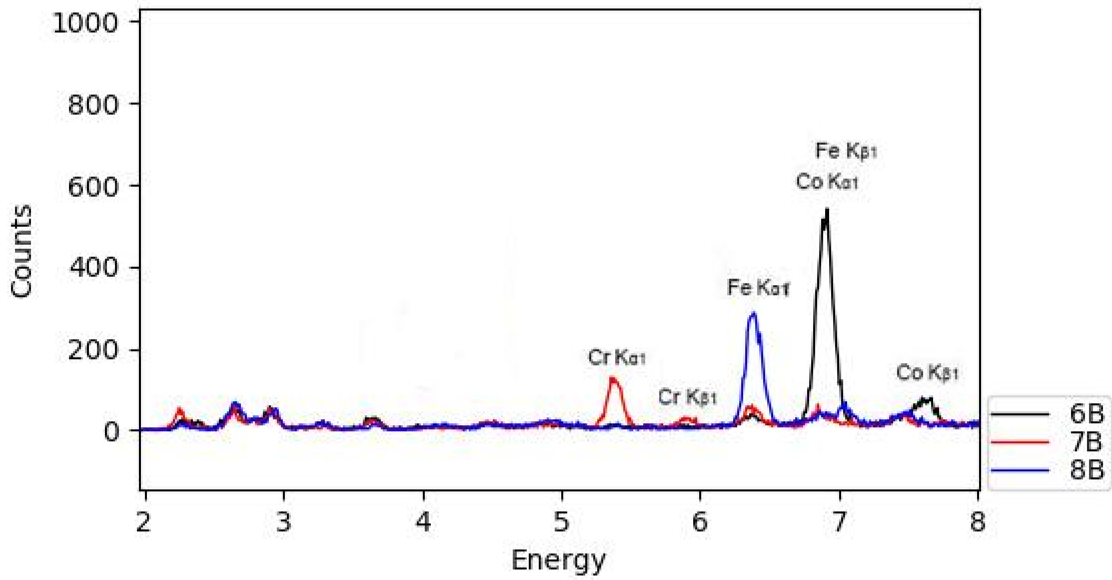


Figure 5.34: Spectra collected in blue areas of Ragnar Sandberg's paintings, Zoomed in on 2 keV to 8 keV

The spectras in Badande (6B) showed clear cobalt peaks which strongly indicate the use of cobalt blue, in Figure 6.25 possible aluminium peaks can be seen, most likely due to a cobalt aluminate blue as the cobalt peak is quite strong. The blue spectra in embakering (7B) is more inconclusive, but judging by Figure 6.25 it is most likely that an ultramarine was used. In the spectra for Cyklister a prussian blue was likely used based on the strong iron peak and absence of cobalt and aluminium peaks. (note that the aluminium peaks are speculative as they are outside the area of accurate determination).

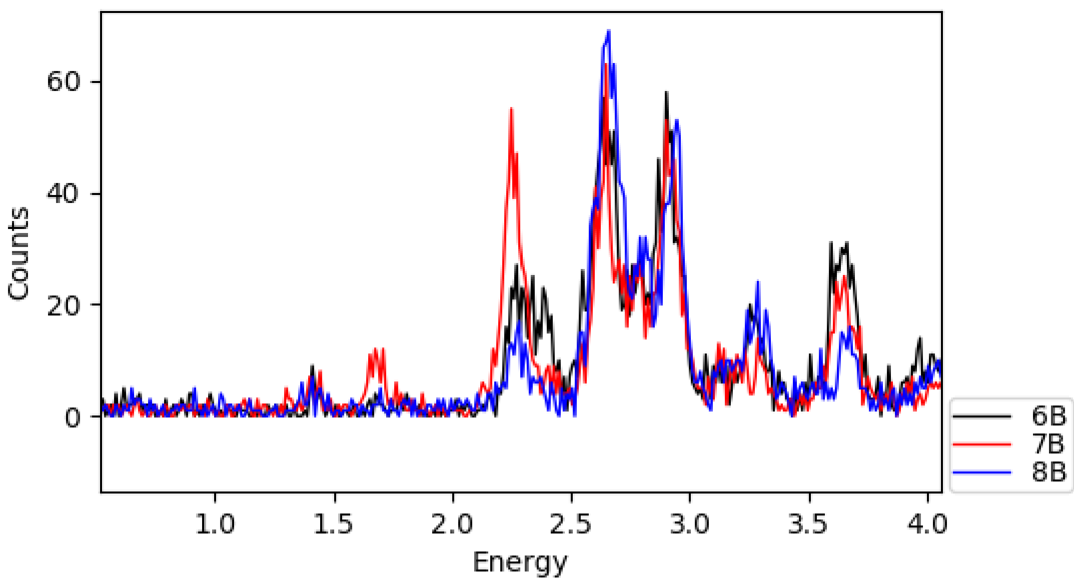


Figure 5.35: Image showing a comparison of the xrf analysis spots in the blue water of Ragnar Sandberg artworks. Zoomed in on 0.4 keV to 4 keV

White

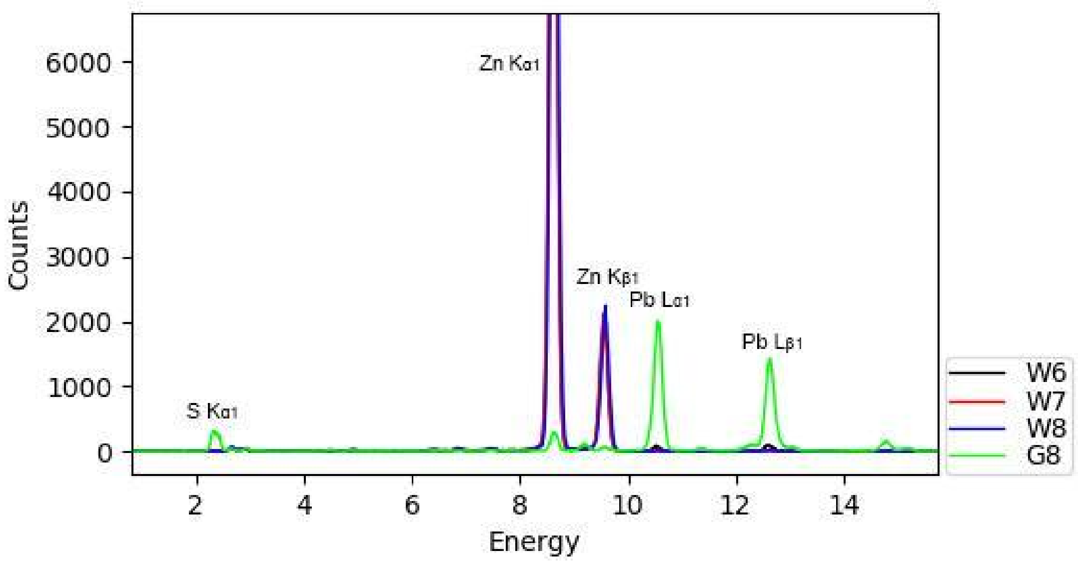


Figure 5.36: Image showing a comparison of the xrf analysis spots in the white areas of Ragnar Sandberg artworks. Zoomed in on 0 keV to 16 keV

Zinc white was found in all spectra, the ground used in Cyklister (G8) also displays clear lead peaks which indicates that a zinc and lead white mixture was used in this painting.

Black and Grey

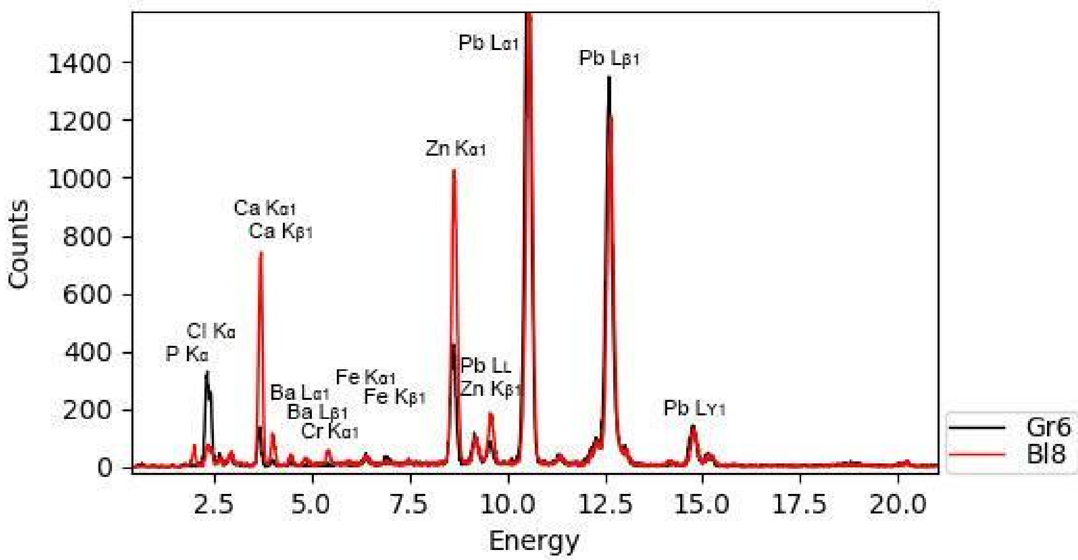


Figure 5.37: Image showing a comparison of the xrf analysis spots in the black and grey areas of Ragnar Sandberg artworks.

Spectra were collected in the grey background of Badande (Gr6) and in the black used in Cyklister (Bl8). In Cyklister a clear peak seen at 2.4 keV likely corresponds to the Kα of phosphorus which along with the presence of calcium indicates the use of a ivory black which is a pigment created by burning bones to charcoal. In the grey areas found in Badande the peak for phosphate can also be seen but less intense, together with the clear peak for calcium a ivory black could certainly have been used in these areas, peaks for iron could also indicate the use of a brown ochre of a mars black but they are quite weak compared with other the peaks seen in ochre colours in the other paintings.

5.3 Infrared false colour photography

Skärgårdskväll

Figure 5.40: Image showing Karin Parrows Skärgårdskväll in IRFC and visible light.

The pink shade of the yellow areas correspond with the expected colour of cadmium yellow as it is noted as being either a light pink or a white to yellowish colour. Many yellow pigments do as well so no clear conclusion can be drawn from the yellow areas using IRFC itself. Sources cite the expected colour of yellow ochre as ranging from brown to yellow which matches what is seen in the IRFC. The expected colour of cadmium red is cited as ranging from yellow to orange which matches well with what is seen in IRFC. Madder lake and carmine is expected to show up in orange which matches what is seen, sources cite red ochre as showing up as brown which matches less well with what is seen in the images. Madder lake has been commonly reported as emitting a pink-orange fluorescence under UV radiation (Pronti, et al. 2018), multispectral imaging using UV found no fluorescent pigments in Skärgårdskväll. Ultramarine is cited as red, cobalt also shows up as red but with a slightly more pink shade. The XRF data suggested the use of cobalt blue in the sky and on the dresses of the figures which would match what is seen, however the cobalt blue is likely mixed which would affect the colour in IRFC. The dark red in the ocean matches the expected colour of blue well, the blackish field found in the ocean could match the expected black to dark blue colour of Prussian blue in irfc which was suggested based on the XRF data. However a Mars black or a dark brown ochre would match well too. No data for arsenic green in IRFC has been found by the author.

Hamnen i Vinterväder

Figure 5.41: Image showing Karin Parrows Hamnen i Vinterväder in IRFC and visible light.

Cadmium yellow and cadmium red match well with what is seen on the imaging, the dark blue colour of the water strongly reinforces the idea that Prussian blue is used, the red areas suggest that an additional blue is used based on the dark tone ultramarine was likely used. The red colour of the skies suggest either cobalt blue or ultramarine, the paint in this area is likely a mixture of zinc white and or lead white mixture with a blue and organic red pigment such as madder lake so any assumption between cobalt blue and ultramarine is likely not accurate. The arsenic green-chromium green is a bluish red, viridian is cited as red while chromium green is cited as pink, as this paint could be a mixture of arsenic green and chromium green any attempt at differentiating is likely to be inaccurate.

Blommor och Flicka

Figure 5.42: Image showing Ivan Ivarssons Blommor och flicka in IRFC and visible light.

The yellow and red areas range from yellowish white to orange, cadmium yellow is listed as pink to white depending on the source, cadmium orange is yellow and cadmium red is dark orange. This corresponds well with what is seen in the painting. Chromium oxide is listed as Red which also corresponds well with what is seen, there is an obvious difference in shade of red in the leaves compared to the table. The clear red shade of the leaves would likely rule out the use of a Prussian blue in the green mixture. The vibrant red in the background does not indicate whether cobalt blue or ultramarine was used. The blue shade of the dress corresponds well to Prussian blue which was suggested based on XRF analysis.

Badande Flicka

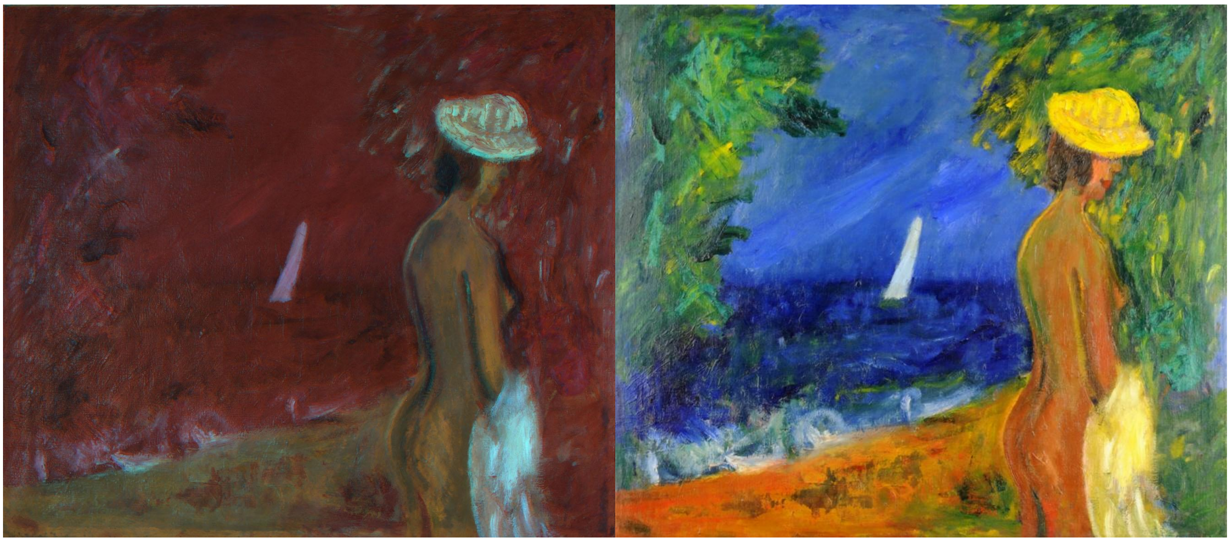


Figure 5.43: Image showing Ivan Ivarssons Badande flicka in IRFC, photography by author

The red to orange areas show up as orange which is similar to what has been suggested, vermillion is expected to show up in orange so no real conclusion can be drawn based solely on FCIR. The bright cadmium yellow is white which does match what is reported. Areas of the vegetation with yellow highlights match the yellowish white suggesting the use of cadmium yellow with the green matching. Reds and greens both show up as red which is to be expected of a chromium green and an ultramarine or cobalt blue colour.

Älvlandskap, Hjärtum

Figure 5.44: Image showing Ivan Ivarssons Badande flicka in IRFC, photography by author

The Cadmium based pigments show up in yellow to orange colours which is expected. Chromium oxide green pigments show up as red, also the blue areas are red which matches the expected colour of ultramarine and cobalt blue well. No difference can be seen in the arsenic containing area.

Badande

Figure 5.45: Image showing Ragnar Sandberg's Badande in IRFC, photography by author

Most colours show up the same in FCIR but the red outlines show up in orange which corresponds well to cadmium red. The greenish colour used for the skin of the centre figure and parts of the right figure show up in a reddish pink hue which does match well with what would be expected of chromium oxide green and cadmium yellow. The more yellowish areas of the skin in the face of the rightmost figure show up in pinkish which is one of the reported colours of cadmium yellow. The blue colour shows up reddish to pink which could match well with both cobalt and ultramarine blue.

Embarkering

Figure 5.46: Image showing Ragnar Sandberg's Embarkering in IRFC, photography by author

Reds show up as orange which is the indicated colour of a cadmium red paint, the yellow areas show up as pink which also corresponds well with cadmium yellow. Blues show up in deep red to pink which could correspond to both cobalt and ultramarine blue or in the case of the sky a chromium oxide green such as viridian. The cadmium containing yellowish skin of the rightmost figure shows up as a light greenish yellow which cadmium yellow is listed as but possibly a different hue than the others used, or possibly only present in a minimal quantity.

Cyklister

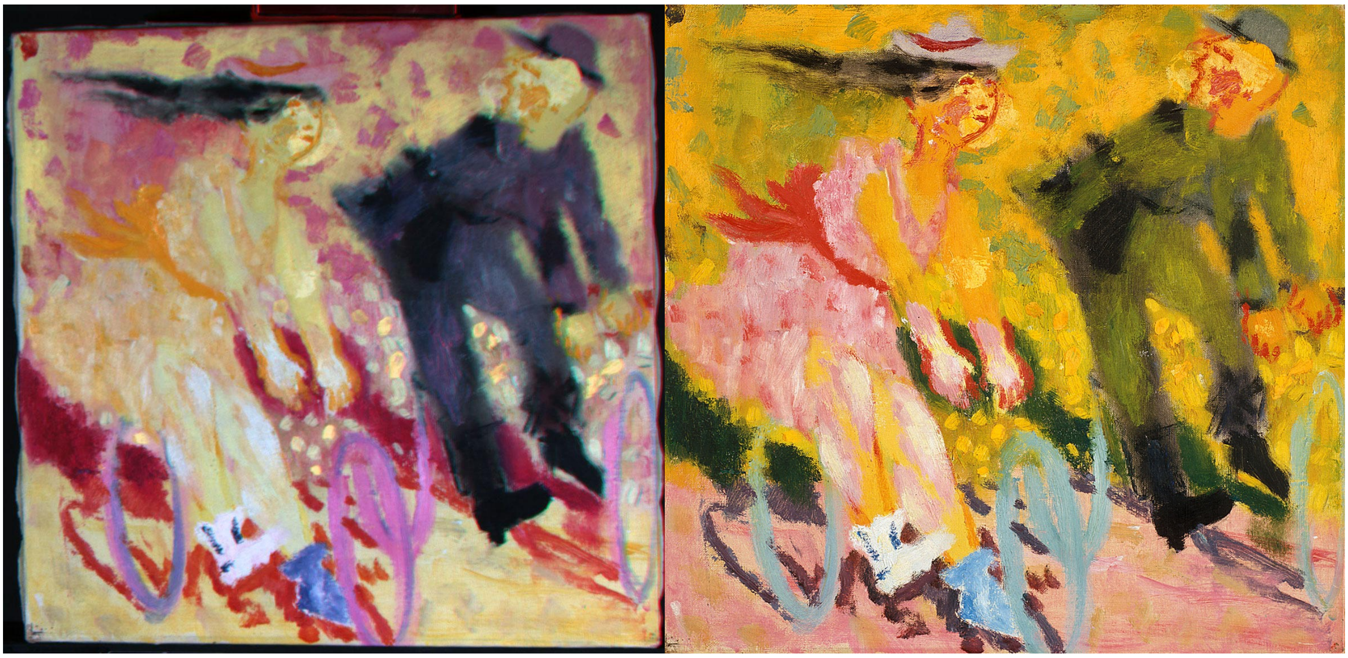


Figure 5.47: Image showing Ragnar Sandberg's Cyklister in IRFC, photography by author

All cadmium yellows show up as light yellow which matches well with what is reported, the cadmium reds show up as orange which also matches well with sources. The chromium containing greens show up as a deep red which matches well with what is reported of chromium green. The red to grey colour of the rightmost cyclist does not entirely correspond with what is expected of the greenish yellow paint. It could be a result of the IR penetrating the top layer thus mostly showing the ivory black used under the greenish yellow colour, and the faint red seen is from a chromium green cadmium yellow paint. The blue found on the shoes show up as blue which indicates the use of Prussian blue which is contrary to the findings of the XRF analysis which rather suggested the use of ultramarine. The wheels are likely a mixture of white, Prussian blue and a blue like cobalt of ultramarine blue.

5.4 Analysis Results tablets.

The following tables are based on the results of the analysis, interpretation of analysis data and identification of pigments were performed to the best of the authors ability.

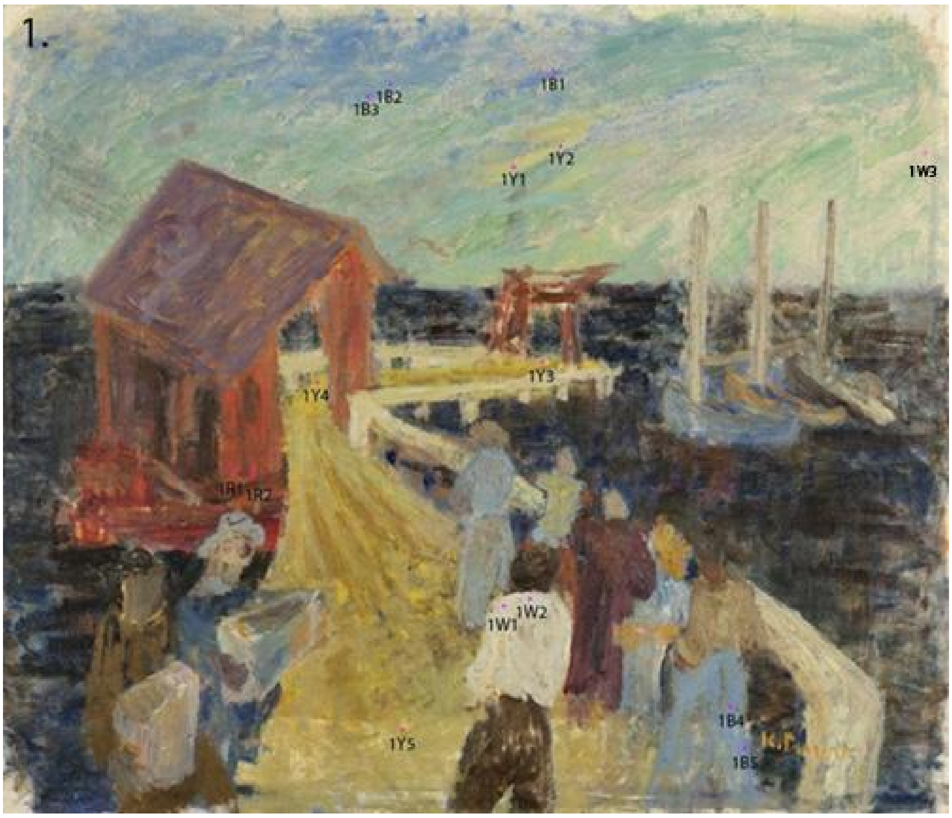


Figure 5.48: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Yellow sky	1Y1-2	Cadmium yellow mixed with a Emerald green/Copper arsenic green Possible mixture with chromium oxide green, chrome yellow or lemon yellow.
Yellow jetty	1Y3-5	Cadmium yellow, yellow ochre/raw sienna.
Light reds	1R1-2	Cadmium red. Possibly mixed with an Iron red.
Darker purple red	1R3	Likely either an organic red madder lake based pigment or an iron red.
Green sky	1G1-2	Emerald green/Copper arsenic green mixed with cadmium yellow

Blue sky	1B1-3	Cobalt blue. Chromium based green. Arsenic green.
Blue ocean	1B4-5	Ultramarine blue. Possible use of a prussian blue and/or mars black and/or dark umbre.
White shirt	1W1-2	Zinc white.
Ground	1W3	Lead white and zinc white. possible use of titanium white

Table 17. Table of the results from the analysis of Skärgårdskväll by Karin Parrow.

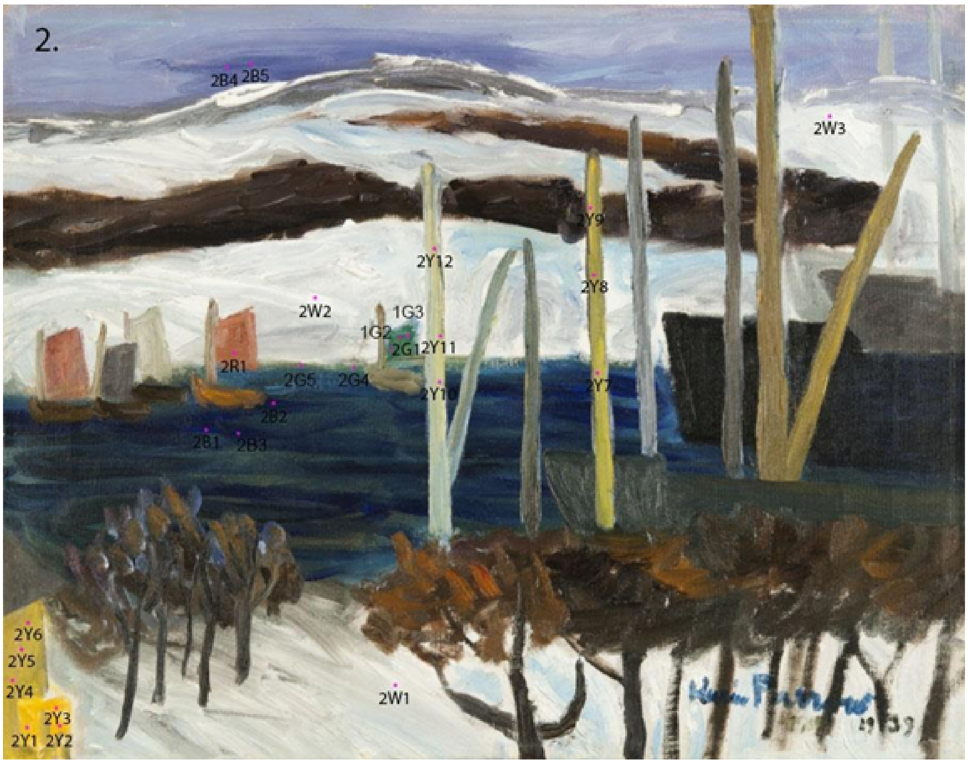


Figure 5.49: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Bright yellow	2Y1-3	Lead containing cadmium yellow.
Darker yellow	2Y4-6	Cadmium Yellow Possible use of a Yellow ochre.
Yellow pole	2Y7-9	Cadmium Yellow Possible use of a yellow ochre.
White yellowish pole	2Y10-12	Cadmium Yellow. Possible use of a yellow ochre.
Red sail	2R1-3	Cadmium Red Possible use of a red ochre.
Green sail	2G1-3	Copper arsenic green (Scheele's green or a copper acetoarsenite). Chromium based green. Possible cadmium containing paint.
Green shoreline	2G4-5	Primarily chromium oxide green with Prussian blue, Ultramarine blue and copper arsenic green (Scheele's green or a copper acetoarsenite) .
Blue water	2B1-3	Primarily Prussian Blue with Ultramarine blue. Possible use of a chromium based green.
Blue sky	2B4-5	Likely a cobalt blue mixed with an organic red.

White snow	2W1-2	Zinc white.
Ground	2W3	Lead white and zinc white. Possible barium sulphate filler with/or titanium white.

Table 18. Table of the results from the analysis of Hamnen i Vinterväder by Karin Parrow.

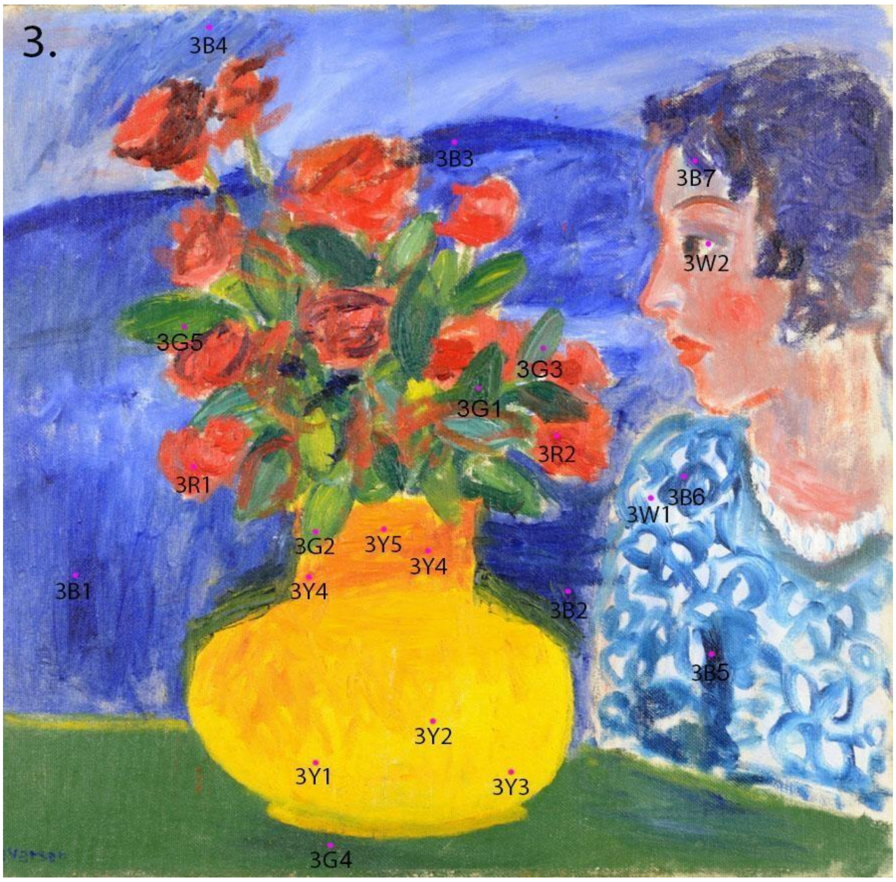


Figure 5.50: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Bright yellow	3Y1-3	Cadmium lithopone yellow
Orange yellow	3Y4-5	Cadmium lithopone yellow and/or cadmium orange/red
Red	3R1-2	Cadmium Red
Green flower stalks and leaves	3G1-3,5	Possibly a mixed green of cadmium yellow with a ultramarine and/or cobalt green, cobalt blue or cobalt yellow. .
Green table	3G4	Chromium based green.
Blue background	3B1-4	Ultramarine blue.
Blue dress	3B5-6	Prussian blue.
Blue/purplish hair	3B7	Ultramarine blue/violet.

White	3W1	Zinc white with chalk filler
Ground	3W2	Zinc white with chalk filler

Table 19. Table of the results from the analysis of Blommor och Flicka by Ivan Ivarsson.

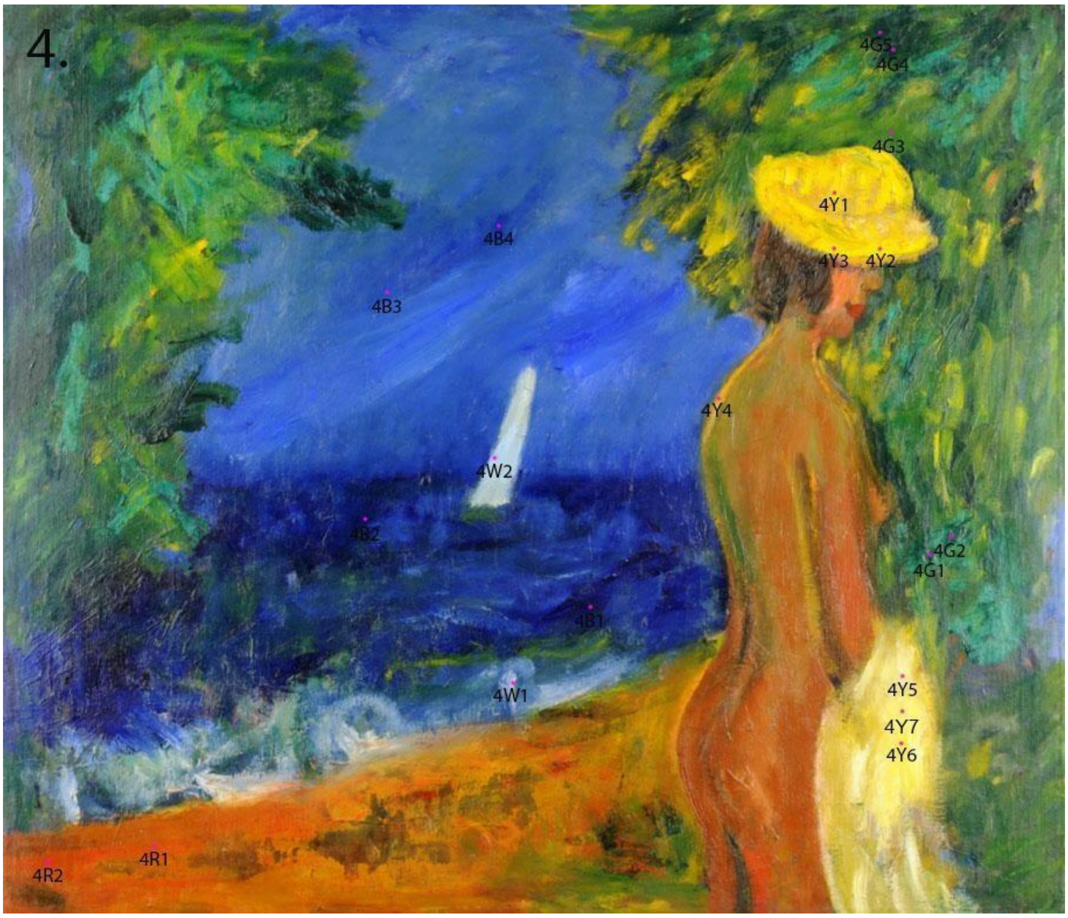


Figure 5.51: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Yellow hat	4Y1-3	Cadmium yellow/orange (presence of selenium) Possible Lead siccative and/or leaded cadmium yellow and/or lead white ground.
Orange-yellow line on the back of the figure	4Y4	Cadmium yellow/orange, chromium based green Possible Lead siccative and/or leaded cadmium yellow and/or lead white ground.
Light yellow cloth	4Y5-7	Cadmium yellow/orange (presence of selenium) ,Zinc white Possible Lead siccative and/or leaded cadmium yellow and/or lead white ground.
Red colours found on the beach	4R1-2	Cadmium/mercury sulfoselenide red or a Vermillion red and cadmium red cadmium red mixture.
Cold green	4G1-2	Chromium based green with lead siccative. Zinc White
Yellow green	4G3	Chromium based green with lead siccative. Cadmium yellow/orange

Dark green	4G4-5	Chromium based green with lead siccative. Possibly mixed with a mars black
Dark blue ocean	4B1-2	Ultramarine blue.
Light blue sky	4B3-4	Likely a cobalt blue mixed with/or ultramarine blue. Zinc white
White	4W1	Zinc White
Ground		Zinc white with chalk filler Possible Lead siccative and/or lead white ground.

Table 20. Table of the results from the analysis of Badande Flicka by Ivan Ivarsson.

Figure 5.52: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Yellow parts field.	5Y1-2	Cadmium yellow/red mixture or yellow/orange mixture. Possible earth pigment-based paint or a iron based siccative.
Orange-yellow haystacks.	5Y3-4	Cadmium yellow/red mixture or yellow/orange mixture. Possible earth pigment-based paint or a iron based siccative.
Yellow areas along the road.	5R5-6	Cadmium yellow/red mixture or yellow/orange mixture.
Red area in the foreground and red haystack.	5R1-2	Cadmium red Possible earth pigment-based paint or an iron based siccative.
Mid-green tone used in the field	5G1-2	Chromium based green with lithopone. Possible earth pigment-based paint or an iron based siccative.
Dark green used in the field.	5G3-4	Chromium based green with lithopone. Possible earth pigment-based paint or an iron based siccative.

Yellowish green used in the field	5G5	Chromium based green with lithopone. Cadmium yellow/orange Possibly mixed with a mars black
Dark blue canal	5B1-2	Likely a Ultramarine blue
Light blue sky	5B3-4	Likely Ultramarine blue or cobalt blue
White house	5W1	Zinc White
Ground	5W2	Zinc white and lead white mixture with chalk filler

Table 21. Table of the results from the analysis of Älvlandskap Hjärtum by Ivan Ivarsson.

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Figure 5.53: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Yellow details in skins.	6Y1-2	Low pigmentation or mixed cadmium lithophone yellow. Likely mixed earth pigment-based paints or an iron based siccative.
Reddish skin.	2R1,3-4	Low pigmentation cadmium lithophone red (presence of selenium). Likely mixed earth pigment-based paints or an iron based siccative.
Red outlines.	6R2	Most likely an iron red pigment based paint but could possibly also be organic pigment based.
Greenish skin.	6G1-2	Chromium based green with lithopone. Possible earth pigment-based paint or an iron based siccative.
Grey background.	6Gr1	Possibly an iron or carbon based black.
Blue water	6B2,4	Likely a cobalt blue.
Brown background.	6B1	Earth based pigment.

White skin.	6W1-2	Zinc white
Blueish white.	6W3-4	Zinc white
Ground.		Mostly Lead white with smaller quantities of zinc white, chalk based filler.

Table 22. Table of the results from the analysis of Badande by Ragnar Sandberg.

Figure 5.54: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Yellow details in skins.	7Y1-3	Cadmium yellow.
Yellow hair and hat.	7Y4-6	Cadmium yellow.
Red outlines.	7R1	Cadmium red possibly mixed with a iron red.
Reddish skin.	7R2-3	Cadmium red possibly mixed with a iron red. Zinc white
Intense blue water and clothes.	7B1-3	Ultramarine blue.
Turquoise blue background.	7B4-5	Chromium based green most likely a bluish viridian mixed with a zinc white, possibly also mixed with a blue.
White	7W1-2	Zinc white
Ground.		Mostly Zinc white with smaller quantities of lead white or possibly lead siccative, chalk based filler.

Table 23. Table of the results from the analysis of Embarkering by Ragnar Sandberg.

Figure 5.55: Image showing the points of analysis, photography by Hossein Sehatlou.

Area	Spectrum points	
Orange skin on the leftmost cyclist	8Y1-3	Dark low pigmented cadmium lithophone yellow. High amount of zinc.
Chalky whitish yellow skin areas	8Y4-6	Highly pigmented cadmium lithophone yellow, possibly leaded. Low amount of zinc.
Yellow dots	8Y7	Cadmium yellow Possible strontium yellow.
Darker yellow dot	8Y8, 8y10	Highly pigmented cadmium lithophone yellow, possibly leaded. Low amount of zinc.
Greenish yellow	8Y9	Cadmium yellow, Chromium based green. Possible strontium, barium or zinc yellow.
Yellowish green	8Y11	Cadmium yellow. Chromium green.

Whiteish yellow hands	8Y12-13	Primarily zinc white Cadmium yellow.
“Isolated” yellow dot.	8Y14-15	Cadmium yellow.
Red “belt”	8R1-2	Cadmium red
Dark green shadow	8G1-2	Chromium oxide green. Chromium yellow.
Green background.	8G3-5	Chromium oxide green. Chromium yellow. .
Blue shoelaces	8B1-3	Prussian Blue.
White shoes	8W1-2	Zinc white.
Ground	8W3	Zinc and lead white mixture. .
Black shoes		Ivory black.

Table 24. Table of the results from the analysis of Cyklister by Ragnar Sandberg.

6. Discussion:

Analysis has found evidence of the use of several pigments. Karin's choice of colours sets her apart from both Ivan and Ragnar, who were found to primarily use a handful of paints most of which belong to the category known as normal paints. In comparison Karin was found to have used a larger variety of colours and does not seem to favour specific colours as heavily instead using a wider range of colours and more complex mixtures. Ivan and Ragnar's expressive use of colour are quite different from each other, while they mostly employed the same types of pigments their use of them is what sets them apart. Ivan mainly uses strong vibrant primary colours often seemingly applied direct from the tube with less instances of mixed paints. Ragnar's paintings show a larger range of colours than Ivans, in some artworks the colours are muted and mixed with dark pigments with only smaller areas of vibrancy, while in some artworks the chosen colours are highly vibrant.

6.1 Cadmium Yellow

information on cadmium yellow pigments contained in this chapter is based on Fielder, Bayard (1986) unless any other source is stated.

Evidence of use of both red and yellow cadmium based paints were found in Karin's works, but they are mostly used more sparingly and less pigmented and often mixed with other paints. Ivan Ivarssons main yellow is cadmium yellow as it is found in all yellow, and orange spectras. Furthermore Cadmium yellows and oranges are mentioned as one of the paints Ivan favoured which further reinforces the interpretation of the analysis. Ragnars use of cadmium paints seems to have been more sparingly with the exception of Cyklister, which seems to have been almost entirely made up of different cadmium based paints.

Cadmium yellow could be mixed with a variety of other pigments such as lead white for brighter shades and vermillion, venetian red to form shades from light yellow to dark oranges, blue pigments or viridian for a pigment sold as cadmium green. Additionally, cadmium sulphide could be reacted with other elements such as magnesium to form an array of colours.

High concentrations of lead can be observed in one of the paintings by Karin Parrow (Hamnen I Vinterväder) which strongly suggests the presence of lead in the cadmium yellow paint. This could either be indicative of a siccative or a premixed lead white cadmium yellow paint. As previously discussed these paints could be one of the more vulnerable cadmium yellows. Cadmium paints produced based on a mixture of cadmium sulphide and lead white and cadmium pigments produced using a mixture of calcined cadmium sulphide, zinc sulphide and zinc or magnesium oxide have been suggested as being highly unstable. This might suggest that this artwork will be more prone to degradation in the future.

A green area of Ivan Ivarssons Blommor och flicka showed no indication of chromium, instead the peaks were predominantly zinc and cadmium. A cadmium green could have been used in this area, the green could also likely be a mixed green as cadmium is observable throughout the green area with an increase in the more bright green to yellowish areas. If a cadmium green mixture is present it is likely a mixture containing a blue pigment. The most likely blue pigment could be ultramarine as prussian blue and cobalt blue is unlikely, as the IRFC did not suggest prussian blue and cobalt blue is noted as a colour that Ivan disliked.

It is suggested that cadmium yellow based on cadmium chloride reactants are more photoative and prone to degradation than their counterparts based on other cadmium salts (Pouyet, 2015). Chlorine was indicated to be present in most cadmium yellow areas which could indicate residual chlorine compounds in the paints. But the identification is not conclusive as it could just as likely be backscattering caused by the X-ray tube, especially as the peaks are present in most of the spectras collected.

Modern manufacturing of cadmium pigments is often produced with the inclusion of zinc in the crystal structure of the pigment by simultaneous precipitation. By 1927 the availability of more cost-effective cadmium lithopone pigments were widespread. Common impurity elements include copper, iron, lead and nickel which can form coloured and unstable sulphides. Additionally, trace amounts of thallium are known to adversely affect the lightfastness. Most problems with the pigment caused by impurities could be avoided by the 1920s, with the introduction of calcination and higher purity reactants. Cadmium pigments created with simultaneous precipitation are suggested to be more prone to degradation (Monico. 2018).

All the cadmium paints found in Ivan's works show small inconsistencies in their chemical makeup suggesting that they are possibly different cadmium yellows which could be explained by the speed at which Ivan is reported to have consumed paint.

Analysis of Ragnar Sandberg's cyklister found that its likely that at least two different shades of cadmium yellow were used, one cadmium paint with a low zinc content and a high barium sulphate content, and another with low zinc content along with no obvious fillers. The intensity of the zinc peaks varied greatly throughout this work which suggests that the paints were mixed with a zinc white by the artist. Small peaks for strontium and chromium were observed which could indicate the use of an additional yellow pigment such as strontium yellow.

6.1.1 Degradation of cadmium sulphide pigments in Ragnar Sandberg's Cyklister.

The stability of cadmium yellows can range from very stable to highly unstable pigments depending on composition, and manufacturing process. Why some cadmium yellow paints seem prone to photocatalytic reduction while others are not has not been conclusively decided. Degradation of cadmium-based pigments have been found in artworks by many notable artists such as Pablo Picasso, Vincent Van Gogh, Georges Seurat, Henri Matisse, Ferdinand Leger, Edvard Munch and James Ensor; While the degradation patterns differ somewhat observed degradation patterns include colour changes (both lightening and darkening) (Pouvet et al. 2015), white globules on the surface (Van der Snickt 2009), surface crusts, chalking and spalling (Van der Snickt 2012), and chalking (Monico et al. 2019, Pouvet et al. 2015).

The literature review led to the identification of several traits displayed in Ragnars Cyklister that are similar to those commonly described for degraded cadmium yellows. Areas of Cyklister exhibit fading, loss of adhesion and chalking of the paint surface. Cyklister is dated to 1936 which is a decade or two younger than other known paintings exhibiting this kind of degradation. No studies on the prevalence of degradation of cadmium yellow paints produced during the 30s has been found. Kumlien (1954) notes that this type of degradation occurs in cadmium yellows but whether this refers to paintings produced during the 20th century or older works is unknown. Additionally Kumlien notes that a way to treat these problems is lightly rub the faded and chalked paint away with a damp cloth revealing the undegraded paint underneath, but notes that if done repeatedly can lead to a removal of the entire cadmium yellow paint layer. Of course this kind of treatment would never be considered today but it poses the question whether if this practice was generally accepted, degradation of cadmium yellows might have been a more common problem during the first half of the 20th century than previously described.

Semiconductors such as cadmium are known to work as a photocatalyst, a photocatalyst is a compound which hastens the photodegradation of materials. Studies on the influence of Relative Humidity and temperature on degradation of cadmium pigments has found that there are two different reactions cadmium can undergo when exposed to light. When cadmium atoms become photoexcited they can either recombine back to their initial state or they can photooxidize generating a free radical which can catalyse degradation processes in the material. Recombination has been found to be the dominating reaction at regular room humidity of 45% RH, while the the photooxidation of CdS to $CdSO_4$ can take place in the absence of light in high humidity environments of RH >95% (Monico et al. 2018, Miliani, et al. 2020)

These free radicals can cause degradation of binding media, or an oxidation of the sulphuric anion resulting in the formulation of a water-soluble cadmium sulphate which is leached out of the paint layer with time, leaving a porous and flaking paint layer (Van der Snickt et al. 2009). This could be a likely explanation for the extensive binding media degradation and subsequent chalking seen in Ragnars Cyklister.

Cadmium based paints has also been found to be reactive with degradation compounds found in binding media and varnishes which leads to the formation of cadmium oxalates (Van der Snickt et al. 2012). Cadmium has been found to also interact with atmospheric pollutants forming cadmium carbonates (Pouyet et al. 2018).

Research has suggested that how the Cadmium and Zinc are bonded together in cadmium zinc pigments likely affects the stability of the paint, as the inclusion of zinc in the cadmium sulphide structure increases the photocatalytic efficiency of cadmium atoms (Monico. 2018). The degraded area exhibits XRF spectra collected in the degraded area showed intense cadmium peaks with weaker peaks for zinc, while they are far from being weak they are still significantly lower than zinc peaks observed in the other areas darker yellows such as the oranges. This could indicate that the whiteness of this area is due to advanced stages of photocatalytic degradation of the cadmium yellow pigment and not a cadmium yellow mixed with white. But it is also possible cadmium yellow could have been simultaneously precipitated creating a light cadmium shade without using a zinc white mixture. It is therefore possible that the degraded area is another type of cadmium paint possibly created with zinc, perhaps in a less favourable structure than the cadmium yellow used in other seemingly undegraded areas.

Crystalline structure has als been suggested as a factor affecting the stability of the pigment with most historical cadmium paints displaying degradation being hexagonal CdS based pigments which exhibit a low degree of crystallinity. This would suggest that the degradation process most likely is affected by the crystalline structure of the cadmium yellow particle. One hypothesis is that the degradation of cadmium yellow is related to poor calcination of the pigment resulting in a poorly crystallised pigment (Ghirardello, et al. 2021).

Pigments exhibithing nanocrystalline of polytype structure are likely more prone to degradation of cadmium yellow pigments due to their increased larger surface to volume ratio, which results in a greater photocatalytic reactivity. It has been found that pigments produced in the late 19th century and early 20th century without calcination could produce a nanocrystalline pigment. (Ghirardello, et al. 2021, Comelli et al. 2019, Levin, 2017).

6.2 Additional Yellow pigments

Possible indications of the use of the pigments known as lemon yellows can be observed in artworks from all the artists. The paint commonly sold as lemon yellow is in fact not one pigment, but three different pigments all based on the chromate ion, zinc yellow, strontium yellow and barium yellow.

Strontium was found in yellow areas in Ivan's artworks, these observations are mostly found in areas of predominantly cadmium containing colour. In Ivan's Blommor och Flicka clear peaks for chromium can be observed in the yellow vase along with strontium peaks, this could indicate the presence of a strontium yellow/cadmium yellow mixture. But it is perhaps most likely that the chromium is from an underlying chromium green as the table the vase is located on is painted with a chromium green. The same is likely true for Ivan's Badande flicka as there likely is an underlying chromium green layer in areas where strontium is observed.

In Karin's Skärgårdskväll and Ragnar's Cyklister chromium can be found along with elements associated with lemon yellows. In Karins case it is perhaps most likely that the chromium is an indication of the use of chromium oxide as the sky has a greenish hue, but it is a possibility that a lemon yellow paint was used which has turned a greenish hue as most lemon yellows have been observed a tendency to shift to green. The presence of arsenic and copper would likely also account for the green hue of the sky.

The degradation patterns of lemon yellows include colour changes, the colour ranges from dull darkened yellows while if occurring under high relative humidity it turns a to greenish colour the a whitish appearance (Zanella et al. 2011), (Kühn, Curran, 1986). The presence of both chromium and strontium in cadmium yellows can also be explained as additives (possibly a calcium chromate additive) , trace amounts of strontium has been found in cadmium yellows and reds which also could explain their presence (Ghirardello, et al. 2018). Barium is commonly found in lithophone (barium sulphate) and zinc is present in zinc white which is a commonly used white and peaks for zinc can be seen in all spectrums collected which could indicate a zinc white ground.

Based on iron peaks found in the yellow areas of Karin's Skärgårdskväll evidence of the use of yellow ochres was also found, the presence of manganese could indicate the use of a Sienna based paint (Eastaugh, 2008)., iron could also be an indication of a Mars yellow pigment which is a yellow based on a ferric hydroxide which is the same as many of the orchres are based on as well. The paint is described by Kumlien (1954) as being closer to chromium yellow in shade than normal yellow ochre. All iron based earth pigments are noted as being totally stable and lightfast (Douma, 2008).

6.3 Cadmium Red

Evidence of use of cadmium red can be seen in all the paintings analysed. Cadmium red pigments are noted to be practically the same as their yellow counterparts in behaviour and appearance but are historically less expensive and more stable. Spectra collected in both Badande flicka by Ivan displayed some unexpected results, weak mercuric peaks were observable in the reds. The presence of mercury could be explained by the production of cadmium red through the substitution of some of the cadmium with mercury to form a (Cd,Hg)S based pigment (Fielder, 1986). But these pigments are suggested to have been developed in 1948. It has been suggested that the mercury-cadmium red/orange paints are less stable than other cadmium sulfoselenide based red and oranges.

Another explanation for this might be the use of a mixture of cadmium red and vermillion which is an mercuric sulphide pigment based paint which reportedly had mostly fallen out of use with the introduction of cadmium red. The use of vermillion in a painting from the 1930 would certainly not be commonplace, but beckers vermillion is reported as having a part of becker's normal paints line up until the 1940s which could explain its possible presence in a painting from the 1930s.

It has been suggested that Ivan would paint several versions of his paintings and choose the one which was the most successful and paint over the other attempts. It is also further rumoured that he would paint over paintings by artists whom he borrowed attliers from. It is therefore also possible that mercury is from an earlier underlying painting, which could be supported as previous conservation reports suggest the presence of a suspected earlier painting in this artwork.

6.4 Additional Red pigments

The areas of dark purplish-red areas of Karin's Skärgårdskväll were found to contain iron which could either be from an iron based pigment or a iron based siccative. If an iron based red pigment was used it would likely be either earth based such as a red ochre or a synthetic iron oxide such as Caput Mortuum. Iron oxides are overall noted as being totally stable and lightfast (Douma, 2008).

It is also possible that a red lake based pigment could have been used since Madder lakes are dyes and not pigments they need to be precipitated onto mordant for use as a pigment in oil paint. (Legan et al., 2016). The presence of iron and the absence of a potassium likely rules out the use of carmine as it is prepared using iron free alum (Schweppe, Roosen-Runge 1986).

This area was sampled for Fourier transform infrared spectroscopy, peaks where seen in the spectra in the general characteristic areas for a madder lake. Some likenesses of the main colourant of madder lake was observed but the match was inconclusive. The presence of iron based pigments could neither be confirmed.

iron can be observed in some of Ragnar's works which suggests the use of an iron oxide based red such as red ochre, venetian red or english red but it is also possible that an organic red lake pigment or aniline based pigment was used. There is lead in several of the red spectras in Badande and Cyklister, Ripolin is known to have produced red lead based paints which could have been used but no evidence supporting this was found. In badande it is possible that some areas such as the outlines of the figures which did not show peaks for cadmium were painted with a lead red paint, based on the IRFC photography it is a possibility. But due to consistent lead peaks throughout and iron peaks in this area it is more likely that an iron based red was used.

In Ivan's Älvlandskap, Hjärtum clear arsenic peaks were observed in a specific brushstroke in the red area of the foreground, there is to the authors knowledge no known arsenic containing red pigment, arsenic is found in the orange arsenic sulphide mineral Realgar and the yellow pigment orpiment. Evidence of the use of Realgar in European art has been established up until the late 19th century (Fitzhugh ,2012). However the use of Realgar by Ivan is unlikely as there is no documented use in early 20th century European art that has been found by the author.

It was also deemed a possibility that the arsenic could be traced to an underpainting therefore a sample was taken from the arsenic containing Älvlandskap, Hjärtum to investigate this possibility. no visual indication was found for the presence of an additional paint layer underneath. XRF analysis of the sample found weak arsenic peaks in the red paint layer. A theory for the presence of arsenic in Älvlandskap, Hjärtum could be the use of arsenic for pest management in museum collections, which could perhaps explain the presence of arsenic on the painting. However it would be unlikely that a painting was treated with arsenic in one specific area. Instead perhaps a likely source of the arsenic could be linked to the fact that it has been found that the arsenic contained in pigments such as emerald green, orpiment and realgar are prone to degradation. Which leads to the formation of highly soluble arsenic trioxide which is highly soluble able to migrate into all parts of a painting including the frame. When in contact with pigments elements such as lead, calcium it was found that the arsenic trioxides would oxidise into the insoluble arsenic pentoxide which is deposited in the paint layer (Keune, 2016) It might be possible that Älvlandskap, Hjärtum has been contaminated with arsenic from a other arsenic-containing painting, perhaps it was once stored in close proximity to a painting containing arsenic trioxide which when stored in a humid environment might allow for the migration to other materials in close proximity.

6.5 Chromium oxide greens

All of the artists were found to have employed chromium oxide greens, especially Ivan who heavily relied on the pigment often mixing it with cadmium yellows. Chromium oxide greens can be found in two different types of pigment chromium oxide and hydrated chromium oxide commonly referenced as Viridian, both pigments are highly stable with no fading (Newman, 1997). Distinguishing between chromium green and viridian is not possible using the analytical setup used in this study, as the only chemical difference between the pigments is that viridan is hydrated. Chromium was found in all green paint layers in the works by Ragnar and Ivan except for one work by Ivan, namely Blommor och Flicka which was discussed in the section about cadmium yellow paints.

Green areas of Ivan's Blommor och flicka and Älvlandskap, Hjärtum both exhibit some degradation of the binding media resulting in loss of adhesion between the layers and formation of cracks in the paint players. Chromium green has not been known to promote binding media degradation; it could be that the binding media degradation is due to the use of a thickly applied lower grade paint.

6.6 Emerald Green

The presence of copper and arsenic in the greens used by Karin in both of the artworks included in this study is a strong indication on the use of a Emerald green such as a copper acetoarsenite (schweinfurter green) or a copper arsenite (Scheele's green). Both paints are highly toxic and had largely been phased out during this period. Determining which type of emerald green used is not possible using the setup used in this study. Copper acetoarsenite is suggested to have been more commonly used than copper arsenate due to its marginally higher stability (Fiedler, Bayard 1997).

The arsenic greens in Karin's works might be a cause for concern as arsenic greens are not considered stable pigments. The degradation of Emerald green not only affects the visual appearance. Emerald green can also react with oil binding media to form copper soaps which hastens degradation of binding media and forms water soluble arsenic trioxide which can lead to the migration of arsenic throughout the whole painting and even into the frame. Emerald Green is also known to react with hydrogen sulphide producing black copper sulphide. As the migration of arsenic is water- based the use of water based cleaning solutions and large fluctuations in humidity should be avoided to limit migration of arsenic. Maintaining a stable RH which does not promote the degradation of cadmium pigments will also limit the risk of degradation of the cadmium yellow pigments and arsenic green mixtures used by karin in Skärgårdskväll. Access to atmospheric pollutants should also be limited. Arsenic greens are also vulnerable to atmospheric hydrogen sulphide which can cause them to blacken.

Emerald greens are noted as being incompatible with pigments containing sulphides despite this Barium sulphate has been found in several arsenic greens, it remains unclear how this affects the stability of the pigment (Keune et al. 2013). In Karin's Skärgårdskväll arsenic copper green has been mixed with cadmium yellow, there has been no visual impact of this mixture but paintings such as this might be more prone to undergo degradation in the future. The photodegradation of cadmium based pigments releases sulphur which likely could react with the arsenic copper pigment.

6.7 Ultramarine Blue

As suggested Karin used a wide range of mixtures to achieve the blue shades in her artworks. Ragnar overall used less blues than the other artists in the examined paintings. Ivan employed a more simplistic approach heavily favouring ultramarine blue which is noted as one of his favourite colours. Karin uses it in mixtures in the water of both Skärgårdskväll and Hamnen i Vinterväder, and Ivan uses it in the clothes of the figures on Embarkering. The paint is applied straight from the bottle with few to no mixtures with other paints than a white. Ultramarine is a relatively unusual mineral that only is found in large quantities in a few places in the world and was therefore very costly. In the early 19th century synthetic ultramarine was invented and has since then been the main ultramarine pigment. Synthetic ultramarine is based on the same main constituents as genuine ultramarine, namely sodium, aluminium, sulphur and silicate.

Ultramarine has been known to develop several types of degradation patterns, most notable a yellow-grey discolouration known as ultramarine sickness. Research into degradation of ultramarine pigments usually favours two different theories. The first attributes the discoloration to a loss or chemical change of the pigment particles themselves, the other attributes the discoloration to formation of microcracks in the binding media which causes light scattering (Schnetz, 2020). Some sources suggest that both theories are likely correct, but that they are two entirely different types of degradation with different symptoms. It has been suggested that true ultramarine sickness is caused by acids which results in the bleaching of the pigment, but this is likely to be a very rare occurrence. (Rie, 2017)

Ultramarine has also been found to closely resemble common industrial catalysts, as both ultramarine and aluminosilicate catalysts such as zeolite share the same aluminosilicate framework. Research suggests that synthetic ultramarine has catalytic properties (Schnetz et al. 2020) the catalytic properties can increase the breakdown of the binding media (Rie et al. 2017). No indication of degradation of ultramarine pigments was observed in any of the artworks, and this type of degradation is noted as rare.

6.8 Prussian Blue

All the artists likely used prussian blues; Karin uses it heavily in the mixture of the water in Hamnen i Vinterväder, Ivan uses it in Blommor och flicka and Ragnar in Cyklister. Prussian blue is highly susceptible to fading if exposed to alkaline environments, but largely unaffected by acids (Berrie, 1993)(Ware, 2016). Pure prussian blue pigments applied in dark shades showed generally great permeance, but Prussian blues applied thinly or in lighter shades have slightly reduced lightfastness, and lastly if mixed with whites the pigments displayed significant fading. (Samain et.al. 2016). During fading the colour giving iron ions are reduced in charge which causes a loss of colour, this reaction is enhanced by the presence of photochemically active white paints. Titanium white was found to affect the lightfastness the least, due to the higher refractive index compared to zinc and lead white. The higher refractive index means the light propagates less in titanium white making it more lightfast. (Samain et al. 2013).

Prussian blue is a regenerative pigment, which can be regenerated if kept in an oxygen rich and dark environment. But as the pigment is bound. In paintings this reversibility is only seen in short term fading, in paintings exposed to long time fading the fading is not reversible (Samain et.al. 2016). No indication of fading of prussian blue pigments can be seen in the paintings, Prussian blue paints used by Ivan and Ragnar are in close proximity or partially mixed with zinc whites which if exposed to high levels of UV light overtime might lead to fading of the pigment.

6.9 Cobalt Blue

Cobalt blue was likely used by both Karin and Ragnar, but it is less likely that it was employed by Ivan in the artworks included as there is no clear indication of cobalt blue in the analysis results, this is further supported by the fact that he is is cited as disliking the pigment making it unlikely that it was used to any greater extent. Cobalt blue is noted as an extremely stable and light resistant pigment. (Eastaugh, 2008).

6.10 Zinc White

All artists were found to have used zinc white, it is likely the main white used by all the artists for painting white surfaces. Zinc white is also present throughout all the spectras collected which strongly indicates its use in the ground. Zinc white paints have been found to be susceptible to metal soap formation. During hydrolysis of the oil binder the oils are broken down into fatty acids which react with the zinc oxides forming zinc soaps (Osmond 2012). Microfissures have been observed to form as a result of the expansion of heavily saponified zinc white paints, and act as the starting stages of paint delamination (Hageraats et al. 2019).

The temperature influences the solubility of the zinc soaps in the oil binder, when the temperature drops below the solubility point the metal soaps are precipitated. To avoid the formation of zinc soaps, control of acids are important, experiments have found straight-chain saturated fatty acids react readily to form metal soaps, and increased chain length was found to be less reactive. Zinc based paints have also been found to be strongly hydrophilic which can cause swelling and enhanced breakdown of the oil binder. Studies have found that degradation is more commonly found in zinc paint layers containing lead white (Osmond 2012). The literature review failed to find research aiming to differentiate at which point precipitation of the zinc soaps occurs.

6.11 Lead White

Lead can be observed throughout all the artworks included in the study which suggests that the ground consists of a lead and zinc white mixture. It is also likely found to a lesser degree mixed with the zinc whites used for painting white surfaces. Metal soaps are also commonly formed in lead white paints. It is also known to react with atmospheric pollutants to form dark crusts. In the case of both zinc and lead white it is important to control humidity to limit precipitation.

Lead soaps are known to cause the formation of mobile lead soaps, aggregates, lead rich crusts and loss of opacity which has the potentiality to seriously affect the stability of the paint layer. These migrations are most likely driven by gradients in temperature and humidity. The displaced or aggregated lead soaps commonly react with atmospheric pollutants to form lead carbonates, oxides, chlorides, sulphates, and potassium sulphates. The darkening of lead white through the interaction of sulphates is commonly reported (Keune et al. 2010).

6.12 Titanium White

Indications of titanium were identified in Karin's Skärgårdskväll; it is therefore likely that Karin used a titanium white paint. The pigment had been introduced commercially during the end of 1910s or early 20s, and the production on large scale would take several years. There are two types of titanium white pigments: rutile and anatase based pigments, the early commercially available pigments were all based on the anatase mineral. early attempts at producing a rutile-based pigment were unsatisfactory. It was not until 1937 that a suitable method for producing synthetic rutile at an industrial scale was possible (Laver, M. 2000). Since the painting was donated to the museum in 1937 and likely painted earlier it is likely that an anatase based pigment was used.

Both rutile and anatase based pigments are cited as being generally lightfast. There are so far few reported cases of degraded titanium white in artworks. It has been suggested that it might be that the degradation rate is too slow compared to the pigments' relatively recent introduction and it's only a matter of time before photocatalytic titanium white containing artworks will start to show signs of degradation. Anatase form has been found to be more photochemically active than the rutile form. The degradation likely proceeds similarly to the degradation of other photocatalytic pigments. (Van Driel et al. 2017, Van Driel et al. 2018).

6.13 Ivory Black

The presence of phosphorus in Ragnars black is a clear indication of the use of Ivory black. Ivory black is noted as being a permanent colour in all types of mediums and compatible with all pigments (Douma, 2008).

7. Conclusion:

The study found clear indications of the use of several pigments, the artists overall used cadmium based yellows and reds, chromium based greens, ultramarine, Prussian blue, zinc and lead whites are predominant. Analysis also found individual characteristics in the different artists' use of colour. In the works studied by Karin Parrow it was concluded that it is likely that copper arsenic greens, cobalt blues and ochres were used. These works generally seem to have been created using less pigmented paints and through the use of comparatively more complex paint mixtures than the other artists included in the study. The clear Indications found of the use of titanium white paints also sets Karin apart from the others, whose use of titanium white based paints cannot conclusively be confirmed. Analysis of her works were in line with the suggestion that Karin put special emphasis on the contrast between sea and sky, as evidence of complex and precise paint mixtures were found in these areas.

Ivan Ivarsson was found to have mostly used clear pure vibrant colours likely applied straight from the tube, with some exceptions. The largely analysis confirmed what had been previously suggested regarding his use of colour, cadmium based yellows, oranges and reds, chromium oxide greens and ultramarine are heavily employed throughout his works. While not mentioned as one of Ivan's heavily employed colours, a clear indication of the use of Prussian blue was found. No clear evidence of the use of a cobalt blue was found which would reinforce the suggestion that Ivan disliked cobalt blue. Some possible indications of the use of vermilion was found. Analysis also found evidence which supported the suggestion that Ivan put great importance in the quality and high ratio of pigment compared to fillers and additives. Ivan seems to mostly have used zinc white paints as his main white pigment with zinc and lead based grounds in his works.

Analysis found Ragnar Sandberg to sometimes be more restrained in his use of colour than the likes of Ivan and at other times the opposite is true. Badande and Embarkering where found to contain less pigmented paints and more mixtures of paints while Cyklister uses heavily pigmented and intense paints. Ragnar was found to rely on cadmium based yellows, oranges and reds, chromium oxide greens, ultramarine, cobalt and prussian blue. Ragnar also likely used several types of earth based pigments. Something which further sets Ragnar apart from other Gothenburg colourists is his use of black, most likely a Ivory black. Ragnar seems to mostly have used zinc white paints and zinc and lead based grounds in his works. Evidence indicating the use of a strontium yellow was also found in Cyklister. Ragnars use of Ripolin in any of the works included is neither confirmed nor disproven, the literature review found that the cadmium based pigments often used by Ragnar were not produced by Ripolin which would conclusively rule out the use of Ripolin in those areas.

Most of the paints used by the artists in this study are included in the normal paints, with some notable exceptions such as the emerald greens. While some of the paints commonly included, perhaps most notably cadmium yellows have been proven to be prone to degradation they are overall stable. But it is important to note that even for pigments considered generally stable it is important that environmental conditions are appropriate for material. Evidence of some less stable pigments were found which requires extra care, notably works containing copper arsenic greens are especially prone to degradation. Keeping these works stable is not only of concern for the wellbeing of the artworks but also for the health of people working with them or in proximity to them as the degradation of pigments containing arsenic copper greens have been found to produce highly mobile soluble arsenic compounds. Further research on the degradation of the cadmium yellow paint found in Ragnars Cylister is warranted to determine the cause behind the degradation and why it is largely localised and if other areas of cadmium yellow are in early stages of degradation. Further studies are also needed to get a better understanding on how Gothenburg colorists use colours.

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IRFC Interpretation

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Boust, C. (2017). Pigment image database under UV and IR radiations Extract #3 Historical pigments : YELLOW

Boust, C. (2017). Pigment image database under UV and IR radiations Extract #7 CADMIUM PIGMENTS : Red, Green, Yellow

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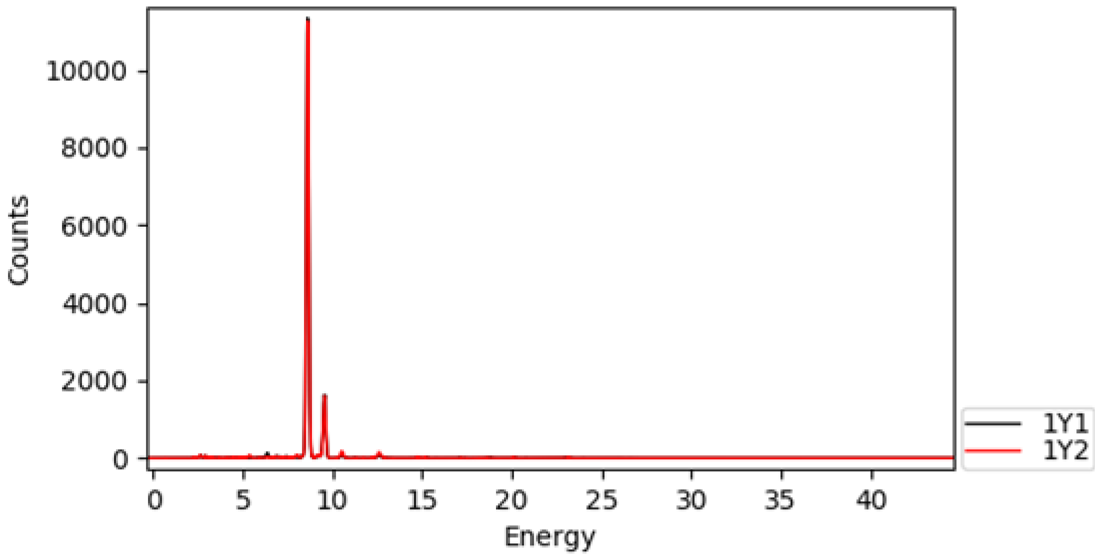
Appendix

XRF Data

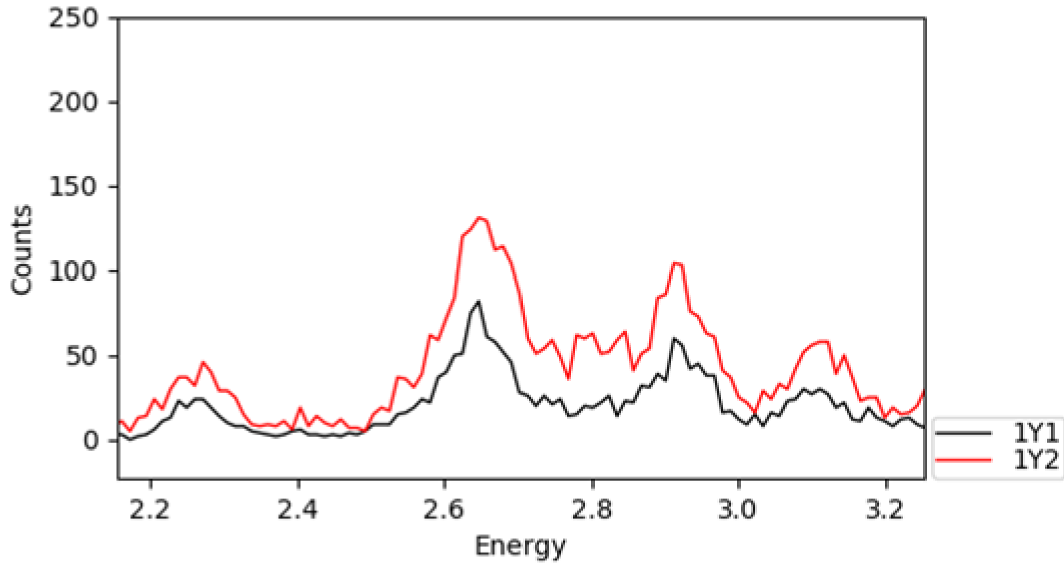
1. Skärgårdskväll - Karin Parrow.

Yellows.

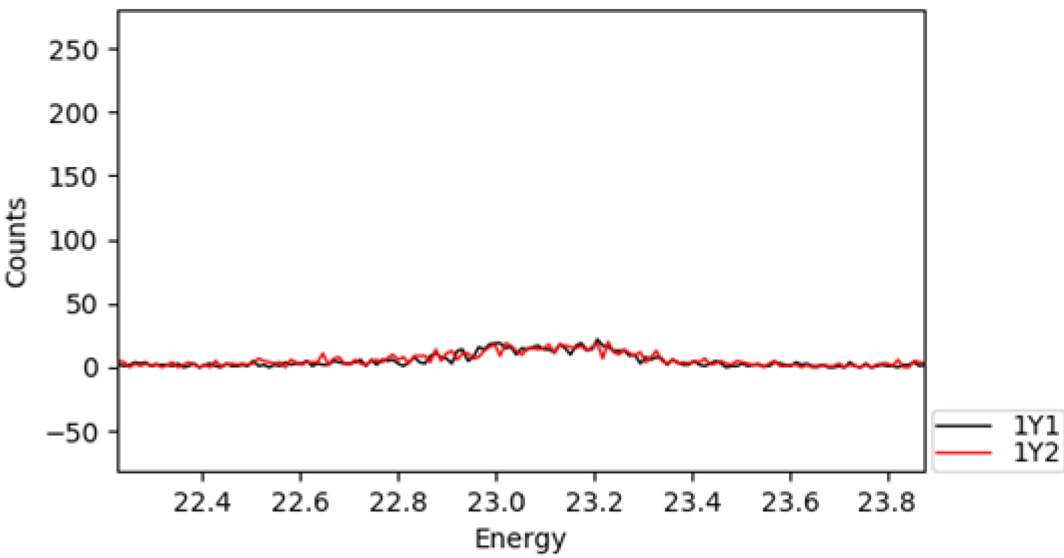
1Y1-3



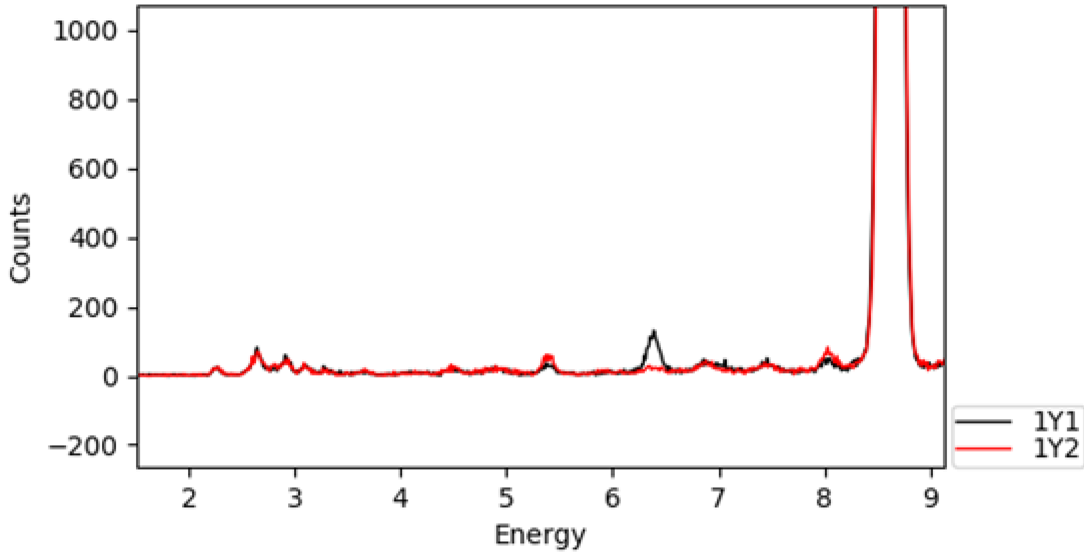
Point 1Y1 and 1Y2 was taken in the yellow areas of the sky, the points collected in this area showed clear peaks for Zinc at 8.6 keV and a peak at 9.5 keV. Faint peaks at 10.5 keV and 12.6 keV is attributed to lead which has a $L_{\alpha1}$ at 10.5 and $L_{\beta1}$ at 12.6.



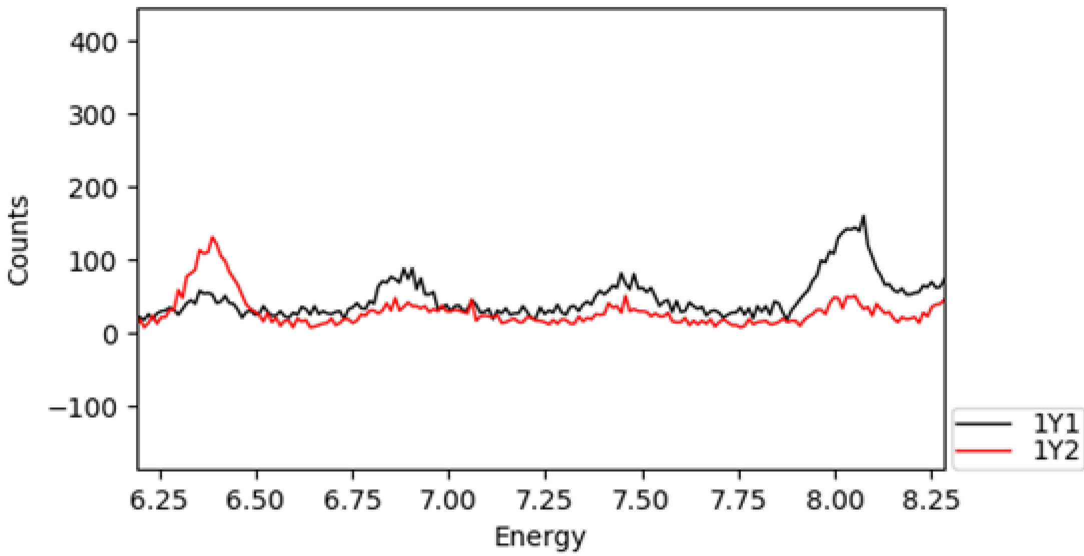
Peaks found around 2,26 keV was attributed to sulphur as sulphurs $K_{\alpha 1}$ peak can be found at around 2,3 keV. A peak was found at around 2,6 keV which is attributed to chlorine which has a K_{α} peak at around 2.6. Rhodium's $L_{\alpha 1}$ and $L_{\alpha 2}$ can be found at around 2,70 keV and 2.82 keV could also add to this peak, the peak found at 2.9 keV could be these rhodium peaks as they are always present in the spectra's and no other matching element has been identified.



A miniscule peak of Cadmium was tentatively identified by the database? Based on the noise found around 23 keV which is the region where cadmiums $K_{\alpha 1}$ peak is found, weak peaks are found around 3.1 keV which would correspond with $L_{\alpha 1}$ and $L_{\alpha 2}$ peaks. No peaks were found around 26 keV where Cadmiums $K_{\beta 1}$ and $K_{\beta 2}$ peaks are found. The $K_{\beta 1}$ and $K_{\beta 2}$ peaks of rhodium are also found at 22.7 keV and 23.2 keV respectively; it is therefore not possible to conclude that cadmium has been identified.

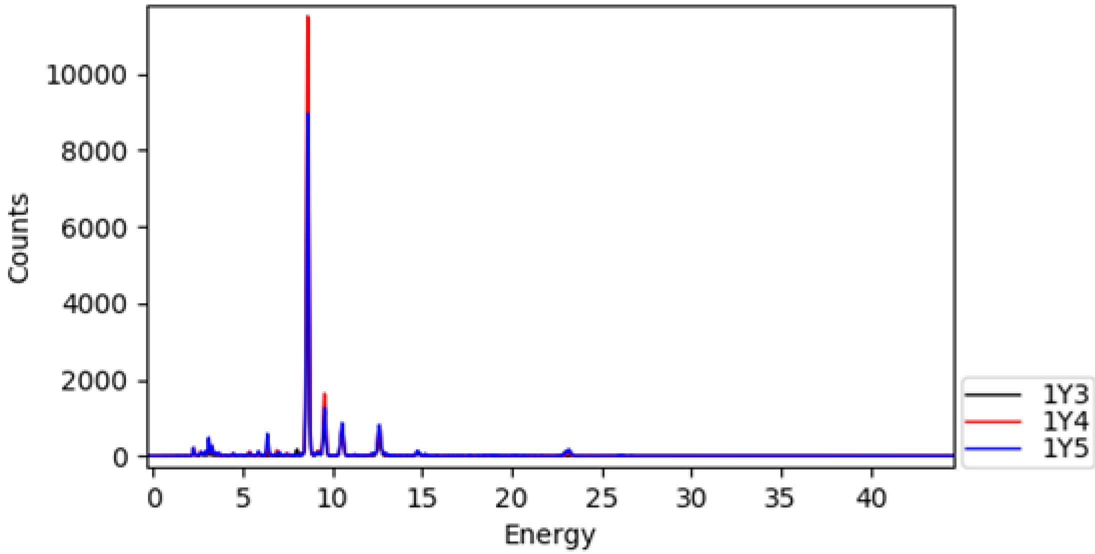


A peak found at 5.4 keV indicative of chromium's $K_{\alpha 1}$ peak can be seen but no clear $K_{\beta 1}$ 5.95 keV is seen. The peak found at 8 keV corresponds to copper's $K_{\alpha 1}$ peak, a slight elevation in the intensity can tentatively be found at around 8.9 keV would correspond to the $K_{\beta 1}$ peak of copper. Slight elevations in the intensity at 4.5 keV and 4.9 keV could correspond to the $K_{\alpha 1}$ and $K_{\beta 1}$ peak of titanium.



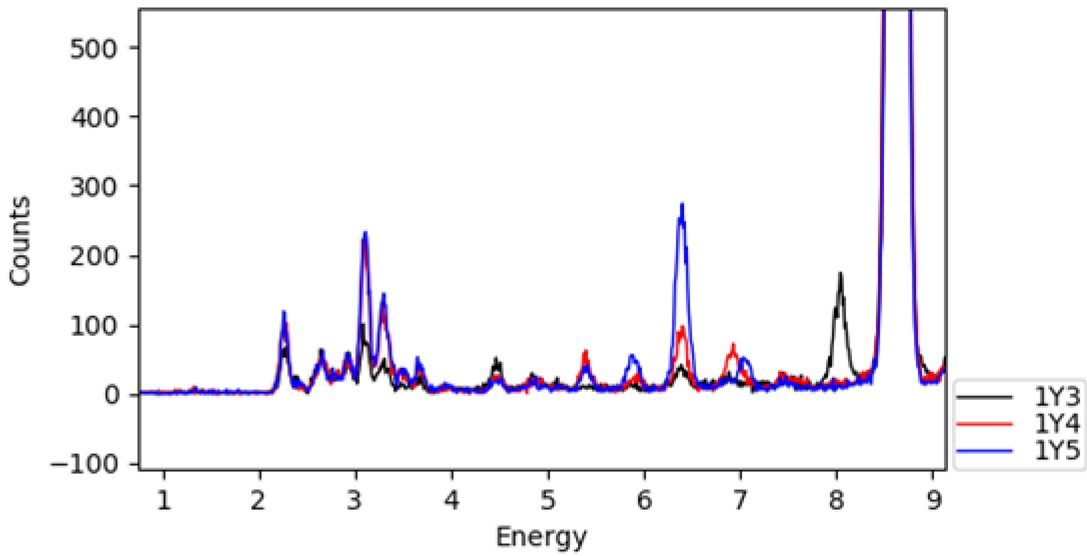
The peak found at 6.4 keV can be attributed to Iron which has a corresponding Kα1 peak; the weaker peak at Kβ1 peak at 7 keV is not distinguishable. A weak peak can be observed at 7,48 keV which is indicative of nickel's Kα1 peak, the Kβ1 peak would be found at 8,2 but that is hard to judge as the noise from the zinc peak obscures it.

1Y3-5



Point 1Y3 to 1Y5 was taken in the vibrant yellow parts of the jetty, the points collected in this area showed clear peaks for Zinc, lead, and sulphur. A peak attributed to chlorine was found.

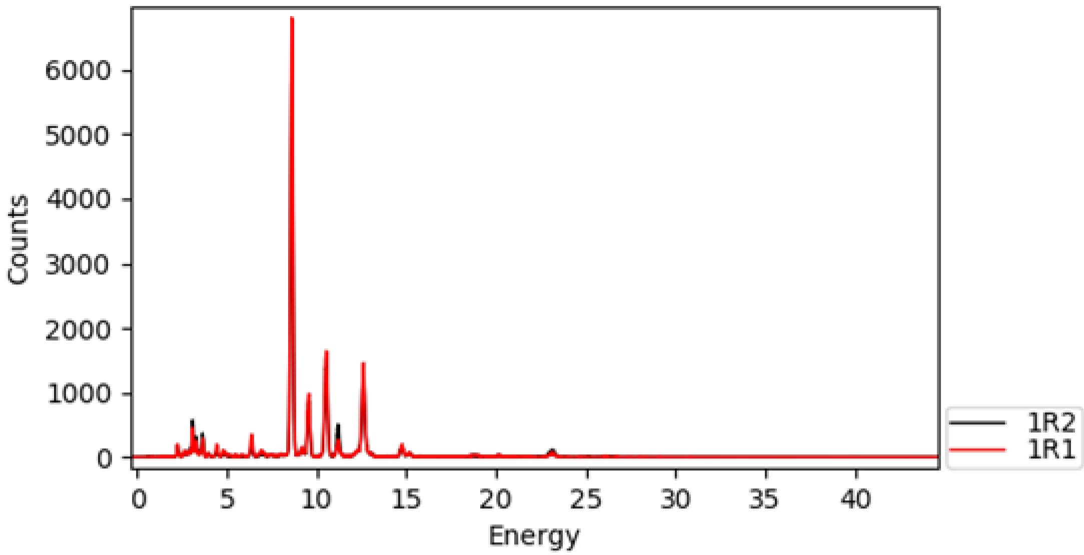
Peaks corresponding to Cadmium was found, as the clear peak found at 3.1 and 3.2 keV correspond with cadmiums Lα1 and Lα2 peaks and a weak broad peak is observable at around 23 keV and at 26 keV corresponding to the Kα1 peak, and the Kβ1and Kβ2 peaks.



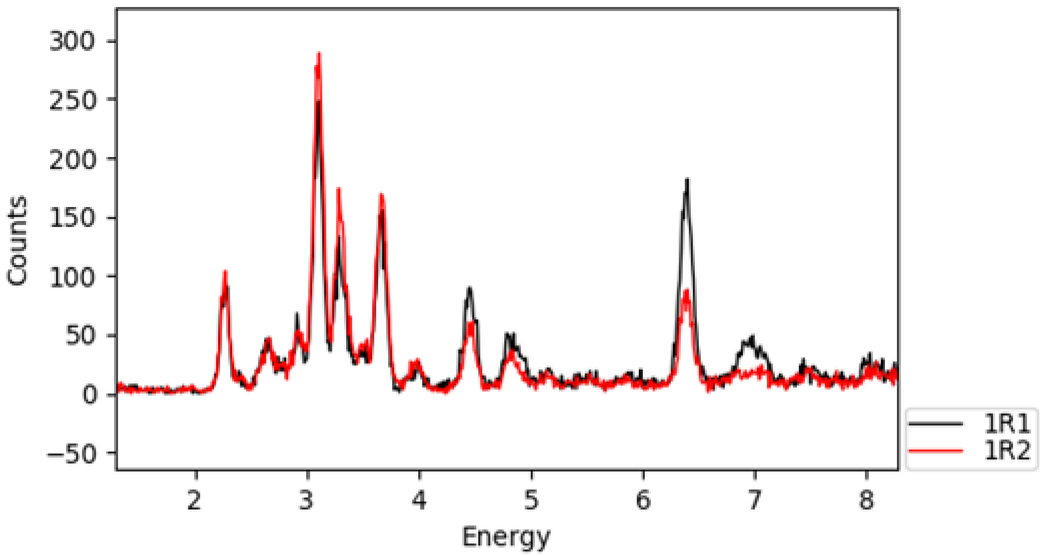
The peaks found at 6.4 keV and 7 keV can be attributed to Iron. Peaks found at 5.4 keV and at 5.9 suggest the presence of chromium. The Peak found at 5, 9 keV is indicative of Manganese $K_{\alpha 1}$ peak, the $K_{\beta 1}$ peak which would be found at 6,5 keV would be largely overlapped by the iron peak. The peaks at 4.5 keV and 4.9 keV correspond to the $K_{\alpha 1}$ and $K_{\beta 1}$ peaks of titanium. A weak peak can be observed at 7,48 keV which corresponds to nickel, a tentative peak can be seen around 8.2 keV corresponding to $K_{\beta 1}$ but can't be confirmed with certainty. Cobalt was suggested which has a $K_{\alpha 1}$ peak at 6.9 keV which is only present on one measure point and no $K_{\beta 1}$ at 7.65 keV can be found.

Reds

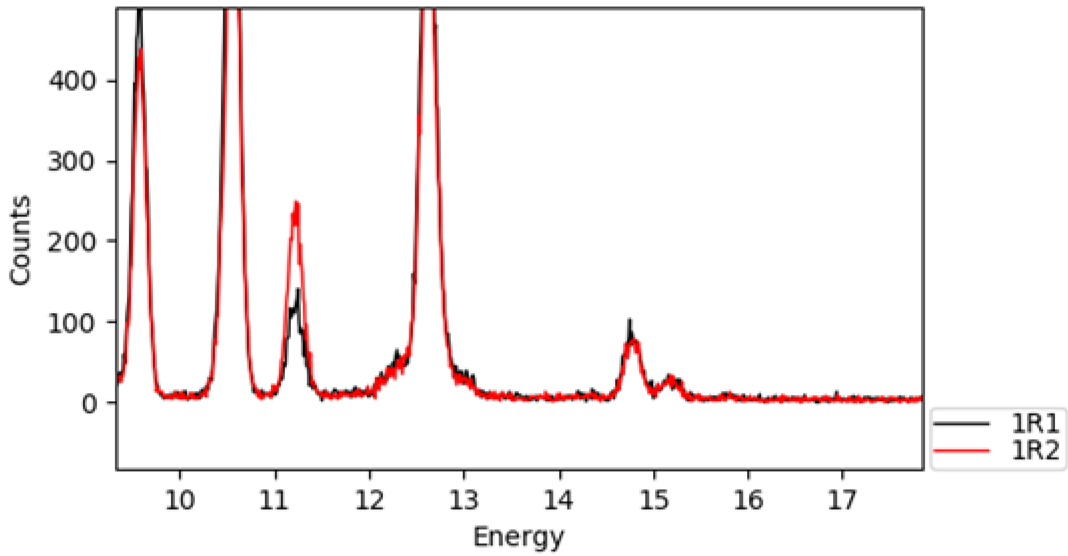
1R1-2



Point 1R1 and 1R2 was taken in the vibrant red parts of the house, the points collected in this area showed clear peaks for zinc, chlorine, lead, iron, and cadmium.

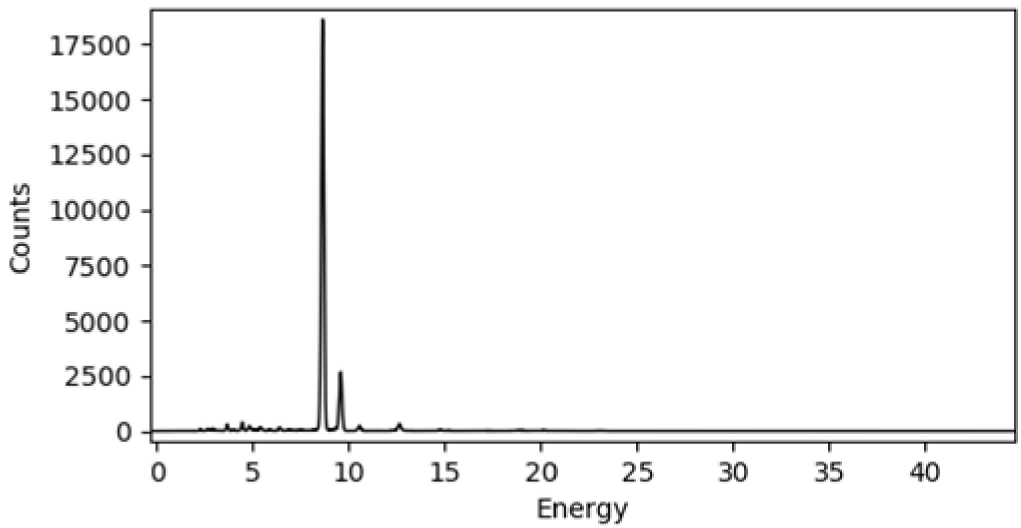


A clear Peak found at 3.6 keV is attributed to the K_{α} peak of Calcium. Peaks found at 4.4 keV are attributed to Bariums Lα1, Lβ1, Lβ2 and Lβ3 peaks. Peaks found at 5.4 keV and at 5.9 suggest the presence of chromium. Undefined peaks attributed to cobal.



Peaks at 11.2 keV are attributed to the $K_{\alpha 1}$ peak of selenium, the $K_{\beta 1}$ peak of selenium is found at 12.5 keV which overlaps the peak of $K_{\beta 1}$ of lead at 12.6 keV.

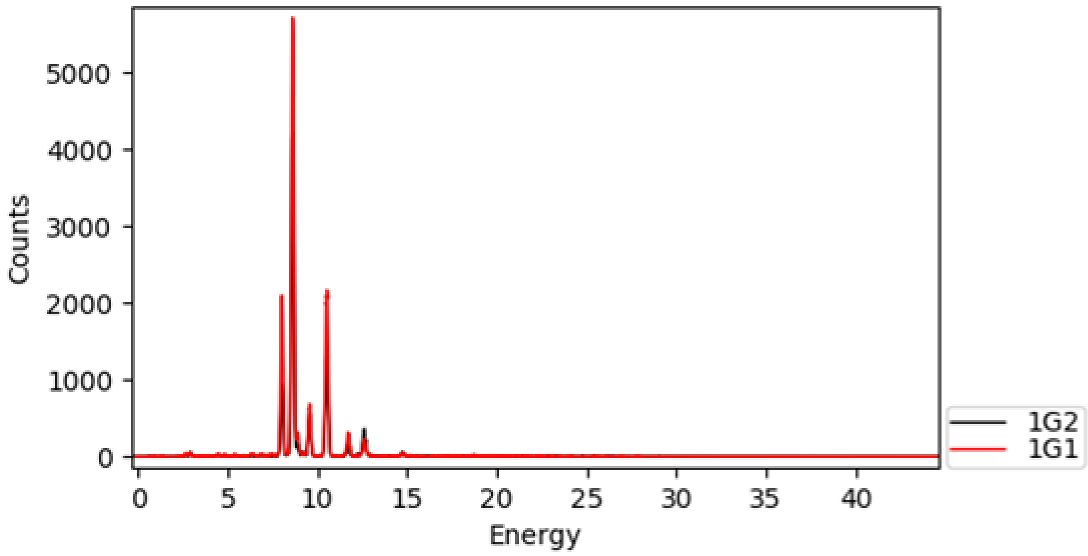
1R3



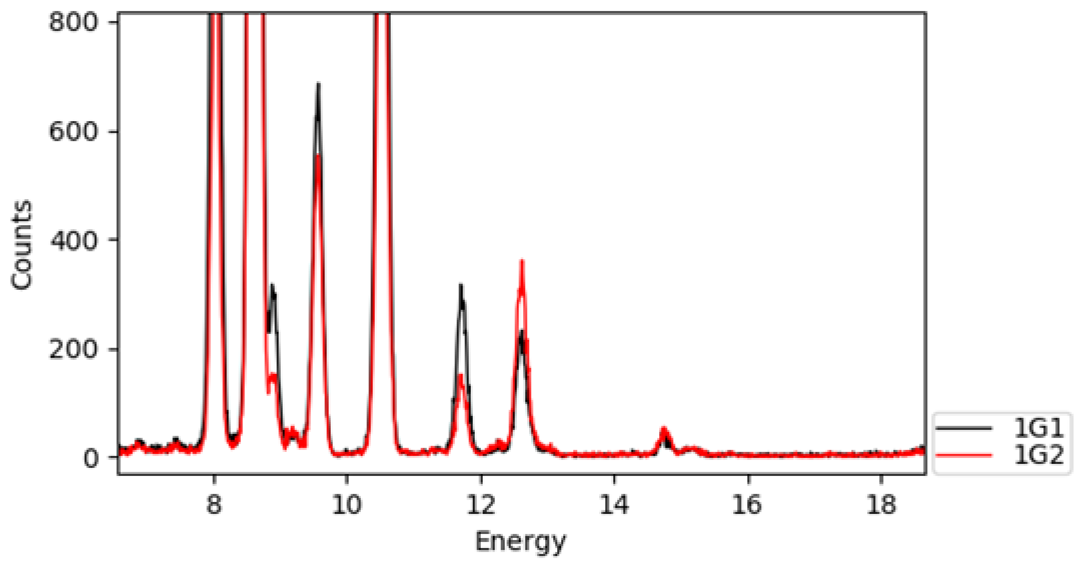
Point 1R3 was taken in the dark wine-red dress, the data collected in this area showed clear peaks for zinc, lead, barium, chlorine, calcium, Iron and chromium were identified. Weak cobalt and cadmium peaks which might indicate the presence of faint traces of these elements.

Greens

1G1 and 1G2



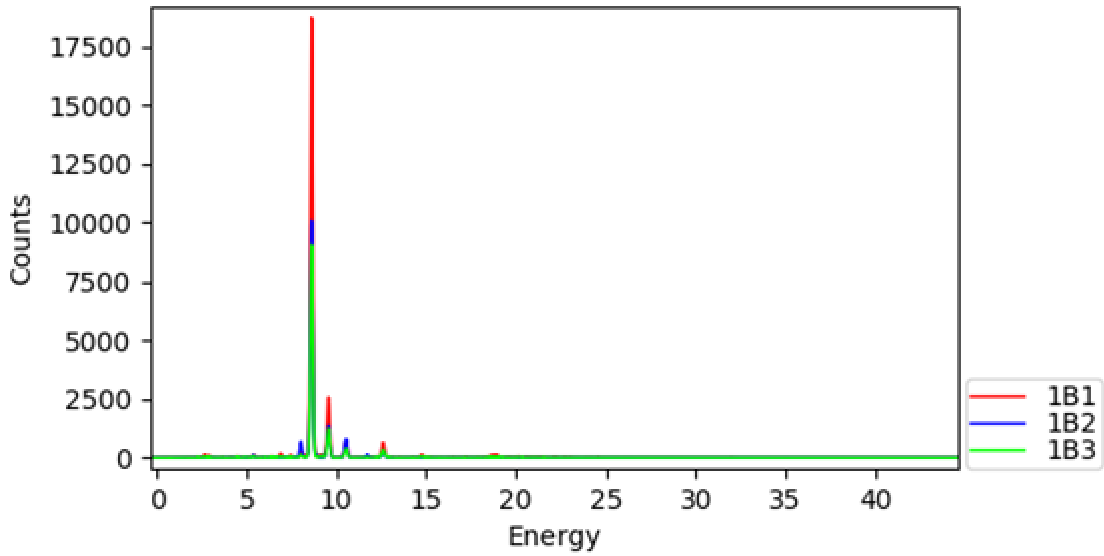
Point 1R1 and 1R2 was taken in the mint green parts of the sky, the points collected in this area showed clear peaks for zinc, lead, copper and chlorine. weak titanium peaks and sulphur peaks.



A peak found at 11.7 keV is attributed to arsenics $K_{\beta1}$ peak, arsenics $K_{\alpha1}$ peak is found at 10.5 keV which overlaps with leads $L_{\alpha1}$ peak. The intensity of the peak might be produced by the combined emission of arsenics $K_{\alpha1}$ peak and leads $L_{\alpha1}$ peak which results in a stronger intensity peak.

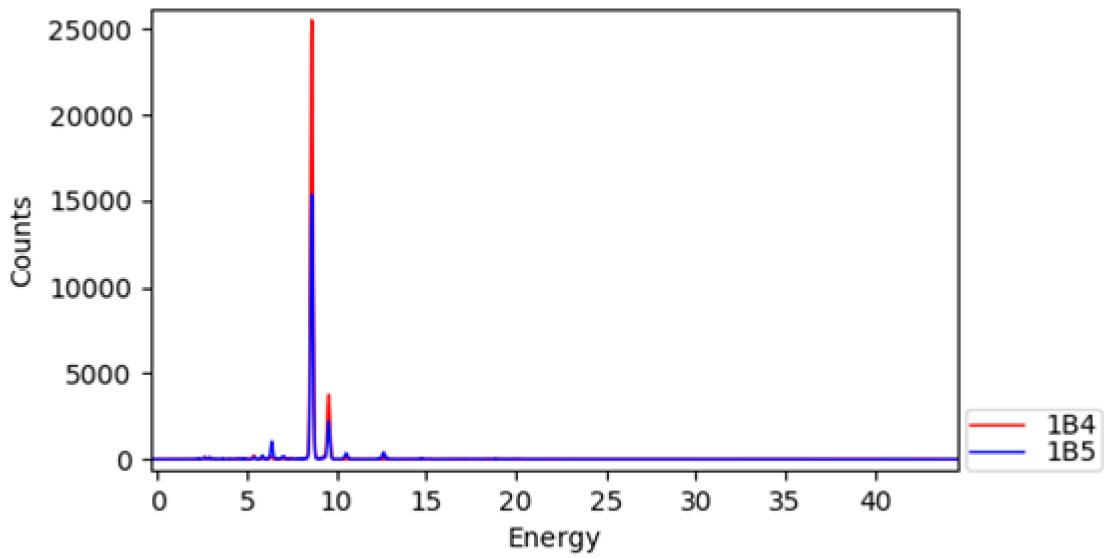
Blues

1B1 to 1B3



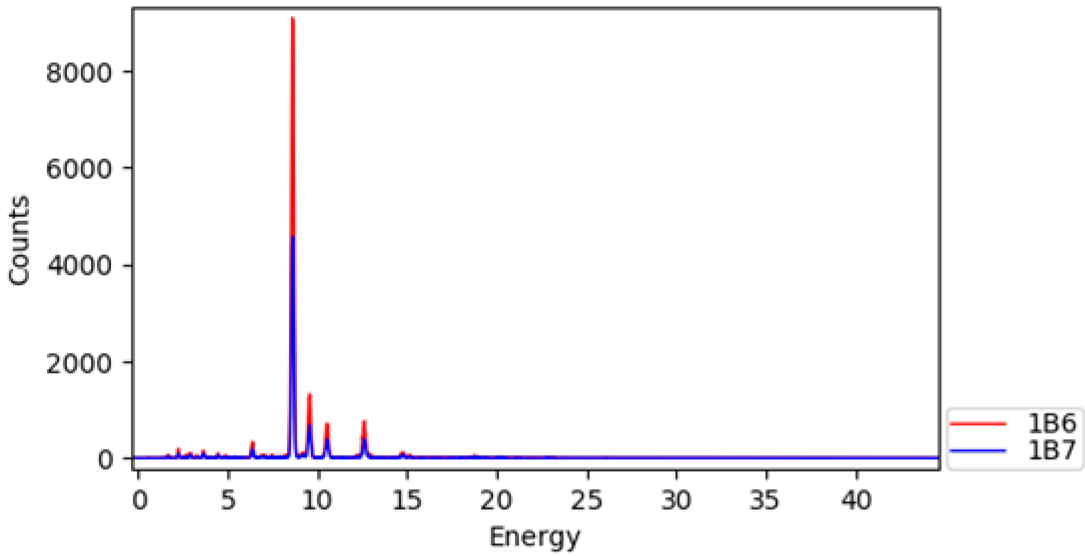
Point 1B1 and 1B3 was taken in the bright blue paint found in the sky, the points collected in this area showed clear peaks for Zinc, Cobalt, Lead, Arsenic, Copper and Chloride. Faint peaks associated with Sulphur, chromium, nickel, titanium, iron can also be found.

1B4 to 1B5



Point 1B4 and 1B5 was taken in the bright blue paint found on the dress of one of the people in the foreground, the points collected in this area showed clear peaks for zinc, Chloride, lead, sulphur and iron. Faint peaks associated with, calcium, manganese, Barium, chromium, and nickel can also be found.

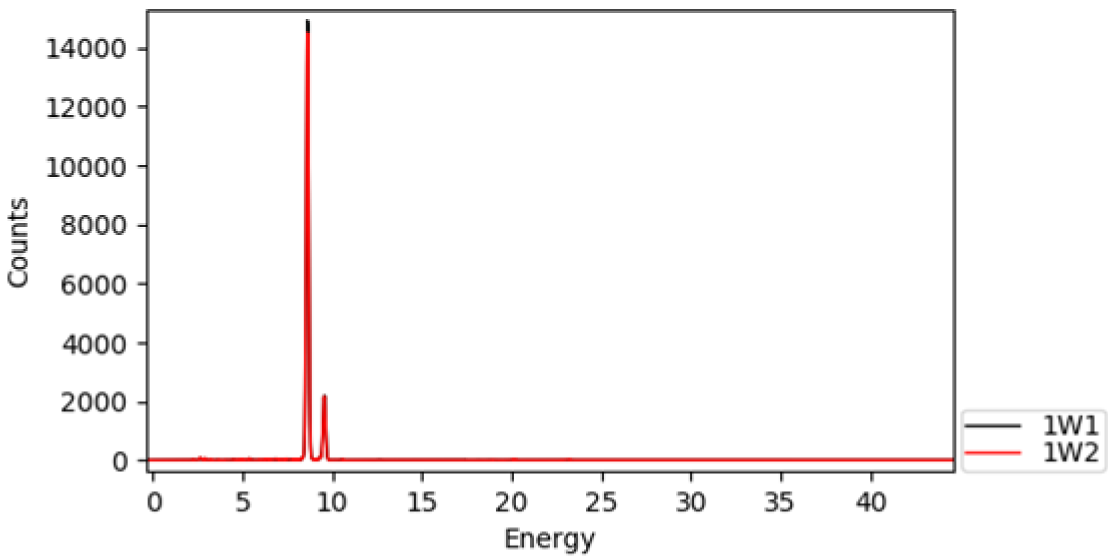
1B6 to 1B7



Point 1B6 and 1B7 was taken in the dark blue paint found used to paint the sea, the points collected in this area showed clear peaks for zinc, sulphur, chlorine, calcium, and lead. Peaks found around 1.74 keV are associated with the Kα peaks of Silicon. Faint peaks associated with, iron, potassium, titanium can also be found.'

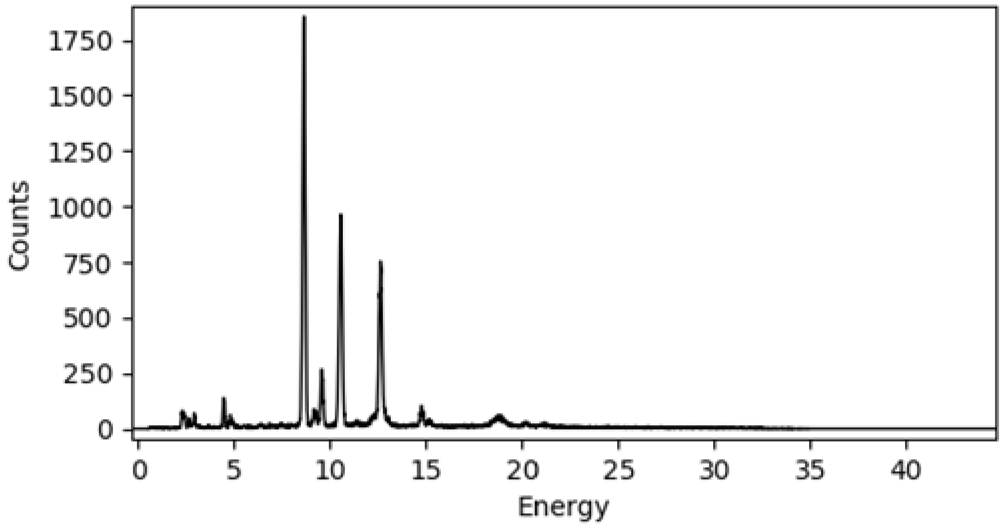
Whites

1W1 and 1W2



Point 1W1 and 1W2 was taken in the off-white paint found on the shirt on one of the people in the foreground, the points collected in this area showed clear peaks for Zinc. Several weak peaks indicative for chloride,chromium, iron, nickel and cobalt can be found.

1W3

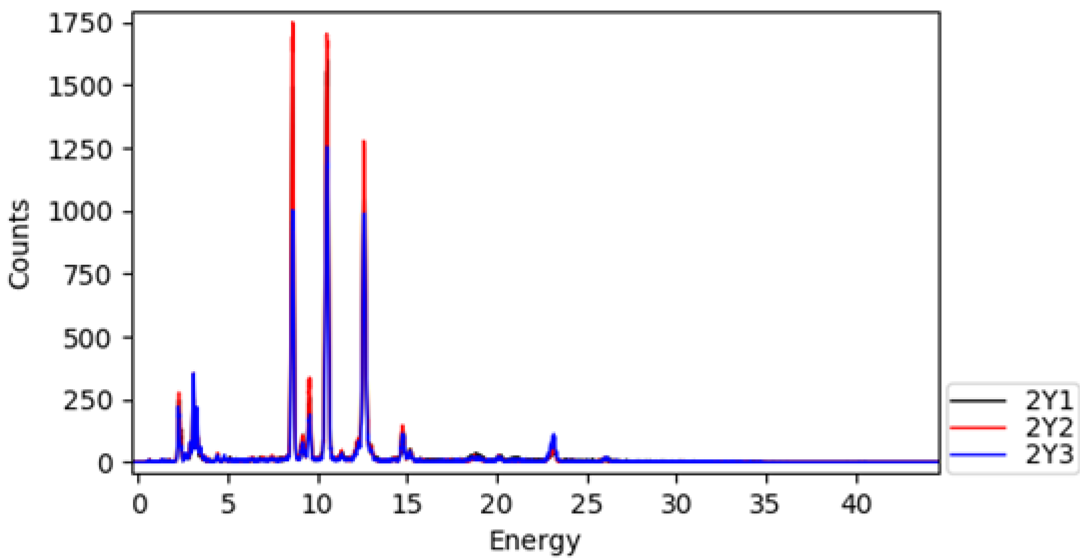


Point 1W3 was taken in an area with exposed ground at the edge of the painting, the data collected in this area showed clear peaks for Zinc and lead. Several weak peaks indicative for chloride, barium and sulphate can be found.

Hamnen I Vinterväder – Karin Parrow

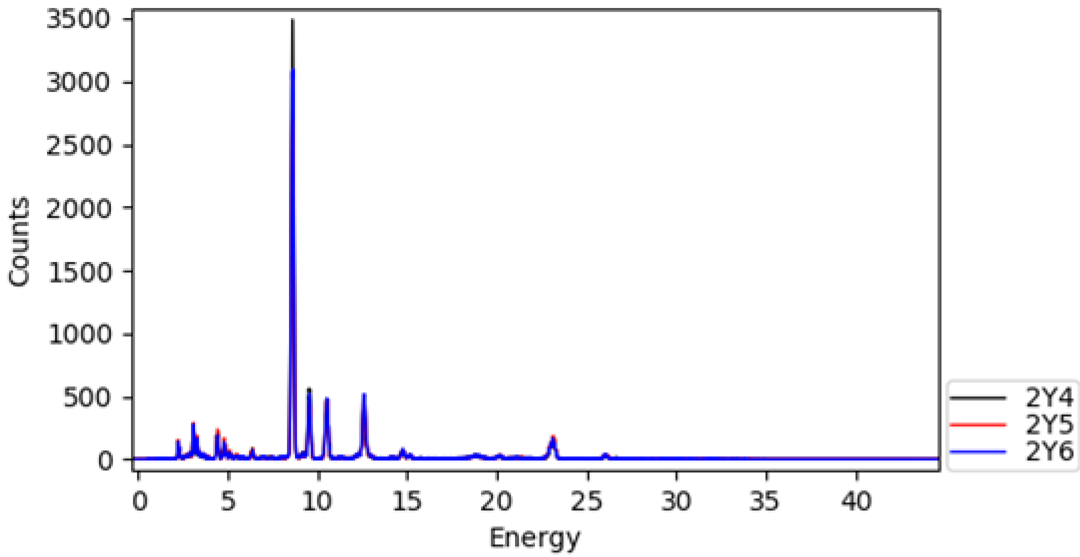
Yellows.

2Y1 to 2Y3



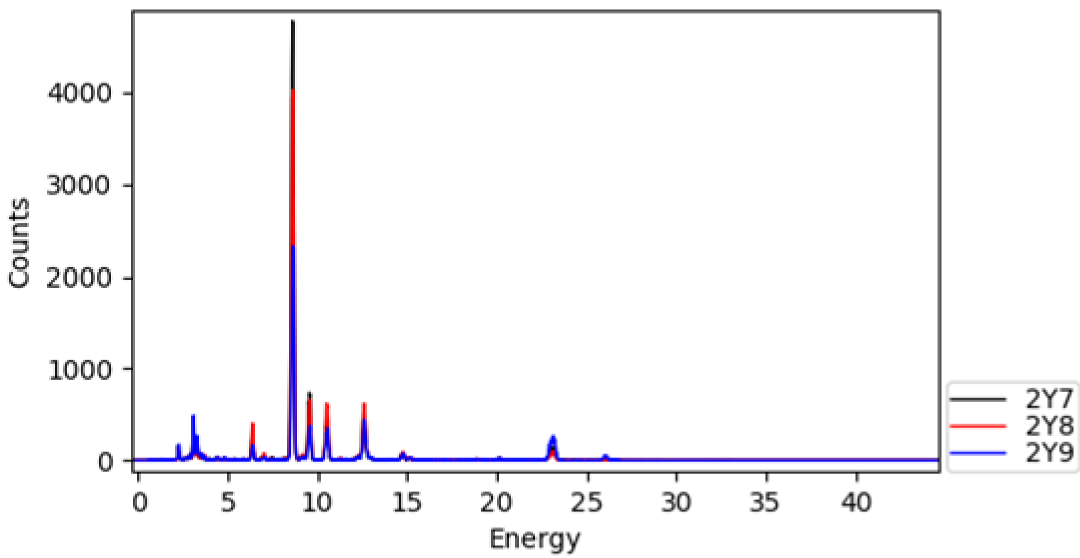
Point 2Y1 and 2Y3 was taken in the bright yellow area found in left bottom corner, the points collected in this area showed clear peaks for Zinc, Sulphur, Lead, Chlorine and Cadmium.

2Y4 to 2Y6



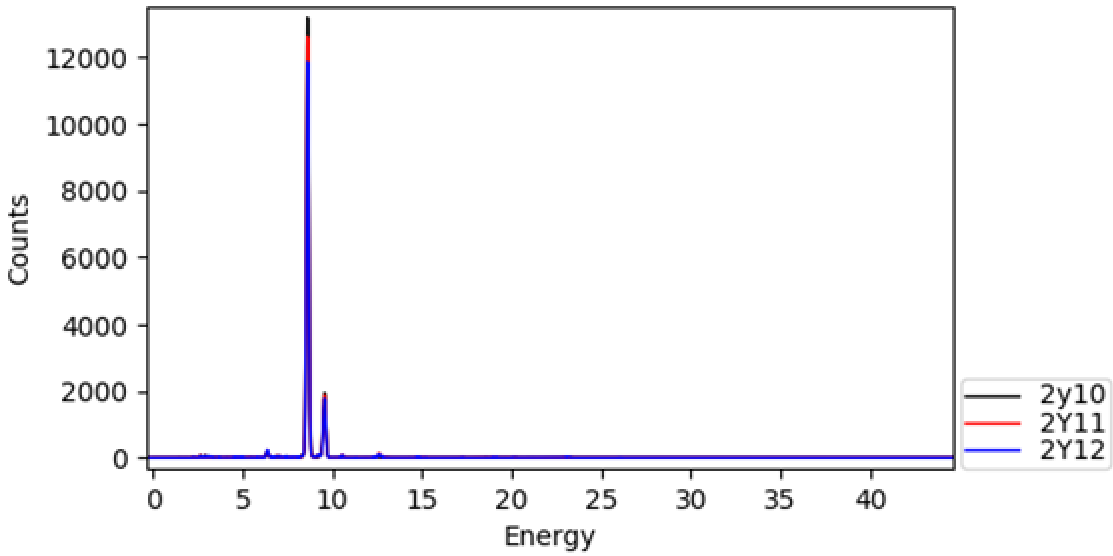
Point 2Y4 and 2Y6 was taken in the dull yellow area found in left bottom corner, the points collected in this area showed clear peaks for Zinc, Sulphur, Lead, Barium and Cadmium with weak peaks for Iron.

2Y7 to 2Y9



Point 2Y7 and 2Y9 was taken in the brightest of the yellow poles, the points collected in this area showed clear peaks for Zinc, Lead, Cadmium, and Iron with weak titanium peaks.

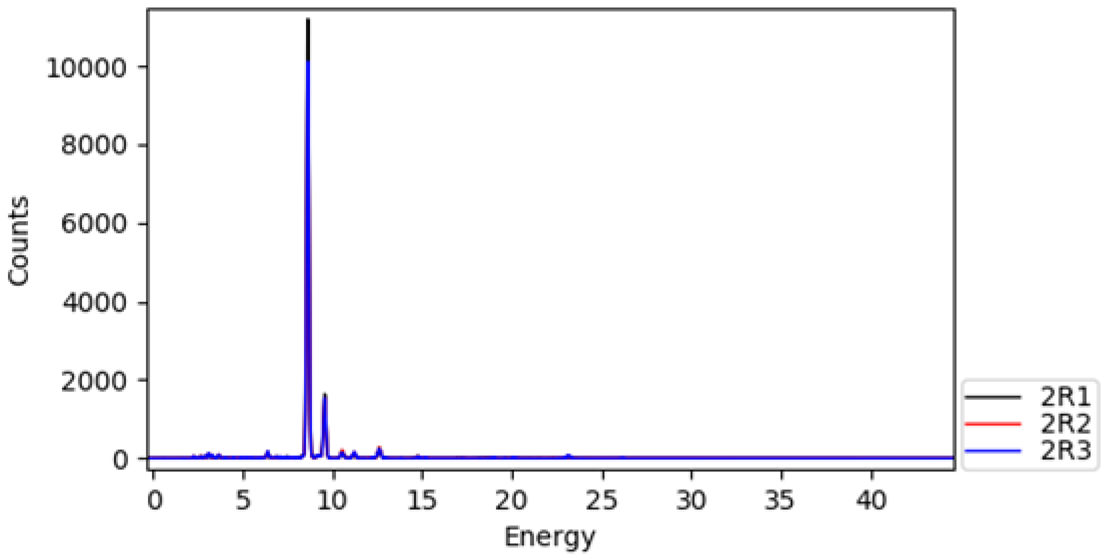
2Y10 to 2Y12



Point 2Y7 and 2Y9 was taken in the brightest of the yellow poles, the points collected in this area showed a clear peak for zinc and chloride. Weak peaks for sulphur, cadmium, Iron, calcium and nickel were also identified, peaks for arsenic was identified by the database but lead is a more likely as possible faint peaks can be seen at 9.2 keV and 14.7 keV corresponding to lead L_L and L_{y1} peaks.

Reds

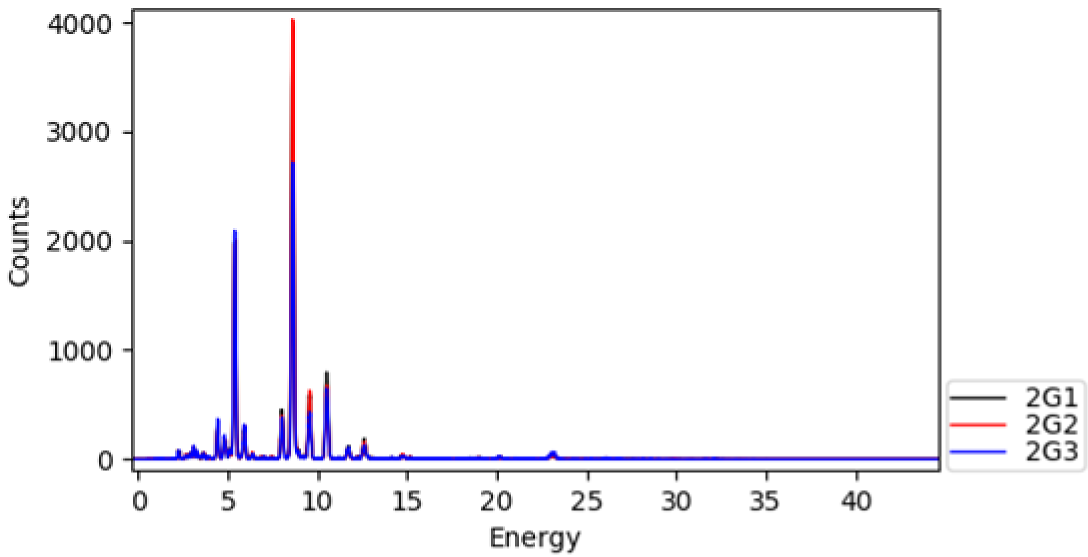
2R1-3



Point 2R1 and 2R3 was taken in on the red sails, the points collected in this area showed clear peaks for Zinc. Weak peaks for lead, cadmium, selenium, iron, nickel, and calcium.

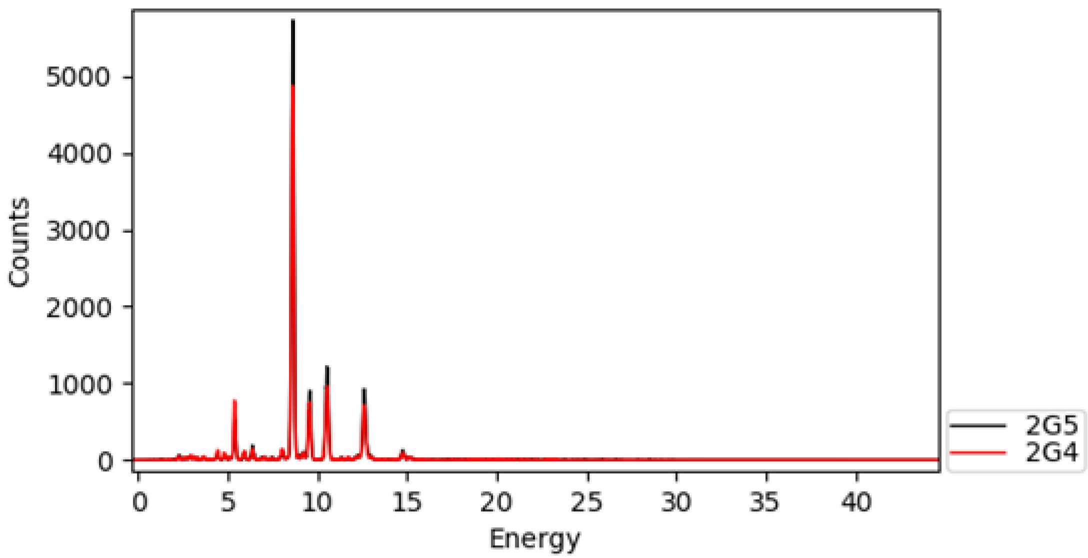
Greens

2G1-3



Point 2G1 to 2G3 was taken on the green sail, the points collected in this area showed clear peaks for zinc, chromium, sulphur, cadmium, chloride, copper and barium. Peaks indicating arsenic was identified along with weak lead peaks. Weak peaks for lead, cadmium, iron, nickel and calcium

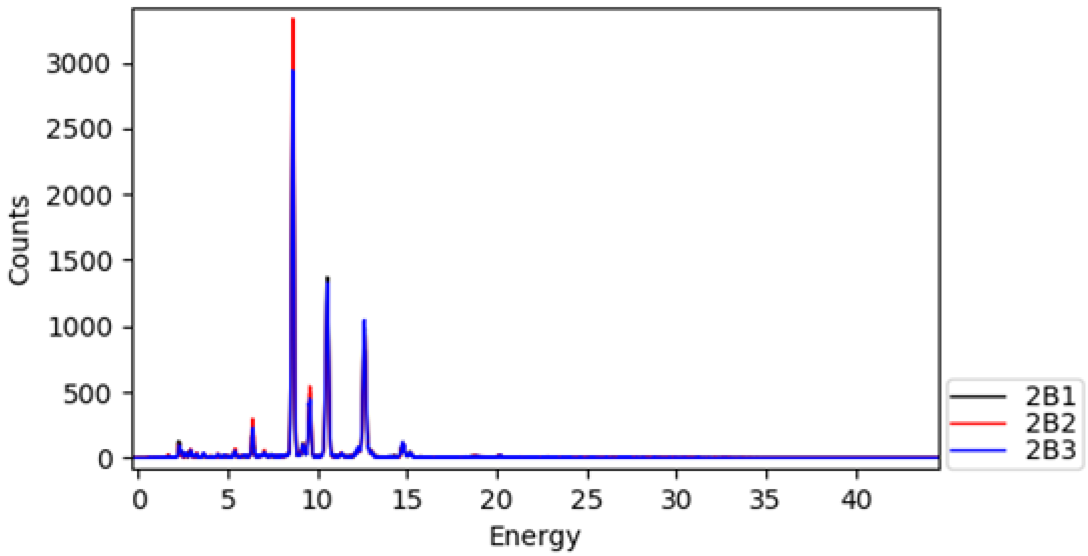
2G4-5



Point 2G4 and 2G5 was taken in the greenish colour found along the shoreline, the points collected in this area showed clear peaks for zinc, sulphur, lead and chromium. With weak peaks for calcium, barium, iron, copper and potassium. A faint peak around 11.7 keV can be seen which could correspond to arsenics $K_{\beta1}$ peak.

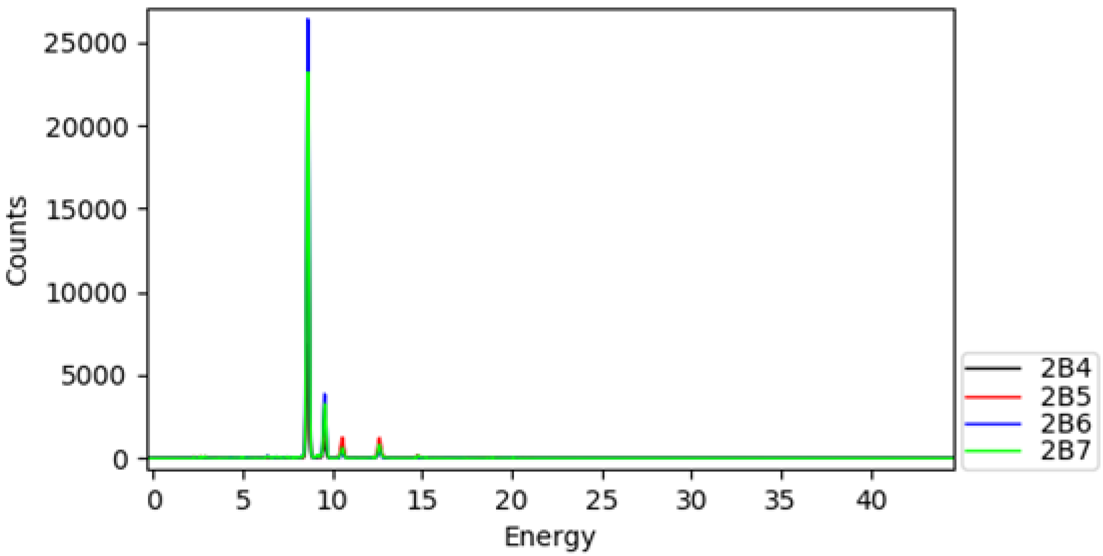
Blues

2B1 to 2B3



Point 2B1 to 2B3 was taken in the dark blue paint used for the sea, the points collected in this area showed clear peaks for zinc, lead, silicate, and chloride. Weak peaks for calcium, potassium, and iron where found along with possible traces of chromium and titanium peaks.

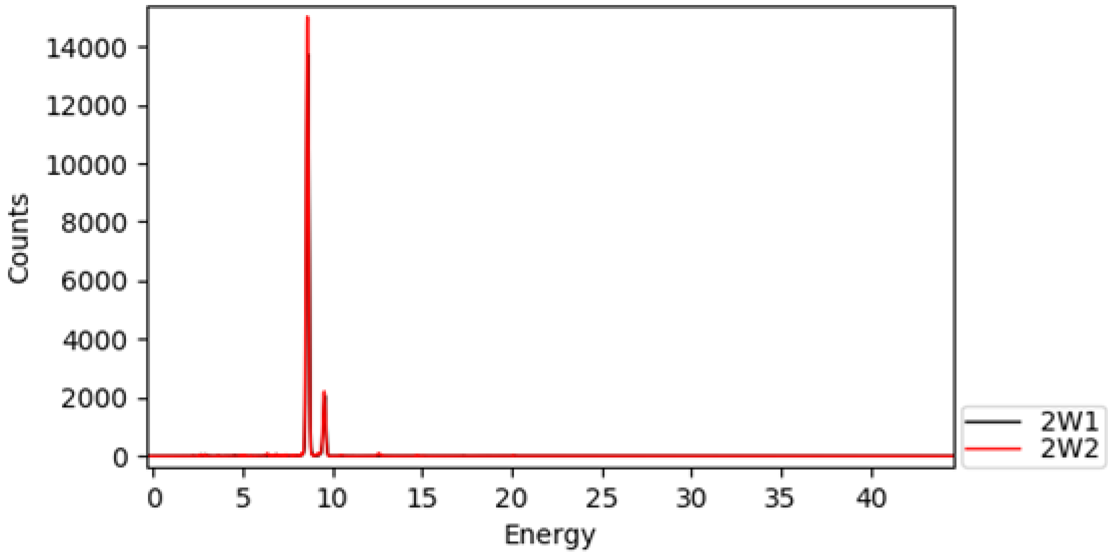
2B4 to 2B7



Point 2B1 to 2B3 was taken in the lighter blue paint used in the sky and the blue used in the snow, the points collected in this area showed clear peaks for zinc, lead, sulphur. Weak peaks for cobalt and Iron were found along with possible traces of peaks for titanium, nickel, and calcium.

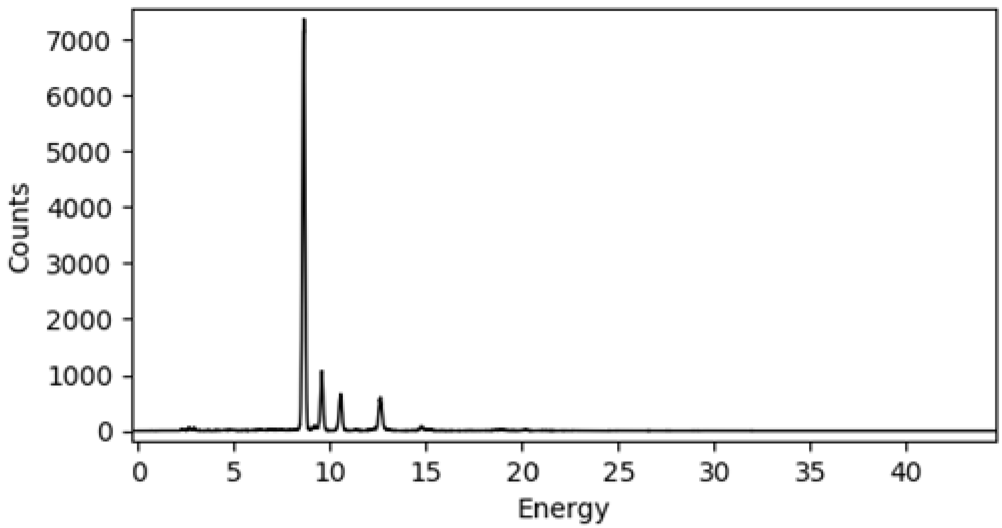
Whites

2W1 to 2W2



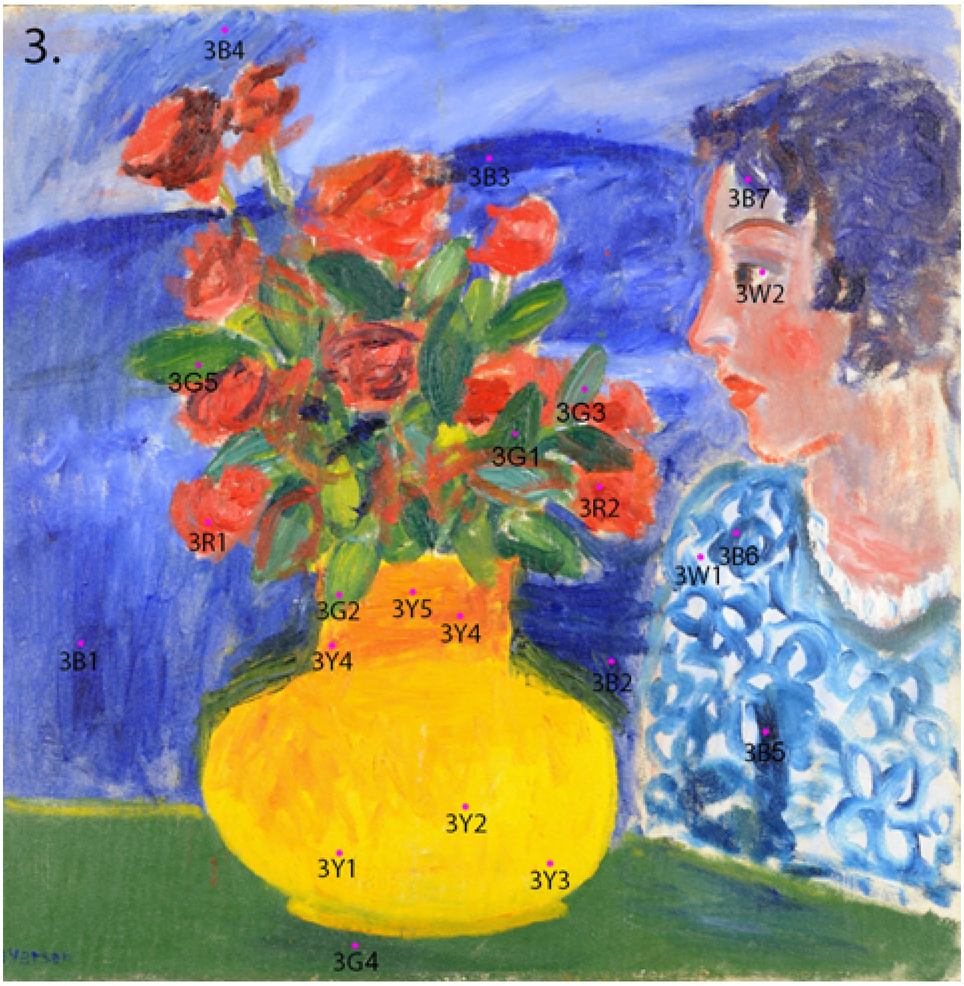
Point 2W1 and 2W3 was taken in the white paint used for snow, the points collected in this area showed clear peaks for zinc. Weak peaks for lead, chlorine and sulphur with possible traces of iron, nickel and cobalt peaks.

2W3



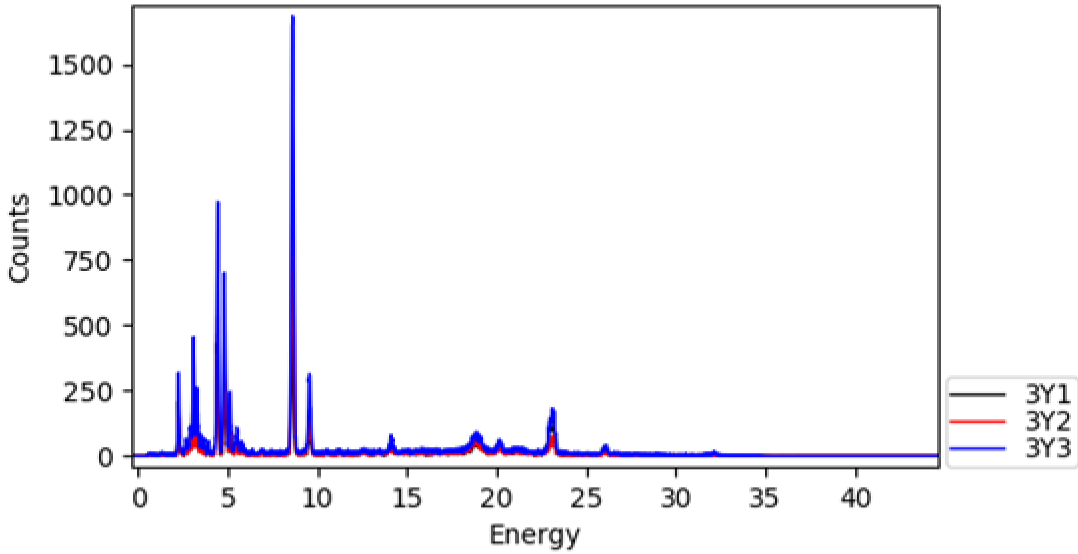
Point 2W3 was taken in on the exposed ground found along the bottom edge of the painting, the points collected in this area showed clear peaks for zinc, chlorine, sulphur and lead. and possible traces of nickel.

Ivan Ivarsson – Blommor och flicka


3.
3B4
3B3
3B7
3W2
3G5
3G3
3G1
3R2
3R1
3B6
3W1
3G2
3Y5
3Y4
3Y4
3B1
3B2
3B5
3Y2
3Y1
3Y3
3G4

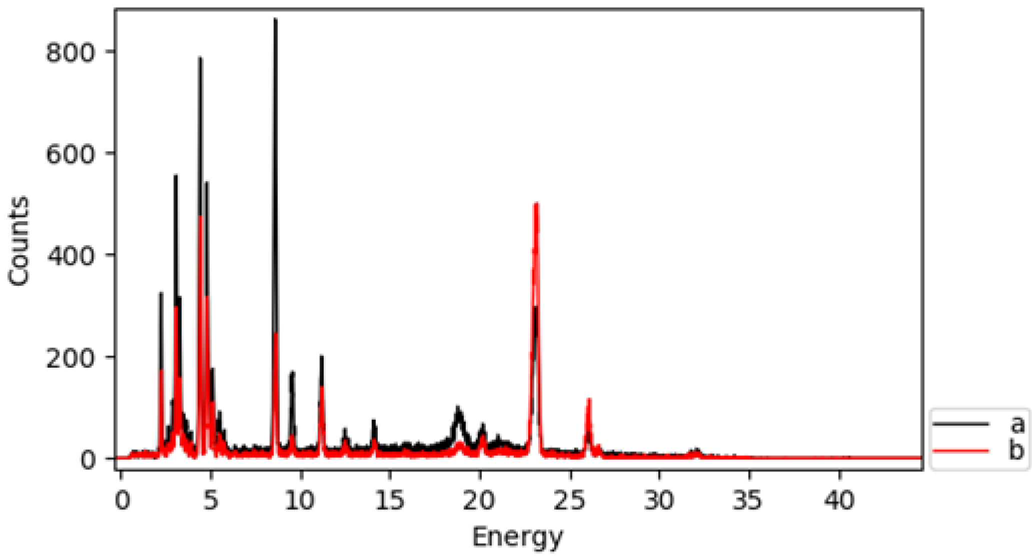
Yellows

3Y1-3



Point 3Y1 to 3Y3 was taken in the bright yellow area of the flowerpot, the points collected in this area showed clear peaks for Barium, Cadmium and Zinc, weak peaks for Selenium and potassium where identified. A weak peak is found 14.1 keV which is indicative of strontium $K_{\alpha 1}$ peak, the expected 15.8 $K_{\beta 1}$ peak is not clearly discernible. The peak attributed to the K_{α} of technetium is found at 18.9 keV and not the expected of 18.4 keV.

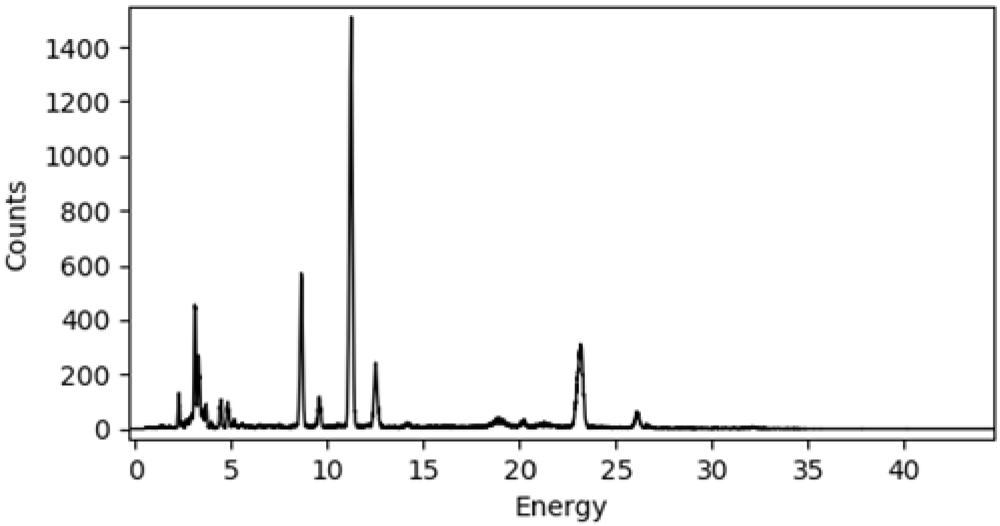
3Y4-5



Point 3Y4 and 3Y5 was taken in the orange yellow area of the flowerpot, the points collected in this area showed clear peaks for Barium, Cadmium, Selenium and Zinc, weak peaks for sulphur and strontium where identified.

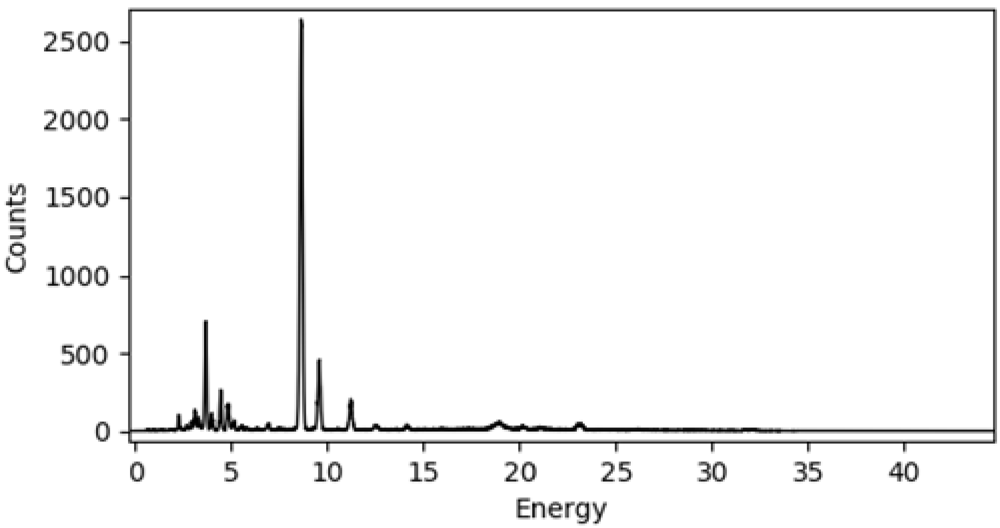
Reds

3R1



Point 3R1 was taken on the red flower in the flowerpot, the points collected in this area showed clear peaks for Barium, Sulphate, Cadmium, Selenium and Zinc.

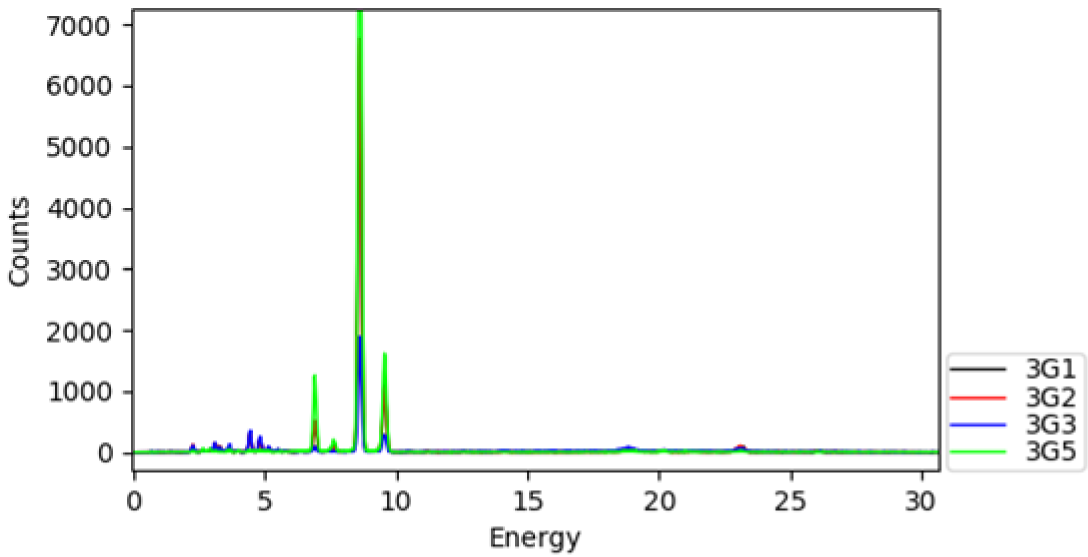
3R2



Point 3R2 was taken on the red flower in the flowerpot in a similar red area as 3R1 but gave a quite different spectra with significantly weaker intensity cadmium and selenium peaks. The points collected in this area showed clear peaks for calcium, sulphate, Cadmium, potassium. Selenium and Zinc with weaker peaks for strontium and cobalt.

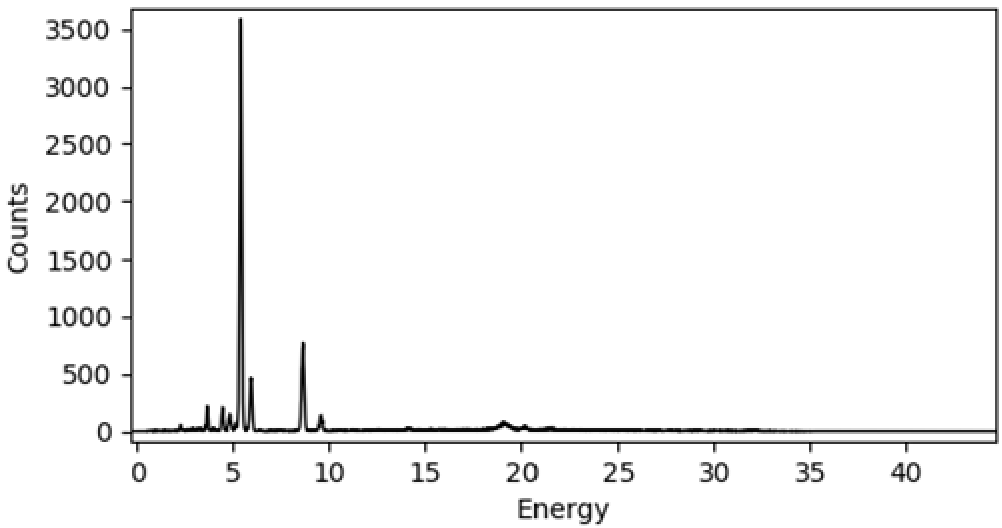
Greens

3G1-3 and 5.



3G1-3 and 5 was taken on the green leaves found on the flower in the flowerpot. The points collected in this area showed clear peaks for zinc, cobalt, cadmium, barium, calcium, Zinc, strontium, sulphur, Chromium and potassium. Weaker faint peaks for chlorine and tin can also be seen.

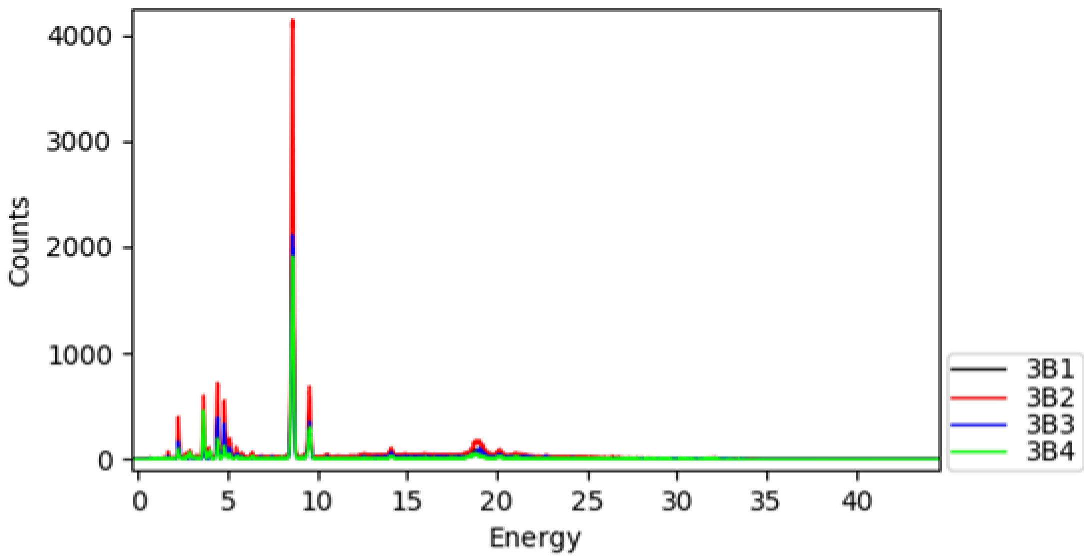
3G4



3G4 was taken on the green table, the points collected in this area showed clear peaks for calcium, sulphate, barium, cobalt, Chromium and potassium.

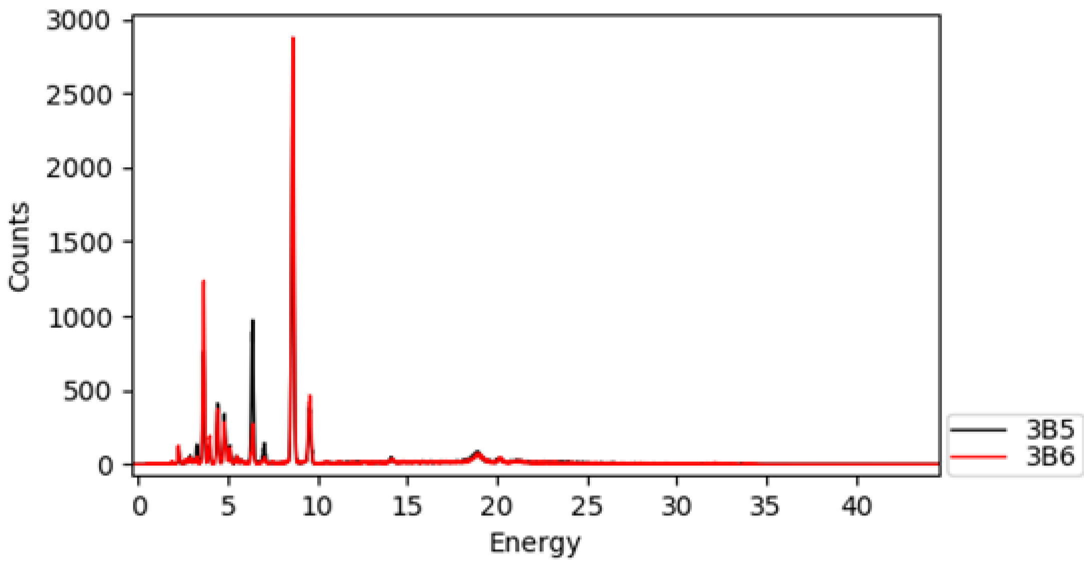
Blues

3B1-4



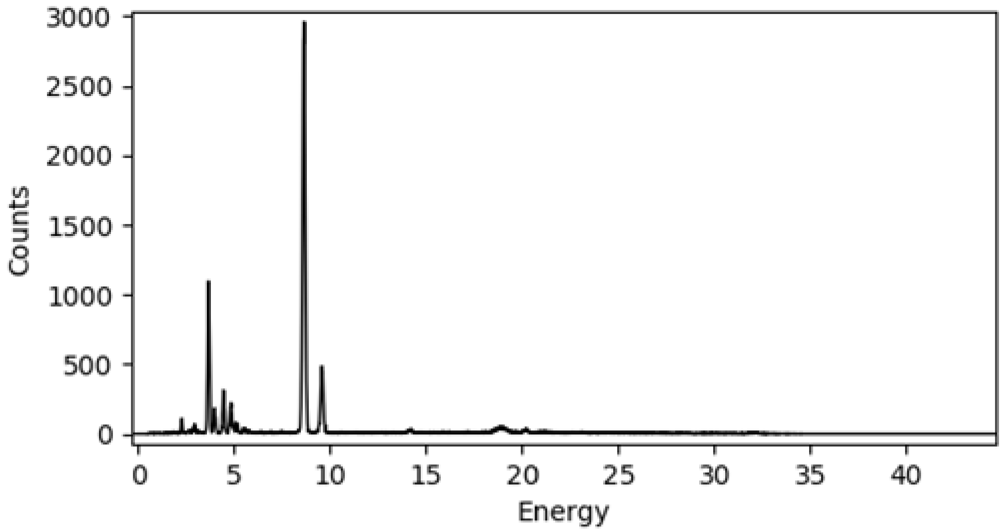
3B1 to 3B4 was taken in the darker parts of the blue background. The points collected in this area showed clear peaks for sulphur, zinc, calcium, barium, potassium, and strontium with weak peaks for iron and lead. A peak can be seen at around 1.7 keV which is attributable to silicon's Kα peak.

3B5-6



3B4 to 3B6 was taken on the blue dress. The points collected in this area showed clear peaks for zinc, calcium,sulphur, Iron, barium, potassium and strontium.

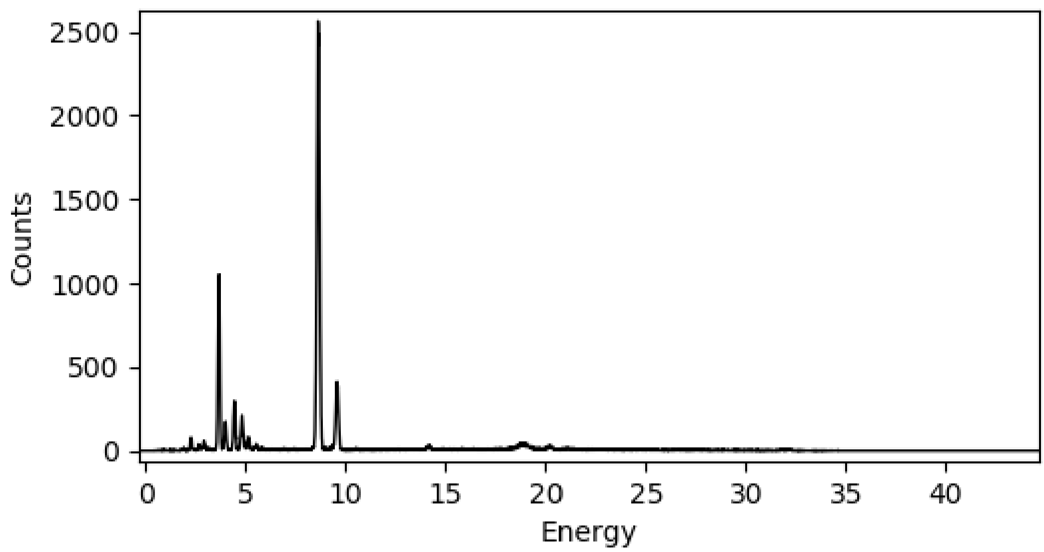
3B7



3B7 was taken on the blue/violet hair. The points collected in this area showed clear peaks for zinc, calcium, barium, strontium, sulphur, and silicate.

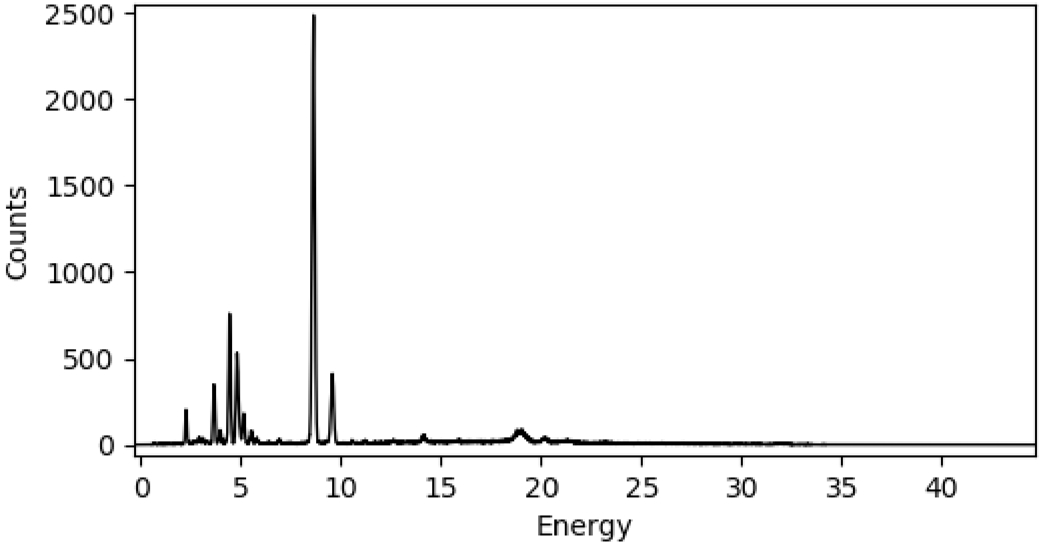
Whites

3W1



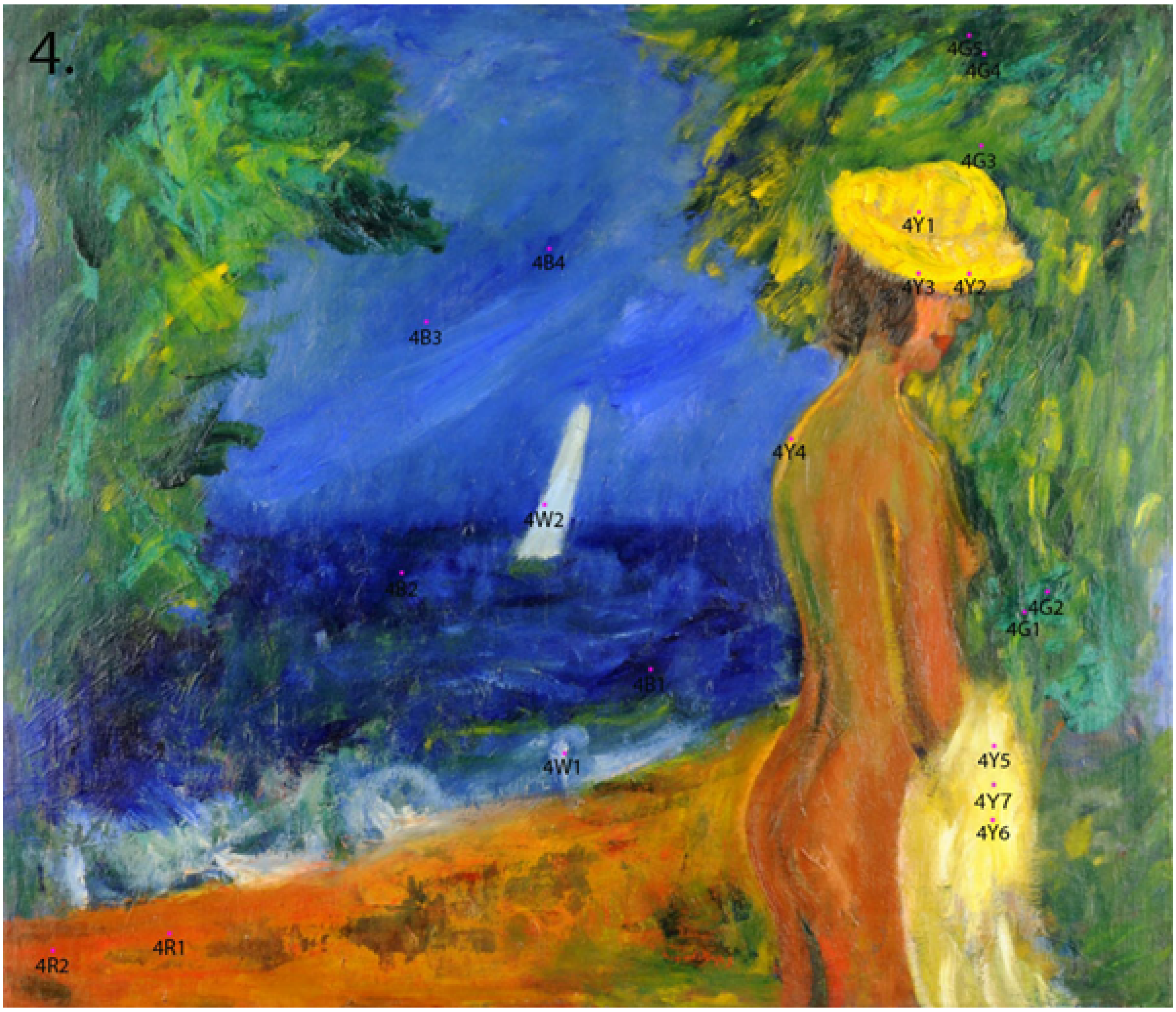
3W1 was taken in the white areas of the dress. The points collected in this area showed clear peaks for zinc, calcium, chloride, sulphur, and barium. Weaker faint peaks for strontium and cobalt can also be seen.

3W2



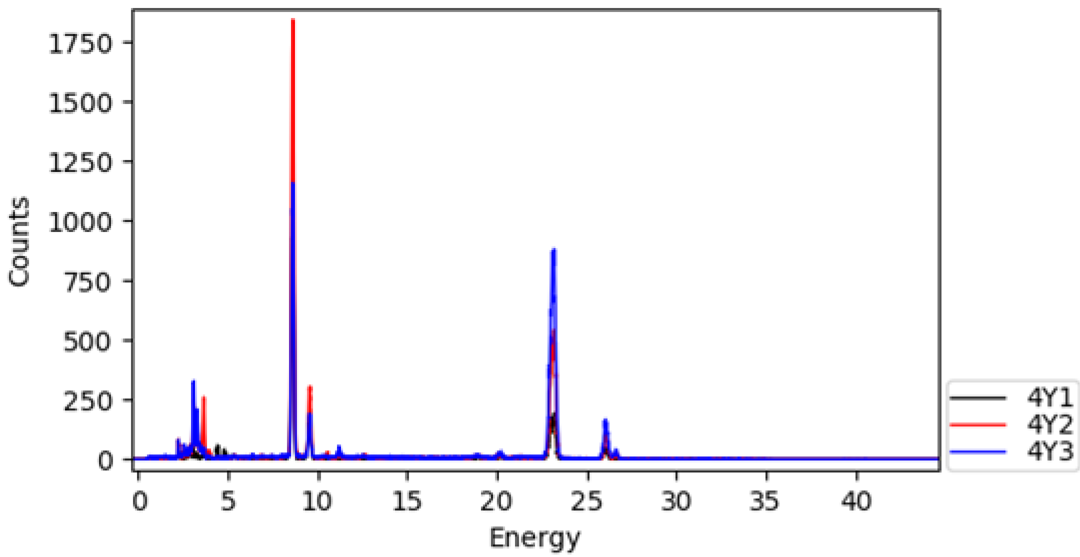
3W2 was taken in the eye which is the exposed ground. The points collected in this area showed clear peaks for zinc, calcium, chloride, sulphur, and barium. Weaker faint peaks for strontium and cobalt can also be seen.

Ivan Ivarsson – Badande flicka


4.
4G5
4G4
4G3
4Y1
4B4
4Y3
4Y2
4B3
4Y4
4W2
4B2
4G2
4G1
4B1
4Y5
4W1
4Y7
4Y6
4R1
4R2

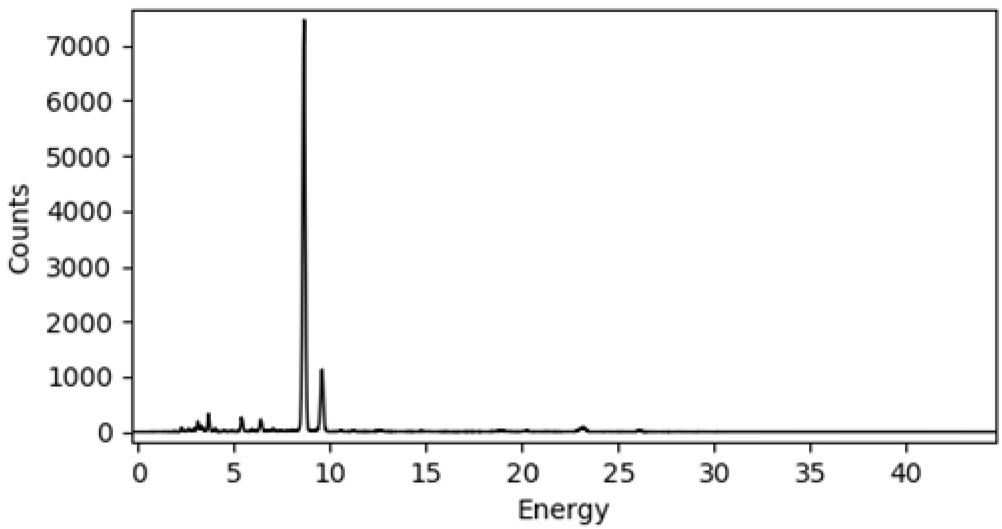
Yellows

4Y1-3



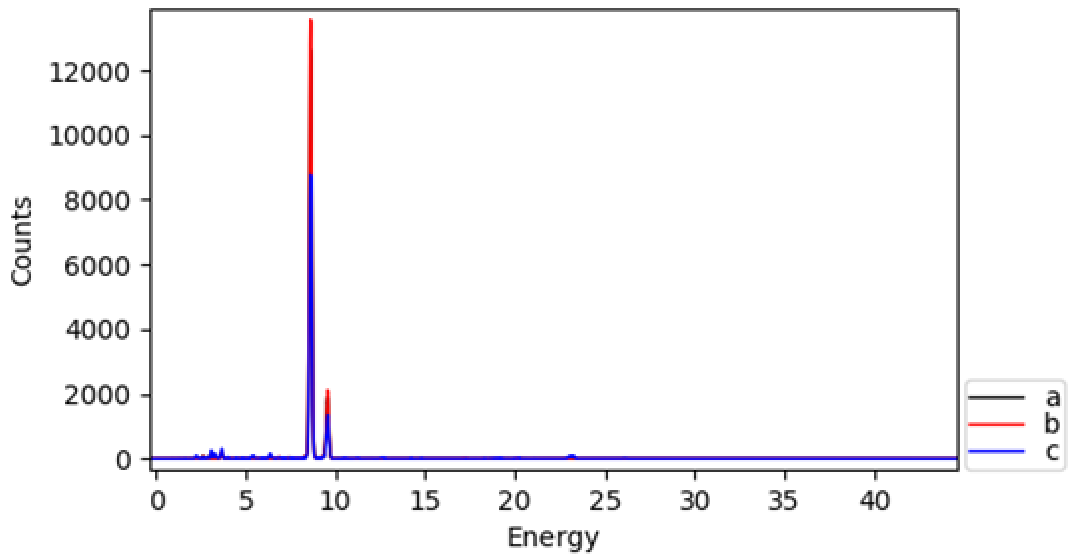
Point 4Y1 to 4Y3 was taken on the vibrant yellow hat, the points collected in this area showed clear peaks for cadmium, sulphur, chloride, barium, calcium, zinc, and selenium. Weak peaks attributable to lead can also be seen. A unattributed peak can be seen at 4.8 keV, which could correspond to the $K_{\beta1}$ peak of titanium which is expected around 4.9, the other possible candidate would be cerium which has its $L_{\alpha1}$ peak at 4.8 keV and its $L_{\beta1}$ at 5.2 keV is technically possible as a small elevation can be seen at 5.2 keV. However, Cerium is quite unlikely considering the material.

4Y4



Point 4Y4 to 4Y5 was taken on the back of figure along the yellow brushstroke, the points collected in this area showed clear peaks for cadmium, sulphur, chloride, barium, zinc, iron and chromium. Weak peaks attributable to selenium and lead a slight elevation can be seen which would be attributable to copper.

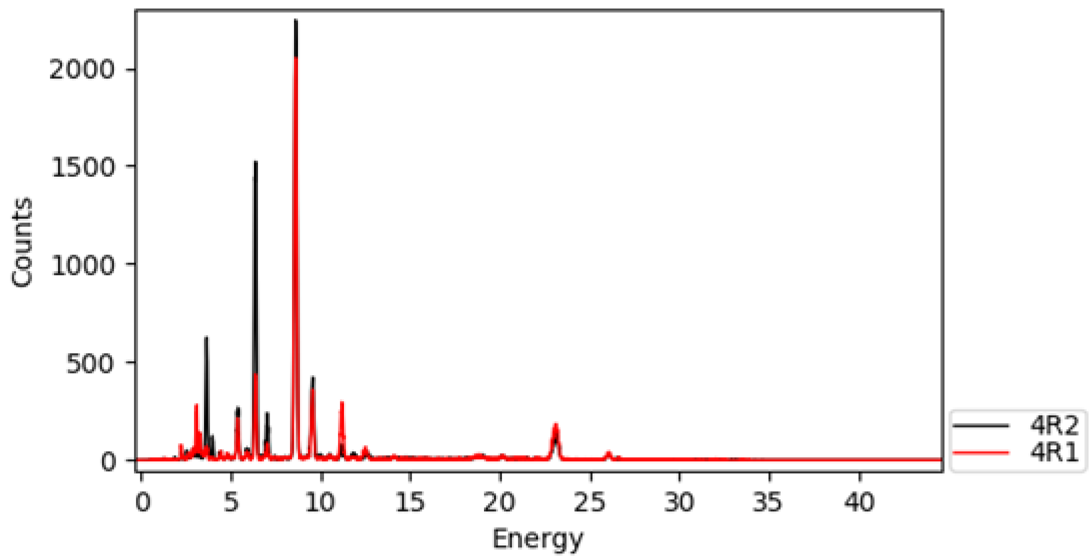
4Y5-7



Point 4Y6 to 4Y7 was taken on the bright yellow fabric held by the figure, the points collected in this area showed clear peaks for zinc, chlorine, sulphur, and calcium. slight elevations in the intensity can be seen which could be attributable to cadmium, cobalt, lead and nickel.

Reds

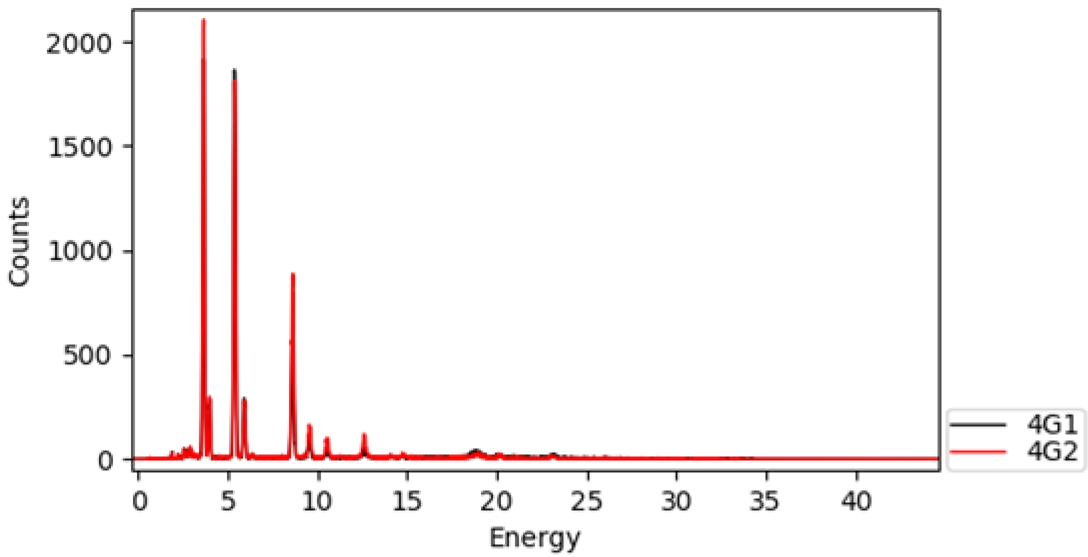
4R1-2



Point 4R1 to 4R2 was taken on the bright yellow fabric held by the figure, the points collected in this area showed clear peaks for cadmium, zinc, iron, chromium, calcium, sulphur, and selenium. Slight elevations in the intensity can be seen which could be attributable to titanium and arsenic.

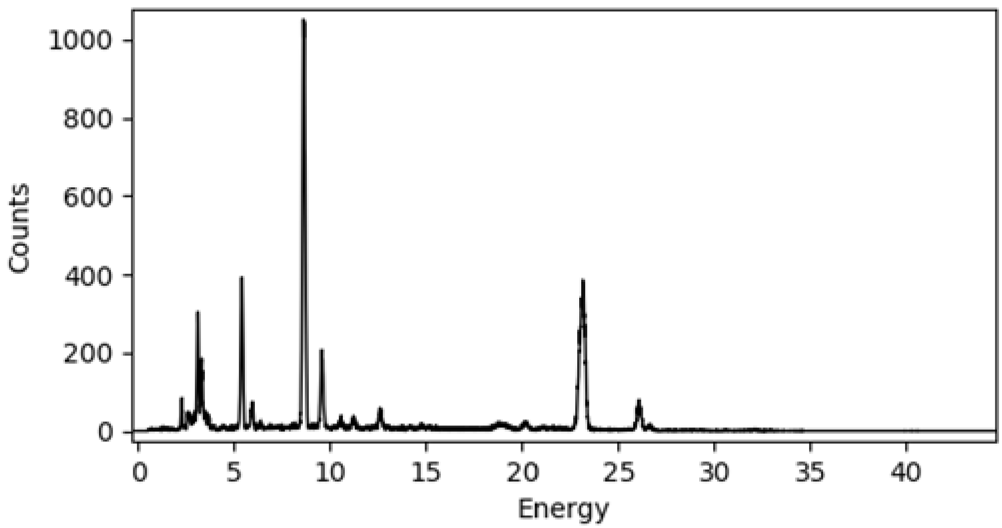
Greens

4G1-2



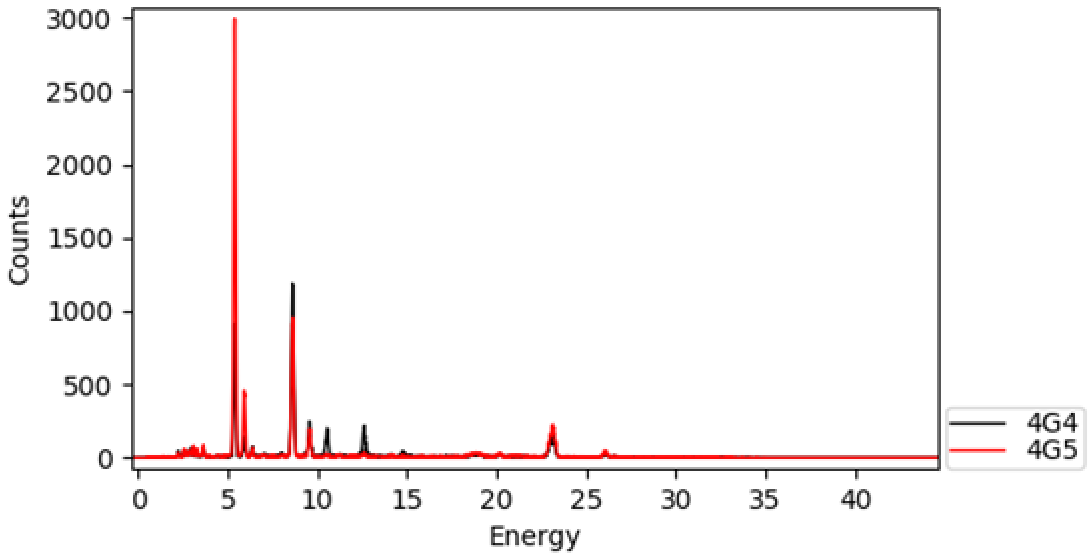
Point 4G1-2 was taken on the cool green colour found in the shrubbery, the points collected in this area showed clear peaks for calcium, chromium, sulphur, chloride, and zinc. Weak peaks for lead, strontium and cadmium can also be seen.

4G3



Point 4G3 was taken on the vibrant yellowish green colour found in the shrubbery, the points collected in this area showed clear peaks for cadmium, chloride, zinc, chromium, lead and selenium.

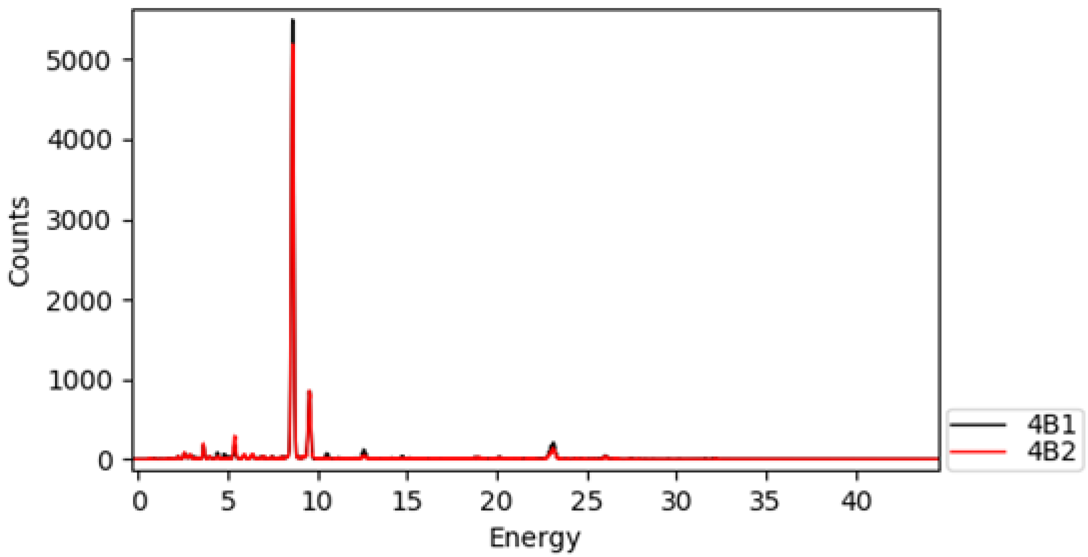
4G4-5



Point 4G4 to 4G5 was taken on the dark green colour found in the shrubbery, the points collected in this area showed clear peaks for chromium, cadmium, sulphur, chloride, zinc, lead, calcium and iron.

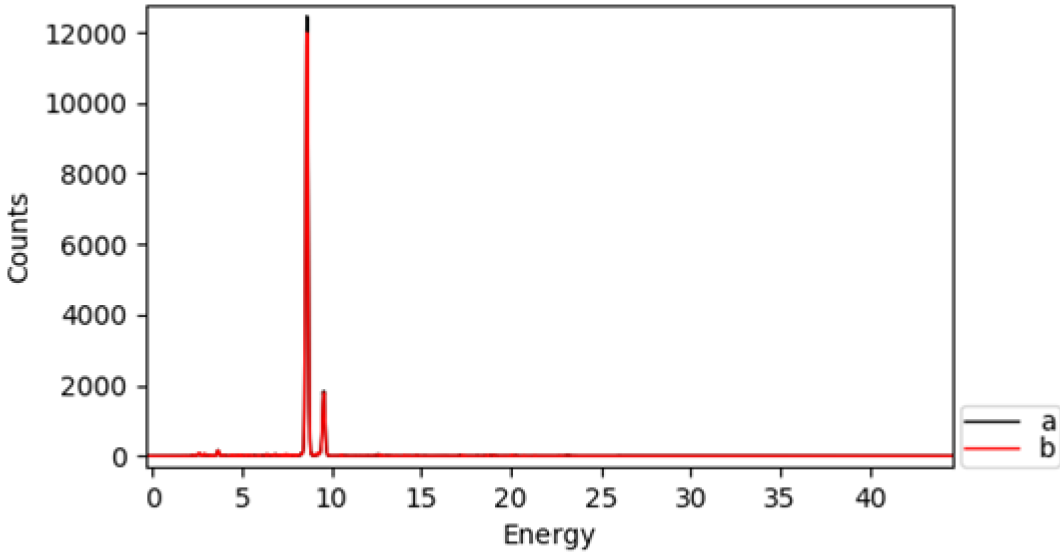
Blues

4B1-2



Point 4G1 to 4G5 was taken in the blue of the ocean, the points collected in this area showed clear peaks for zinc, chloride, sulphur, cadmium, calcium, barium, chromium, lead and iron.

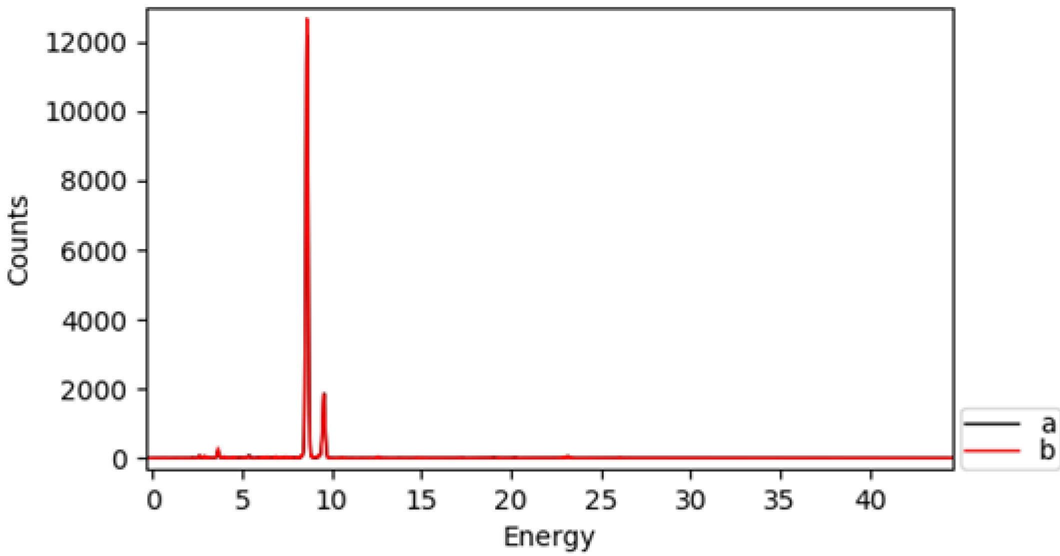
4B3-4



Point 4G3 and 4G4 was taken in the blue of the sky, the points collected in this area showed clear peaks for zinc, chloride, sulphur, calcium, zinc, and chloride. Slight elevations in the intensity can be observed corresponding to the peaks expected from titanium, iron, nickel and cobalt can be seen.

Whites

4W1-2

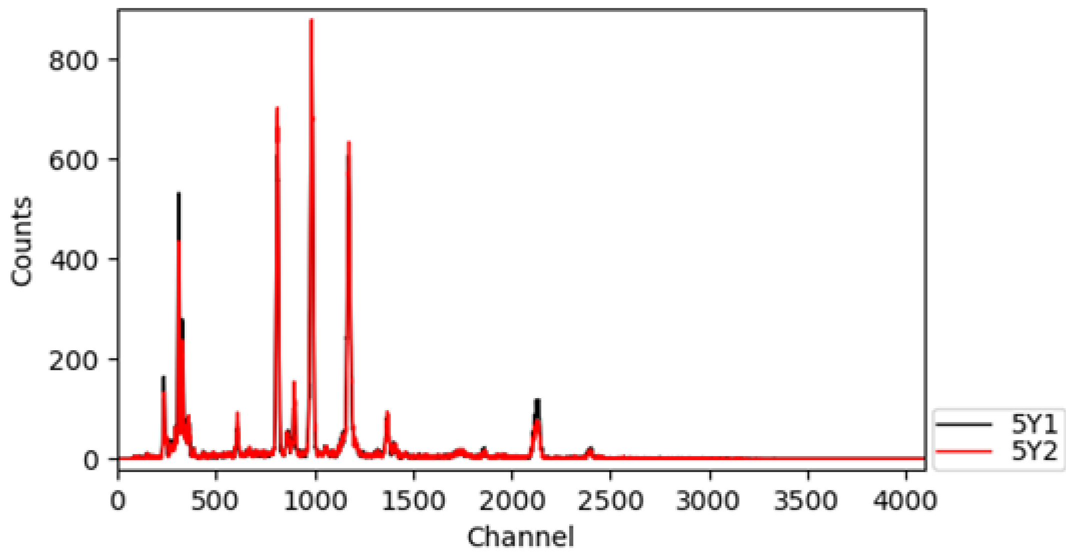


Point 4W1 and 4G5 was taken in the white paint found in the crest of the waves and the sail of the boat, the points collected in this area showed clear peaks for zinc, chloride, calcium, with weak peaks for sulphur.

Ivan Ivarsson – Hjärtum

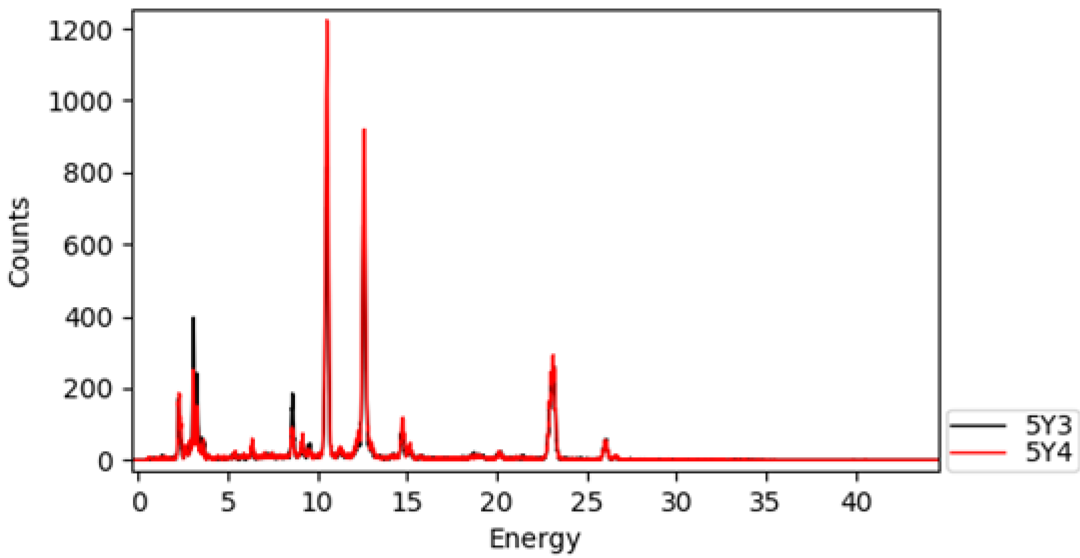
Yellows.

5Y1-2



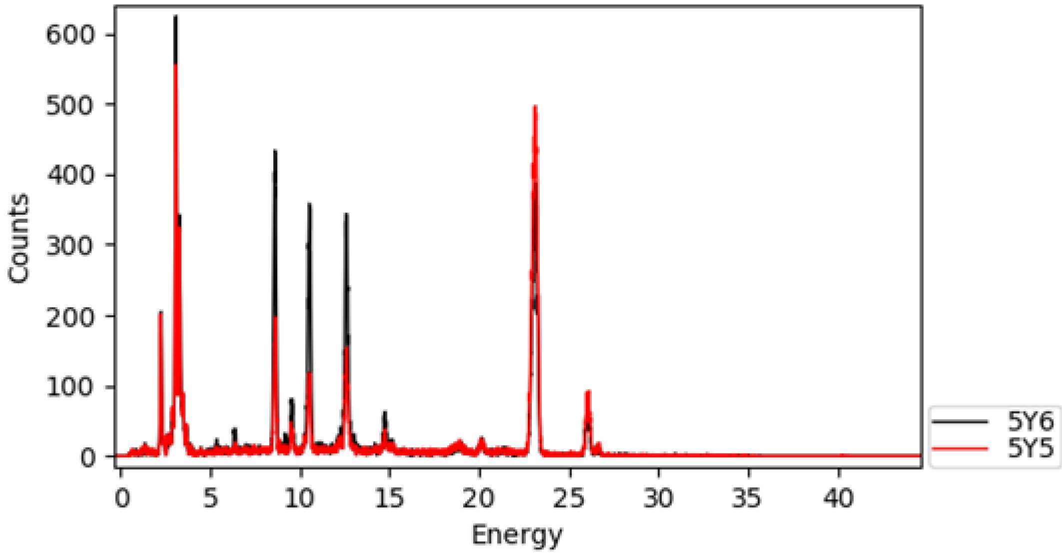
Point 5Y1 and 5Y2 was taken in the bright yellow areas of the field, the points collected in this area showed clear peaks for cadmium, sulphur, zinc, lead, calcium, and iron. Possible peak peaks for selenium and chlorine can be seen.

5Y3-4



Point 5Y3 and 3Y4 was taken in the orange haystacks in the field, the points collected in this area showed clear peaks for cadmium, sulphur, zinc, lead, chloride, and iron. Possible weak peaks for selenium can be seen.

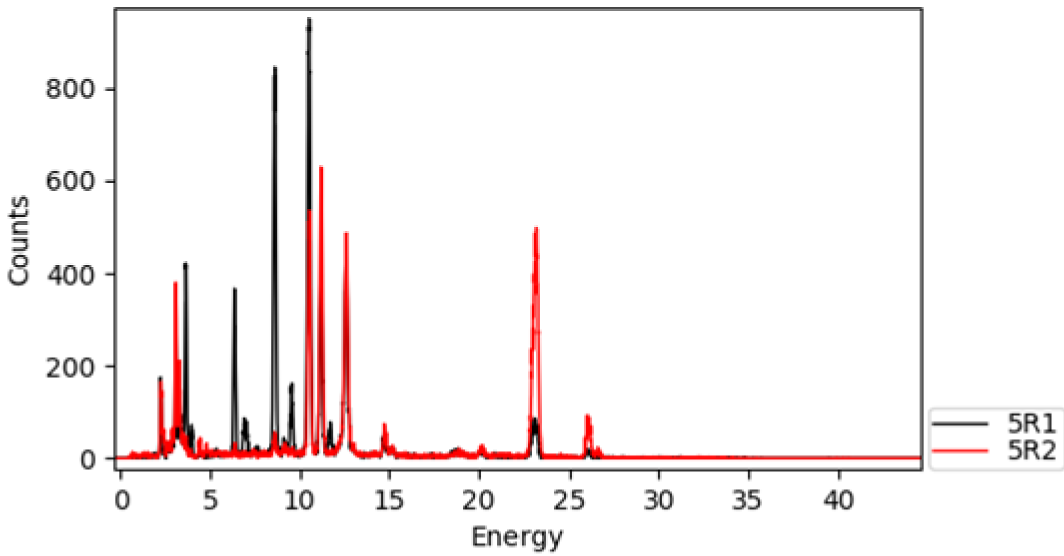
5Y5-6



Point 5Y3 and 3Y4 was taken in the vibrant yellow found in the green areas and along the road, the points collected in this area showed clear peaks for cadmium, zinc, lead, chloride, and iron. Weak peaks chromium and possible peaks for selenium can be seen.

Red

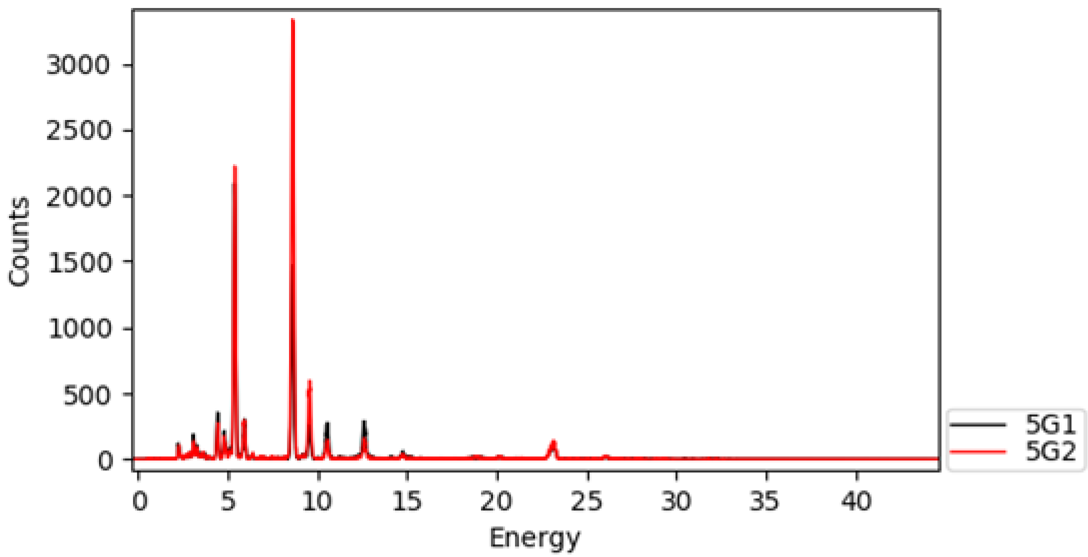
5R1-2



Point 5R1 and 5R2 was taken in the bright red areas in the foreground, the points collected in this area showed clear peaks for cadmium, sulphur, zinc, selenium, iron, calcium and titanium. Peaks corresponding to lead but also arsenic is likely present as its $K_{\beta 1}$ peak at 11.7 keV can be found. This arsenic peak is only present in 5R1 further test suggest that those peaks are only found localized in that brushstroke.

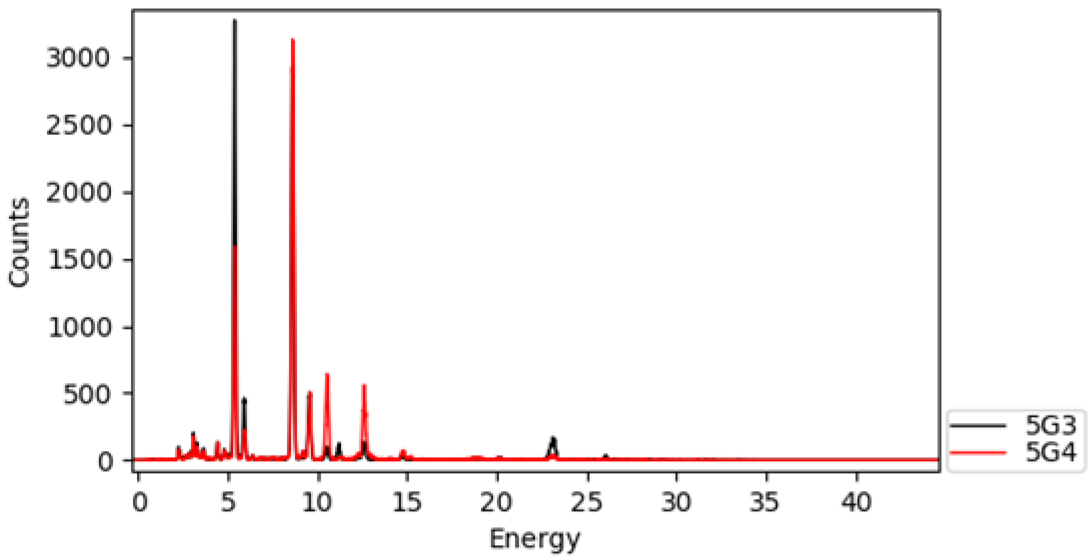
Greens

5G1-2



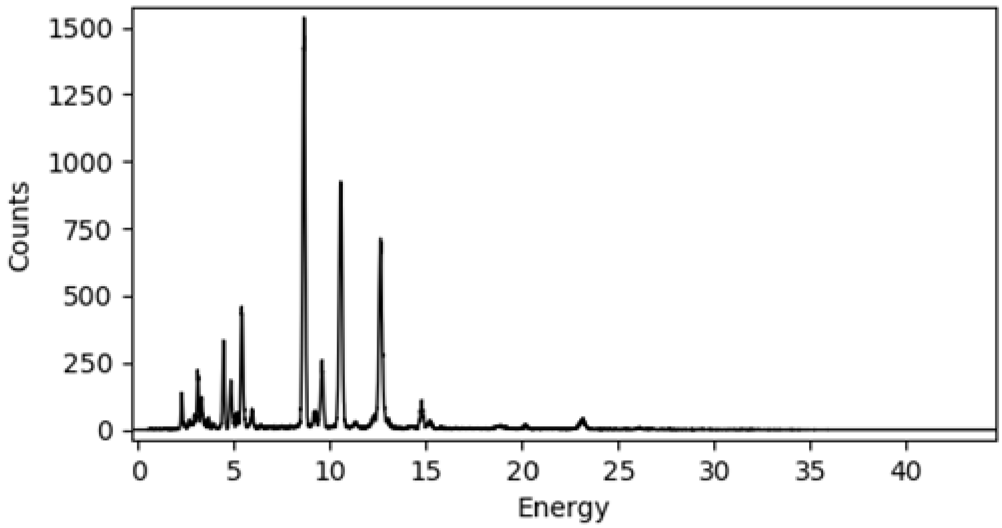
Point 5G1 and 5G2 was taken in the mid tone green used in the field, the points collected in this area showed clear peaks for chromium, sulphur, zinc, cadmium, lead, barium, and iron. A slight elevation suggesting chlorine can also be seen.

5G3-4



Point 5G3 and 5G4 was taken in the dark green used in the field, the points collected in this area showed clear peaks for chromium, sulphur, zinc, cadmium, lead, barium, selenium, and iron. A slight elevation suggesting chlorine and cadmium can also be seen.

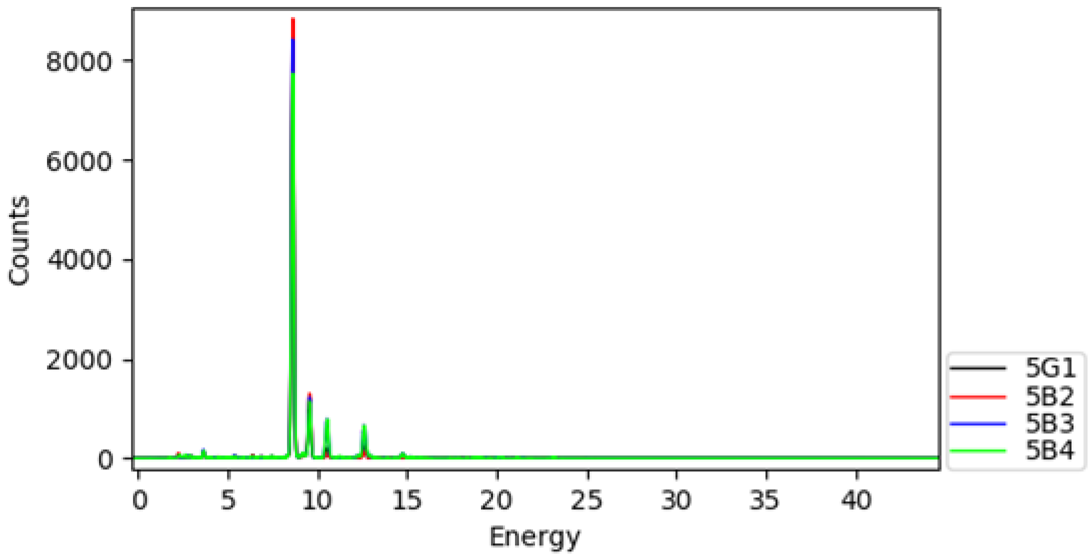
5G5



Point 5G5 was taken in the bright yellowish green used in the field, the points collected in this area showed clear peaks for chromium, sulphur, zinc, cadmium, lead, barium, and iron. A slight elevation suggesting chlorine and cadmium can also be seen.

Blues

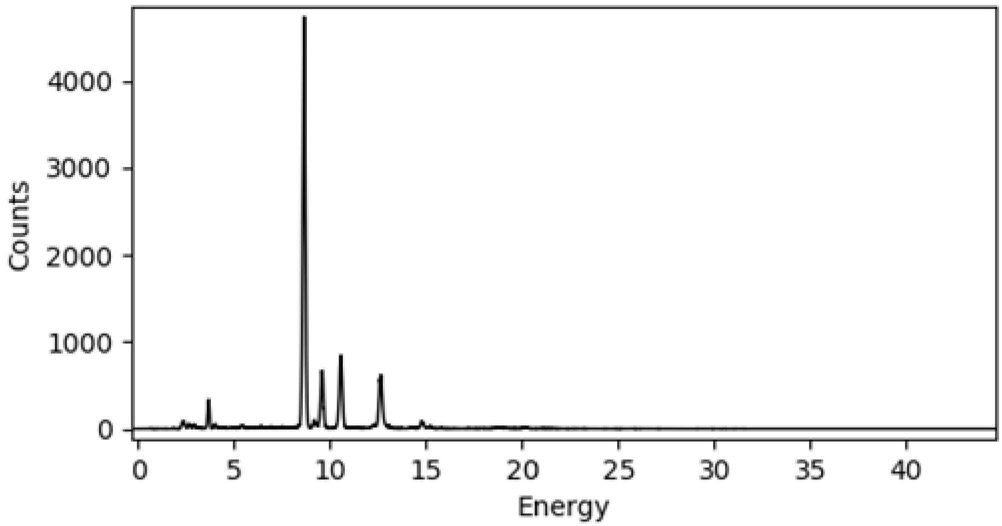
5B1-4



Point 5B1 to 5B4 was taken in the blue areas in the river and sky, the points collected in this area showed clear peaks for sulphur, zinc, calcium, chlorine, potassium, and lead. A slight elevation suggesting silica, chromium, iron, and cobalt be seen.

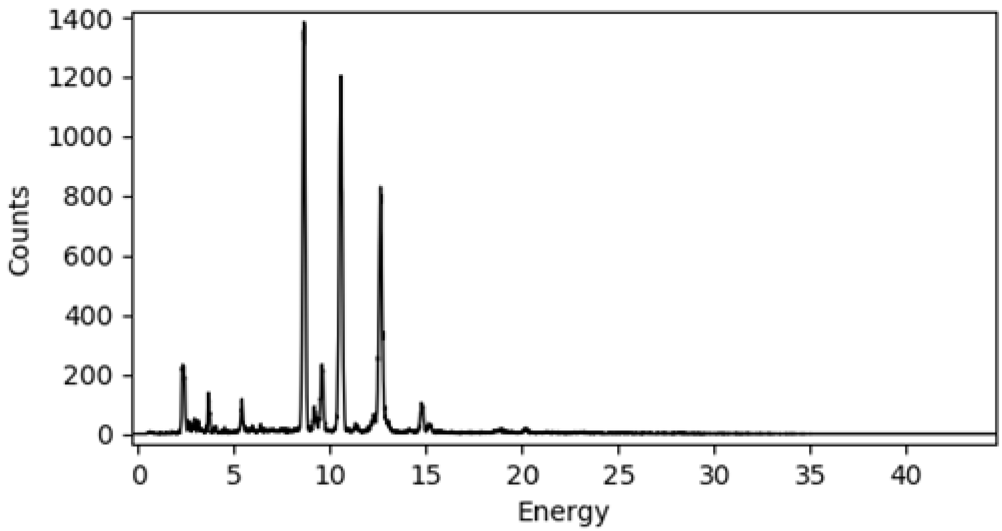
Whites

5W1



Point 5W1 was taken in the white used for the house, the points collected in this area showed clear peaks for sulphur, zinc, chlorine, calcium, chromium, iron, and lead.

5W2

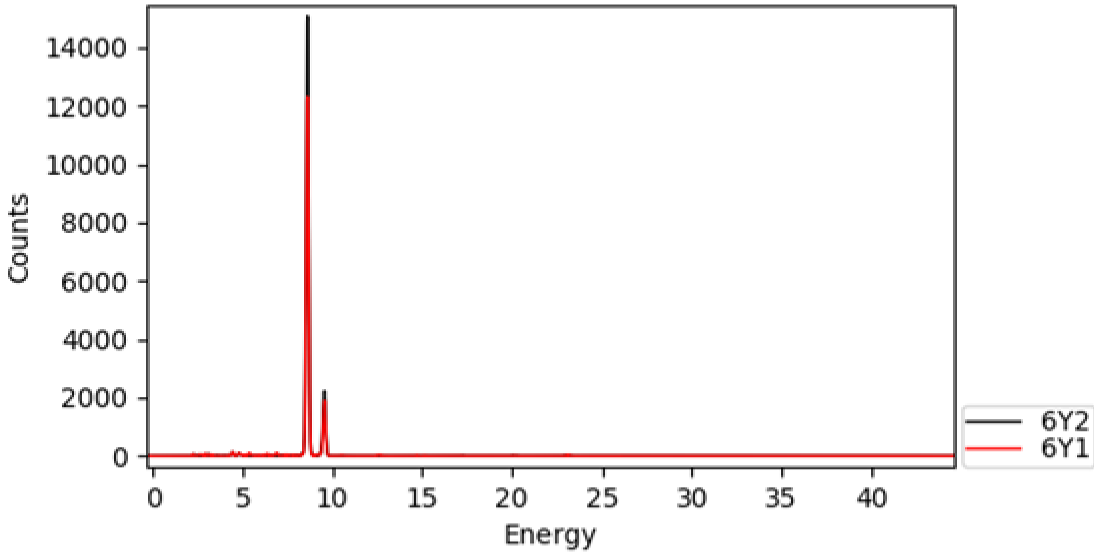


Point 5W2 was taken in the white on an area of exposed ground, the points collected in this area showed clear peaks for sulphur, zinc, chlorine, calcium, chromium, and lead.

Ragnar Sandberg -Badande

Yellows.

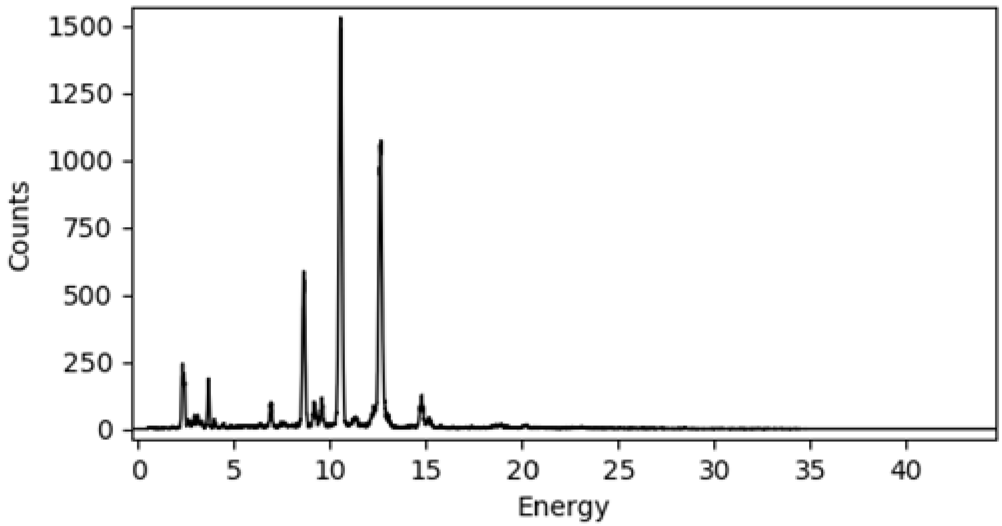
6Y1-2



Point 6Y1 and 6Y2 was taken in the face of the leftmost figure in saturated areas of bright yellow, the points collected in this area showed clear peaks for zinc, weak peaks for chlorine, cadmium, barium, sulphur, chromium, iron and cobalt be seen and a slight elevation suggesting lead.

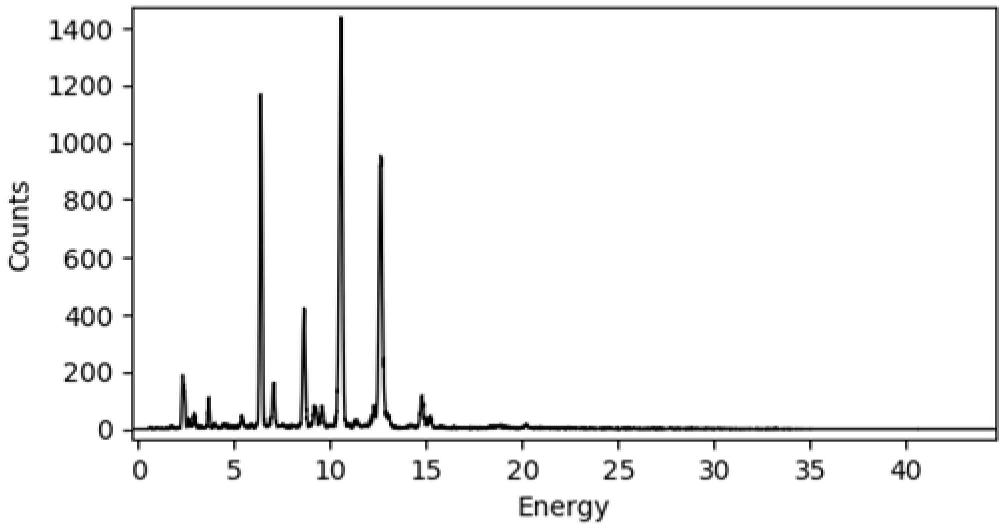
Reds

6R1



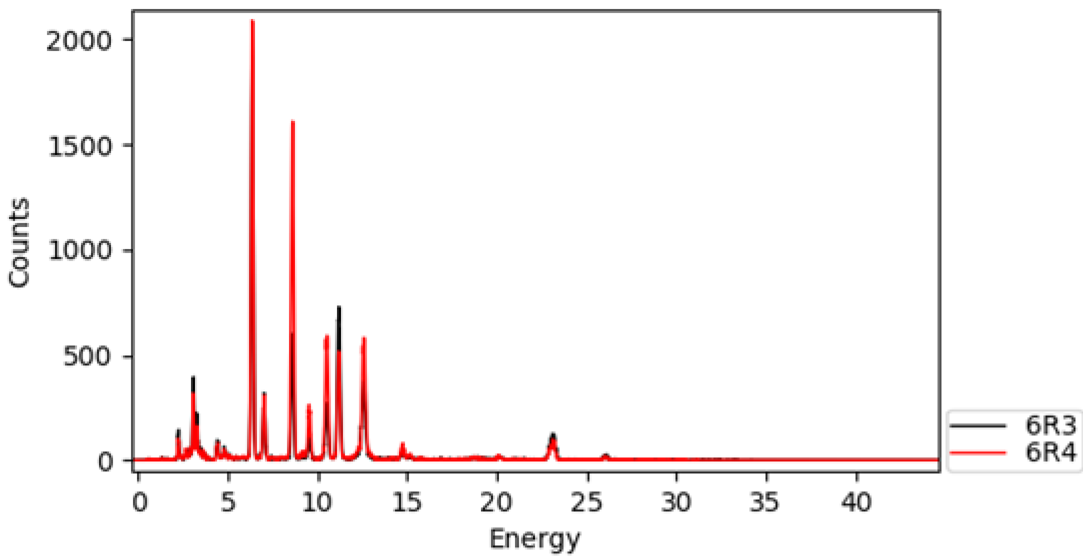
Point 6R1 was on the reddish-purple skin, the points collected in this area showed clear peaks for zinc, lead, cobalt, chloride, sulphur, calcium, with weak peaks for cadmium.

6R2



6R2 was taken on the red outline of the figures, the points collected in this area showed clear peaks for zinc, lead, sulphur, chloride, Iron, chromium weak peaks for calcium.

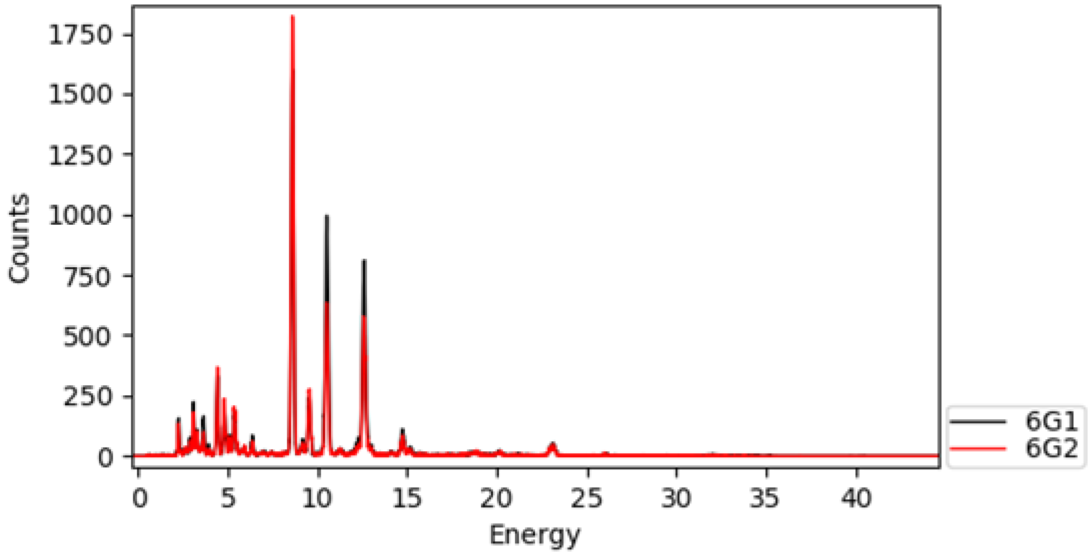
6R3-4



6R3 to 6R4 was taken on the red skin of the figures, the points collected in this area showed clear peaks for zinc, lead, barium, cadmium, sulphur, chloride, selenium, and Iron, weak peaks for calcium.

Greens

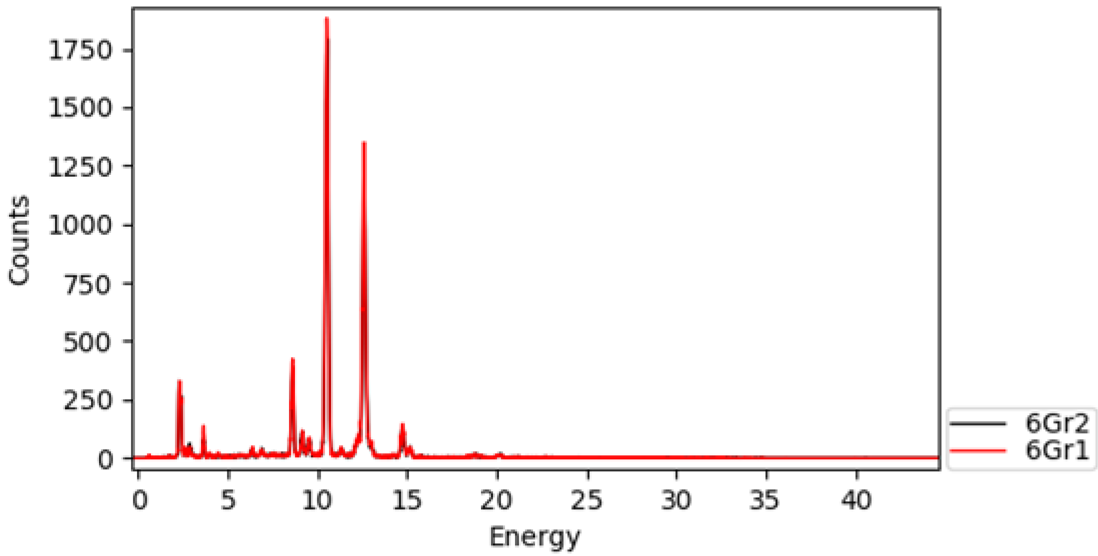
6G1-2



6G1 and 6G2 was taken on the greenish skin of the figures with high green saturation, the points collected in this area showed clear peaks for zinc, lead, calcium, cadmium, sulphur, and chromium, weak peaks for barium, iron and chloride.

Gray

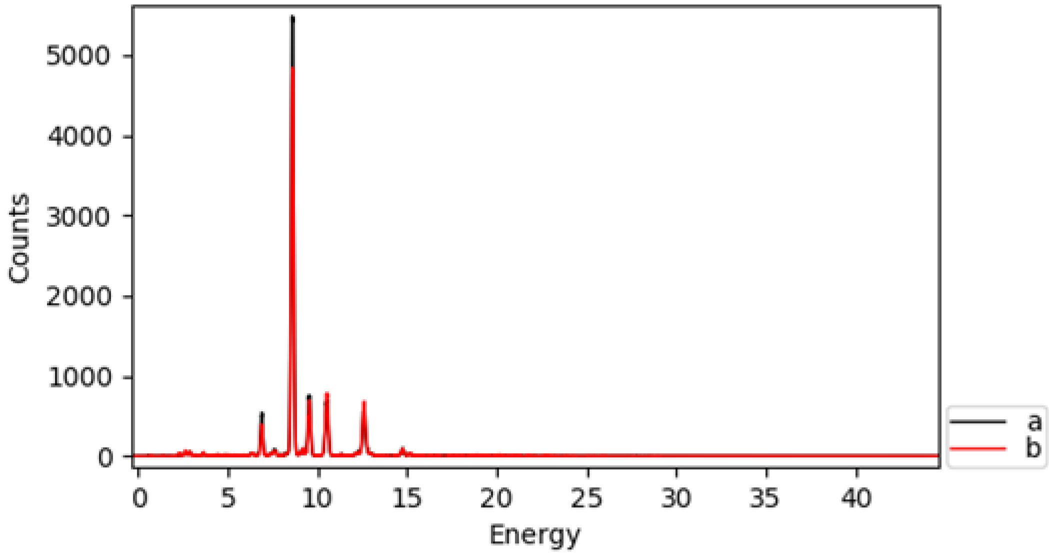
6Gr1-2



6G1 and 6G2 was taken on the grey background, the points collected in this area showed clear peaks for zinc, lead, calcium, and sulphur, weak peaks for iron, phosphorus and cobalt.

Blue

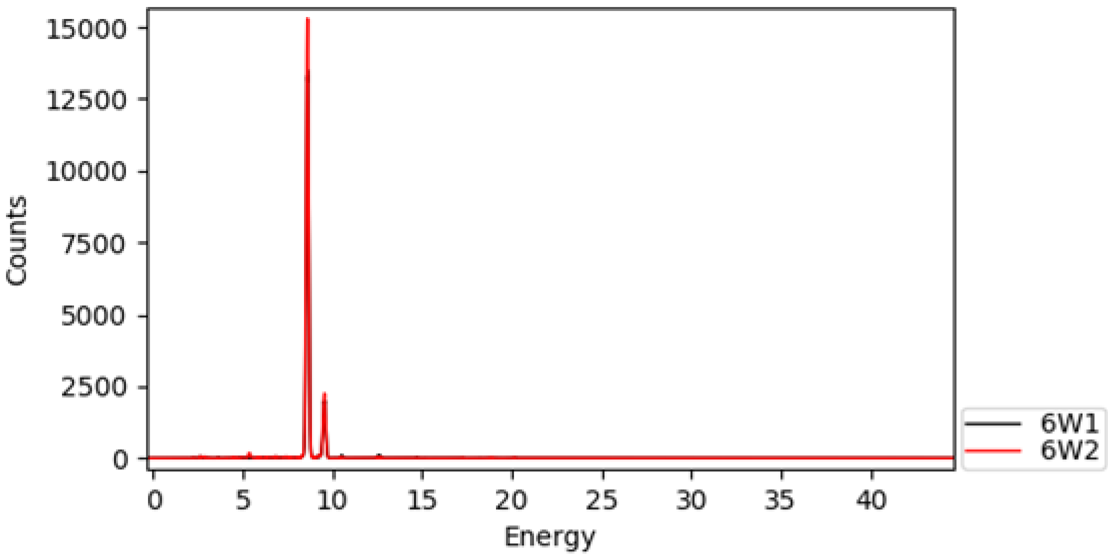
6B1-2



6B1 to 6B2 was taken on the small areas of blue found around the white areas, the points collected in this area showed clear peaks for zinc, lead, and cobalt, weak peaks for iron, calcium and sulphur.

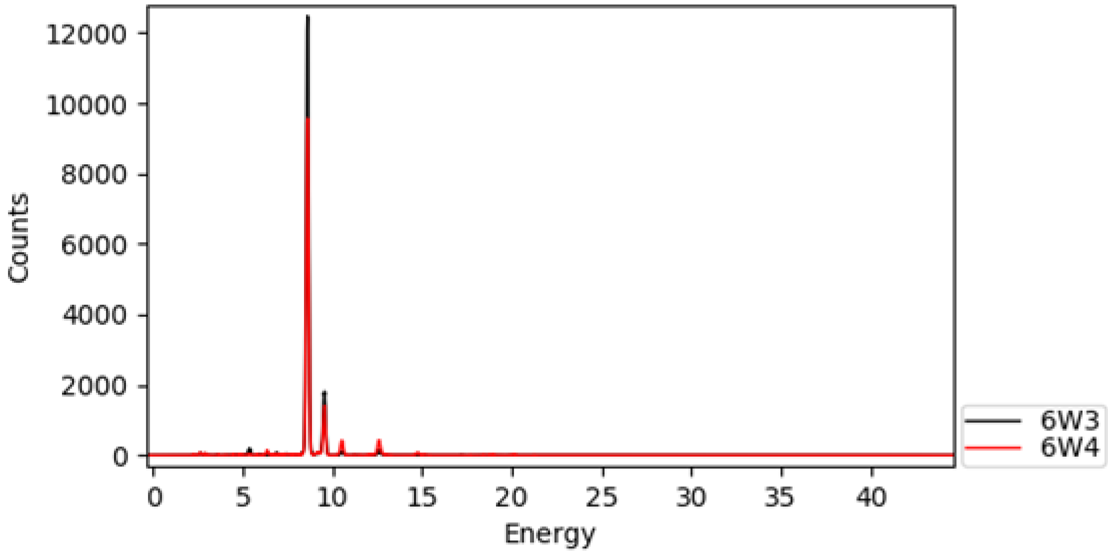
White

6W1-2



6W1 to 6W2 was taken in the whiteish skin areas, the points collected in this area showed clear peaks for zinc and weak peaks for lead, chloride, and sulphide.

6W3-4

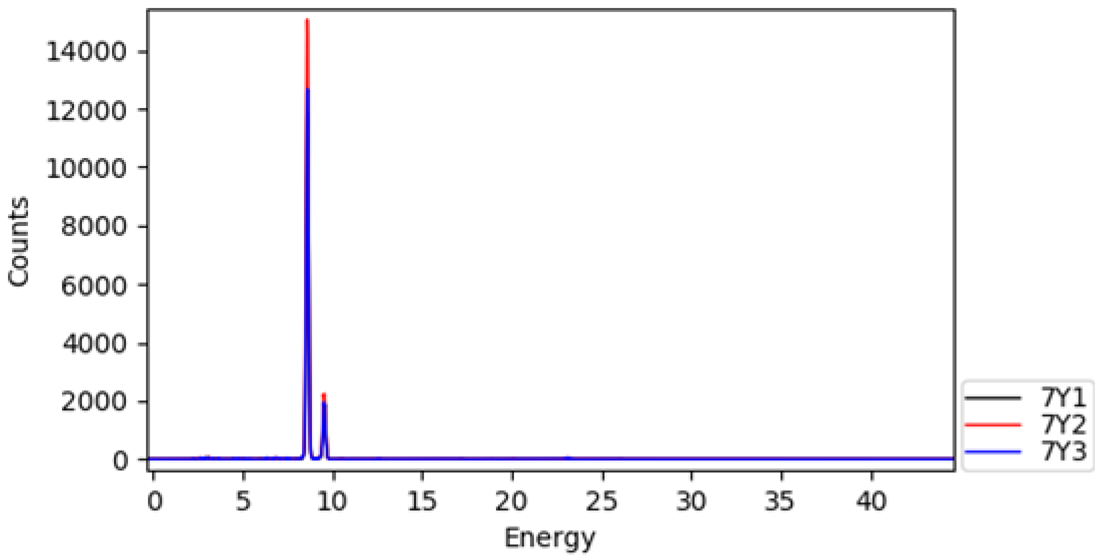


6W3 to 6W4 was taken on the small areas of blue found around the white areas, the points collected in this area showed clear peaks for zinc and lead with weak peaks for chloride calcium, iron, chromium, sulphur, and cobalt.


7.
7B5
7B4
7R3
7B1
7W2
7Y6
7Y5
7R2
7W1
7Y4
7Y3
7R1
7B3
7Y1
7Y2
7B2
7B1

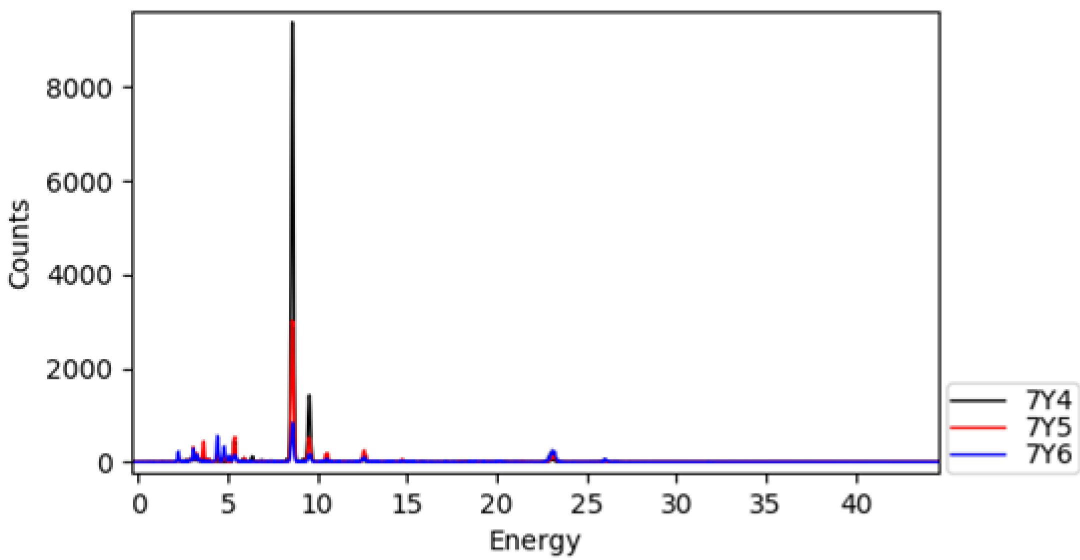
Yellows.

7Y1-3



Point 7Y1 to 7Y3 was taken in the yellowish skin areas of the rightmost figure in the boat, the points collected in this area showed clear peaks for zinc, weak peaks for chlorine, cadmium, sulphur, iron, and cobalt can be seen and a slight elevation suggesting barium, titanium and lead.

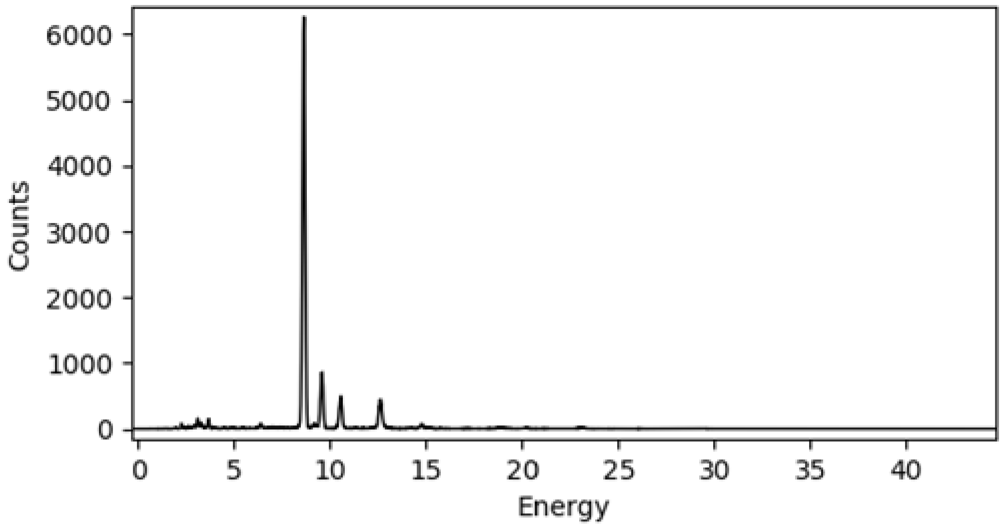
7Y4-6



Point 7Y4 to 7Y6 was taken in the hat and hair of the figures in the boat, the points collected in this area showed clear peaks for zinc, cadmium, chlorine, cadmium, sulphur, iron, cobalt, barium, titanium and lead.

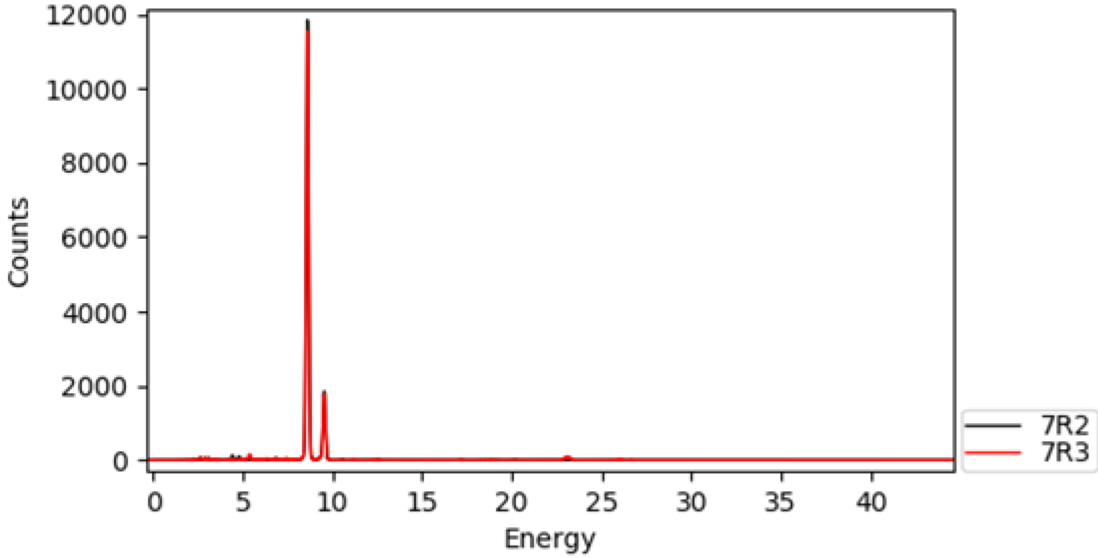
Reds

7R1



7R1 was taken on the red outline on the boat, the points collected in this area showed clear peaks for zinc, lead or possibly selenium, calcium, chloride, potassium, Iron, and sulphur. And possible peaks for cadmium.

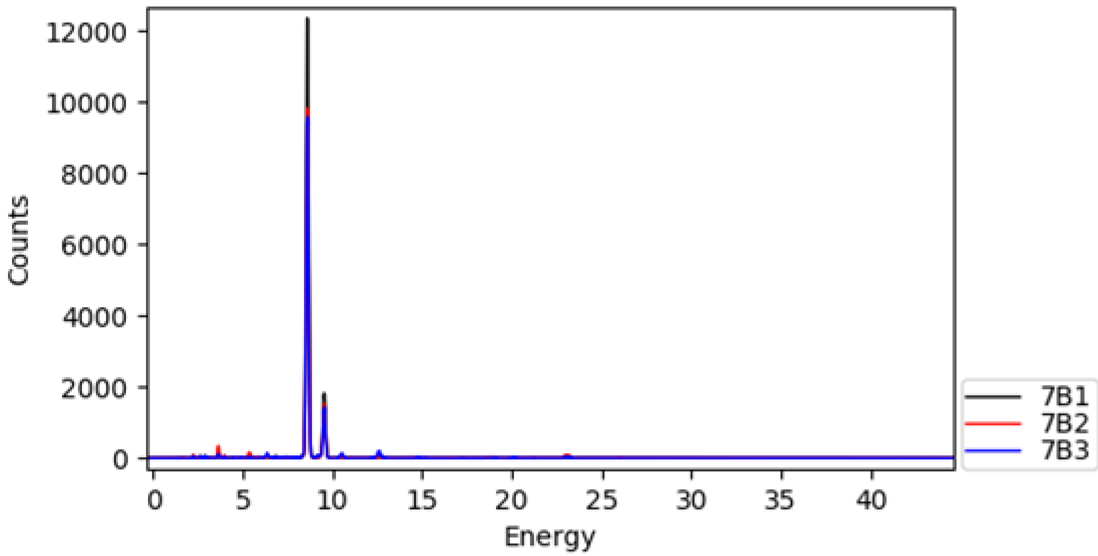
7R2-3



7R2 and 7R3 was taken on the red outline of the figures, the points collected in this area showed clear peaks for zinc, barium, chloride, Iron, and chromium weak peaks for sulphur and calcium with slight elevations suggesting either lead or selenium.

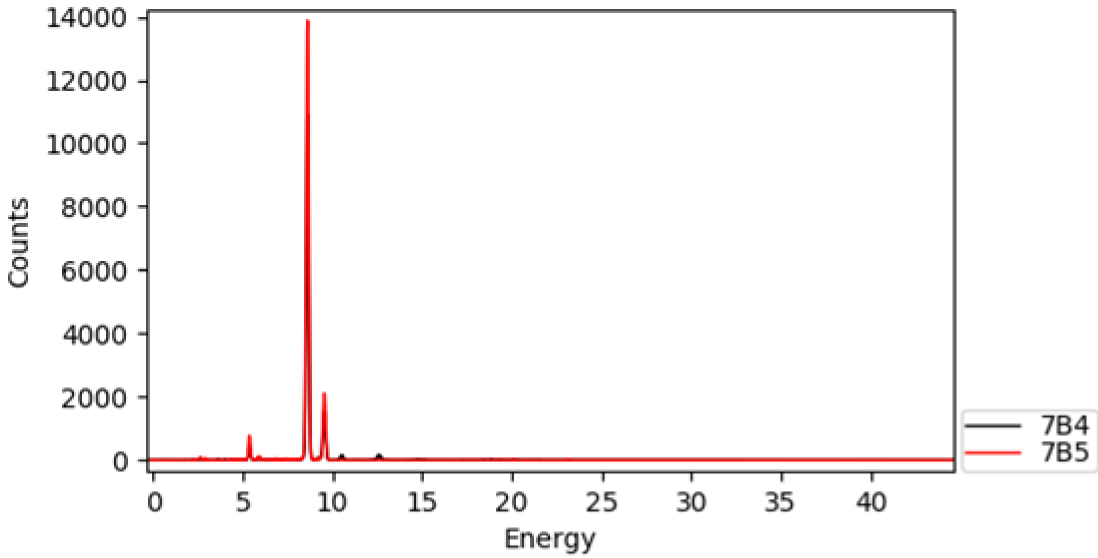
Blue

7B1-3



7B1 to 7B3 was taken vibrant blue found in the ocean and on the clothes of the figures, the points collected in this area showed clear peaks for zinc, lead, sulphur, chlorine, calcium, silicon, chromium, potassium and iron weak cadmium peaks and a slight elevation suggesting nickel.

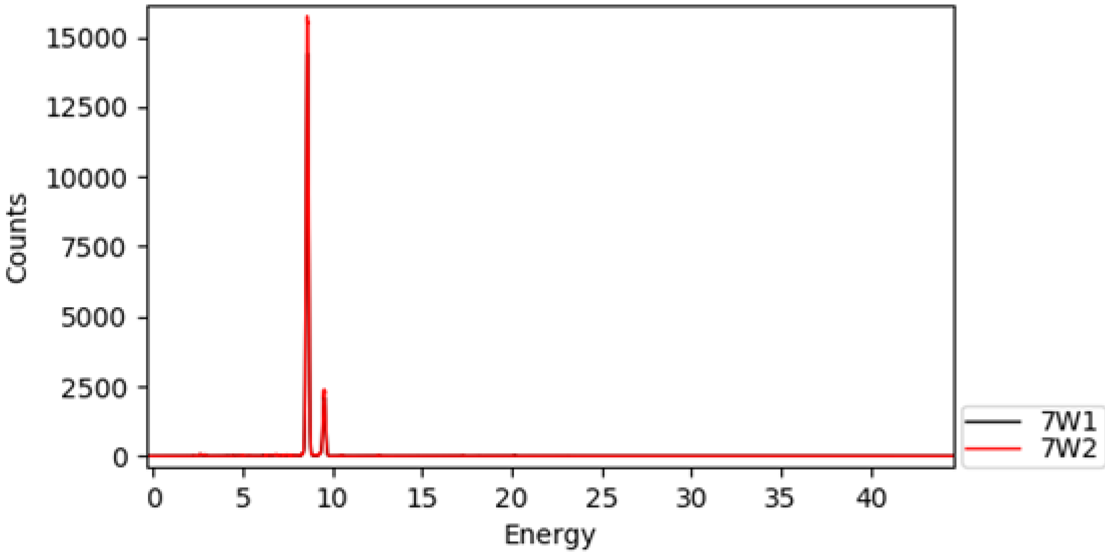
7B4-5



7B4 and 7B5 was taken vibrant blue found in the turquoise background, the points collected in this area showed clear peaks for zinc, lead, sulphur, chlorine, calcium, chromium, cobalt nickel.

White

6W1-2



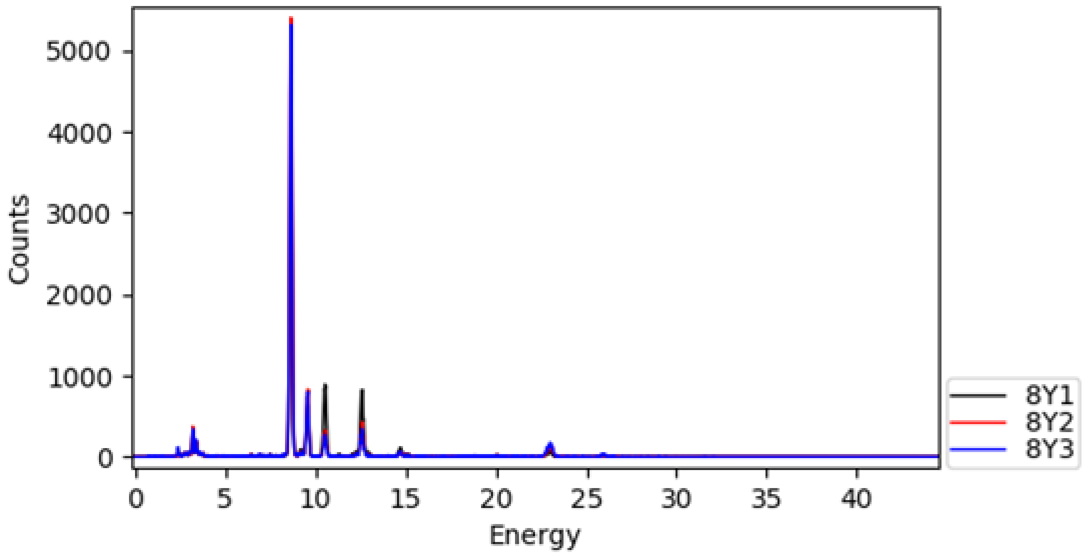
6W1 and 6W2 was taken on the white package. the points collected in this area showed clear peaks for zinc, chloride, titanium and cobalt with weak peaks for sulphur.

Ragnar Sandberg -Cyklister


8.
8Y4
8Y5
8Y5
8Y6
8G3
8Y1
8R1
8R2
8Y2
8Y15
8Y14
8Y4
8Y11
8Y3
8Y7
8Y9
8Y8
8Y12
8R3
8Y10
8G2
8Bl2
8Bl1
8B3
8W2
8W1
8B2

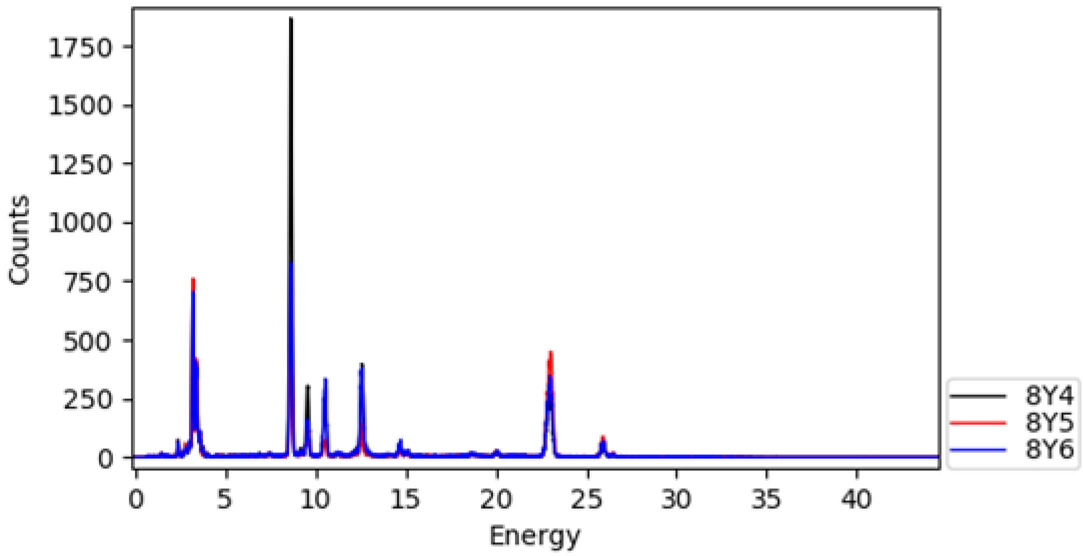
Yellows.

8Y1-3



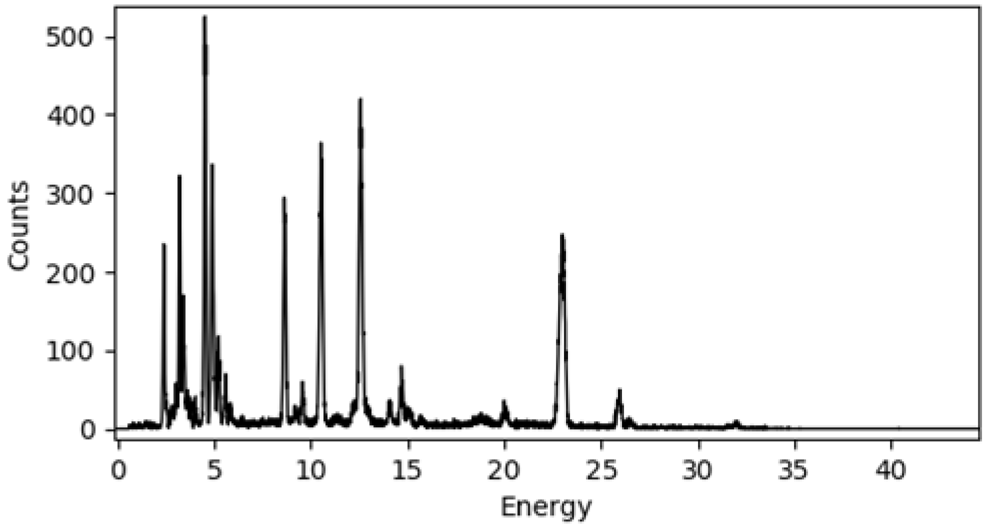
Point 8Y1 to 8Y3 was taken in the orange yellow skin areas, the points collected in this area showed clear peaks for zinc, chlorine, cadmium, lead and sulphur and slight elevations suggesting iron, cobalt, and nickel.

8Y4-6



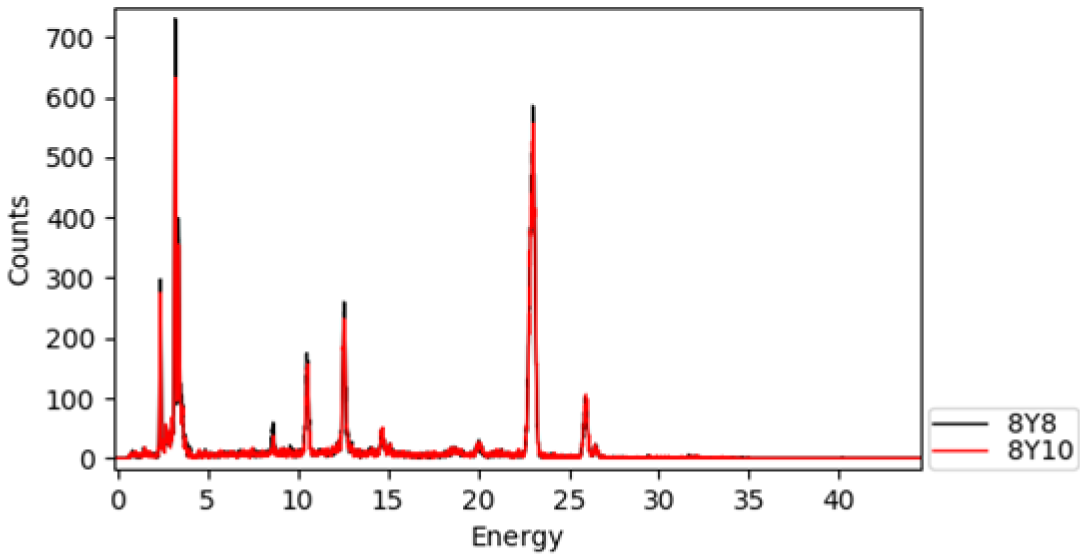
Point 8Y4 to 8Y6 was taken in the bright whiteish yellow skin areas in the face and on the arm of the leftish cyclists, the points collected in this area showed clear peaks for zinc, chlorine, cadmium, lead and sulphur and slight elevations suggesting iron, cobalt, and nickel.

8Y7



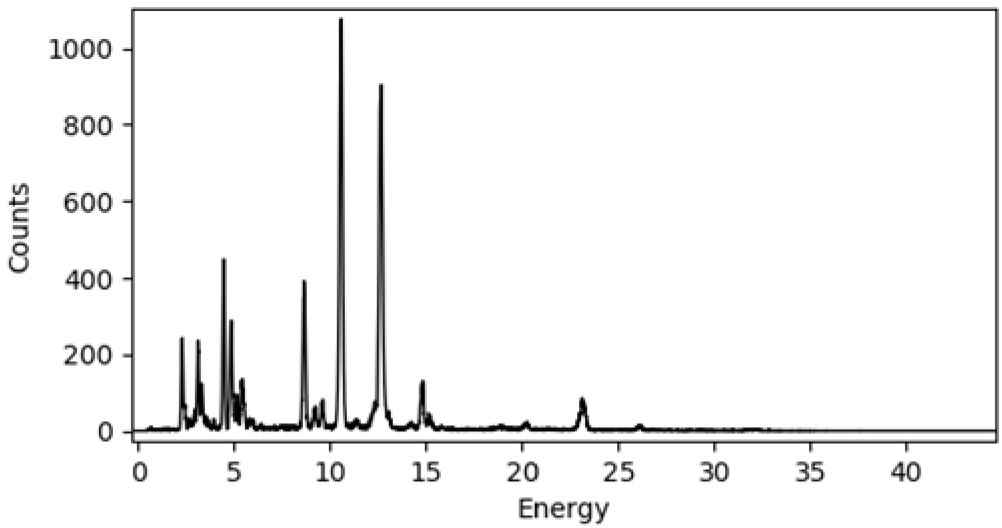
Point 8Y7 was taken in one of the yellow dots, the points collected in this area showed clear peaks for zinc, chlorine, cadmium, lead, barium, strontium and sulphur.

8Y8 and 8Y10



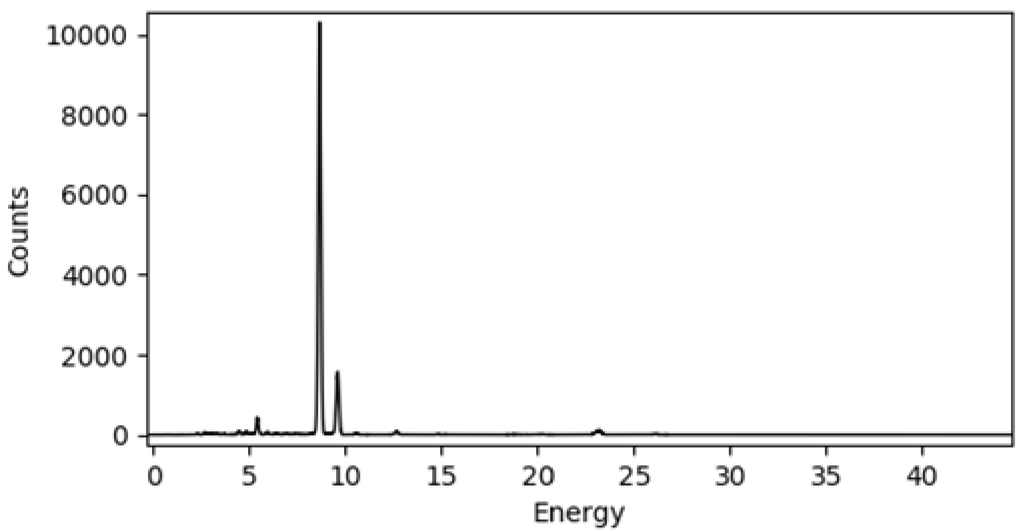
Point 8Y8 and 8Y10 was taken in the yellow dots, the points collected in this area showed clear peaks for zinc, chlorine, cadmium, lead, and sulphur.

8Y9



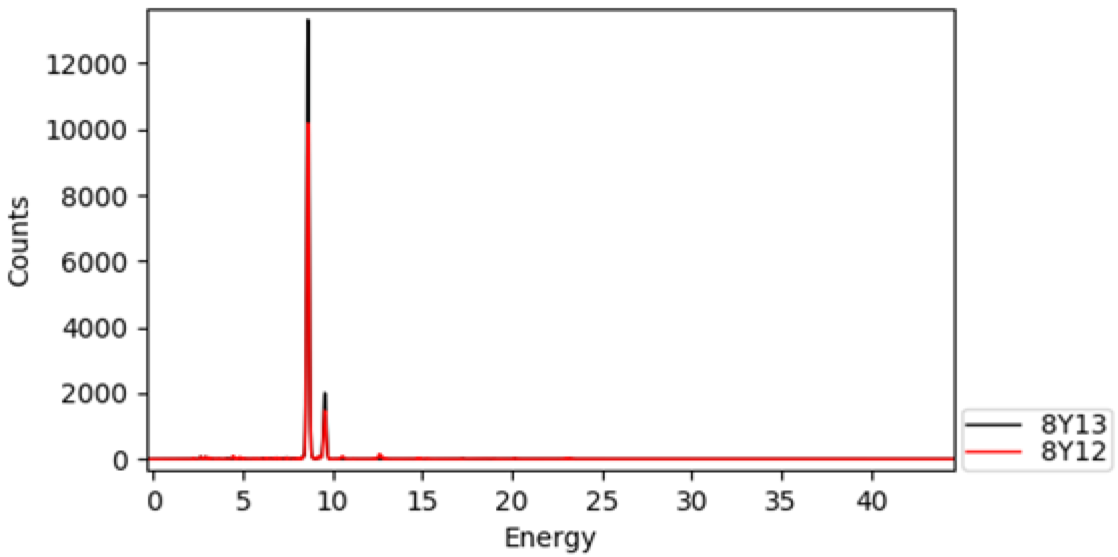
Point 8Y9 was taken in the greenish yellow background, the points collected in this area showed clear peaks for zinc, chlorine, lead, barium, chromium and sulphur.

8Y11



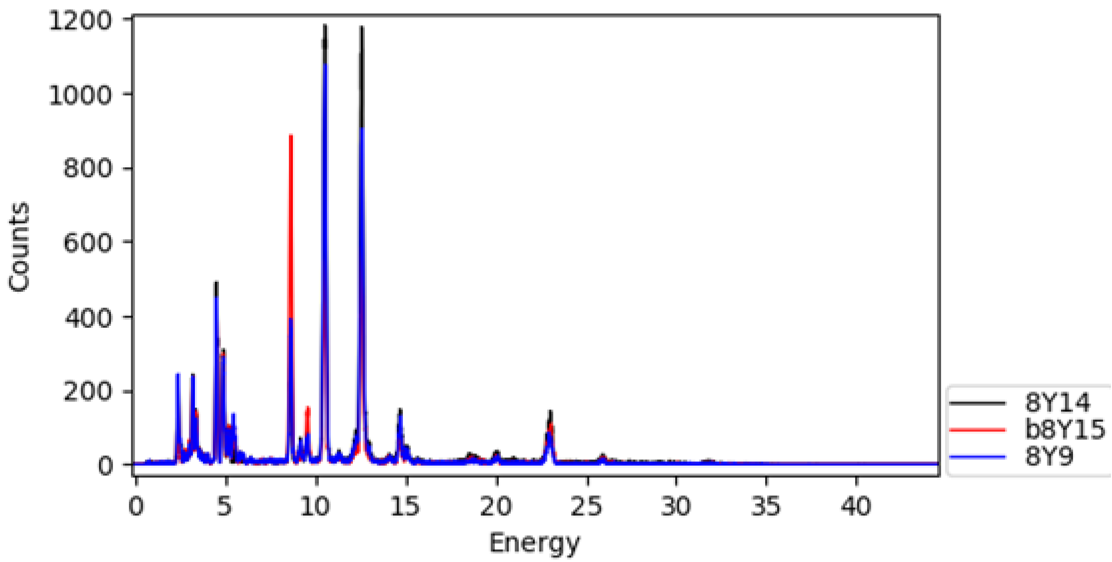
Point 8Y11 was taken in the greenish yellow background, the points collected in this area showed clear peaks for zinc, chlorine, lead, barium, chromium and sulphur.

8Y12-13



Point 8Y12 and 8Y13 was taken in the bright whiteish yellow skin areas in the hands of the leftish cyclists, the points collected in this area showed clear peaks for zinc, chlorine, cadmium, barium, lead and sulphur with weak lead peaks and slight elevations suggesting iron, cobalt, and nickel.

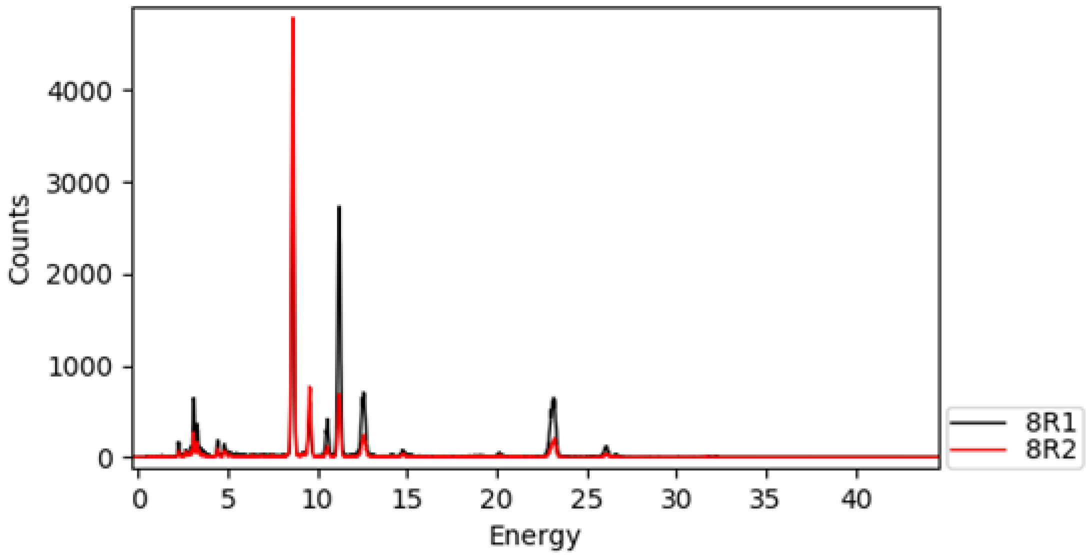
8Y14-15



Point 8Y14 and 8Y15 was taken in the yellow backround, the points collected in this area showed clear peaks for zinc, chlorine, cadmium, barium, lead, and sulphur and slight elevations suggesting iron, cobalt, and nickel.

Reds

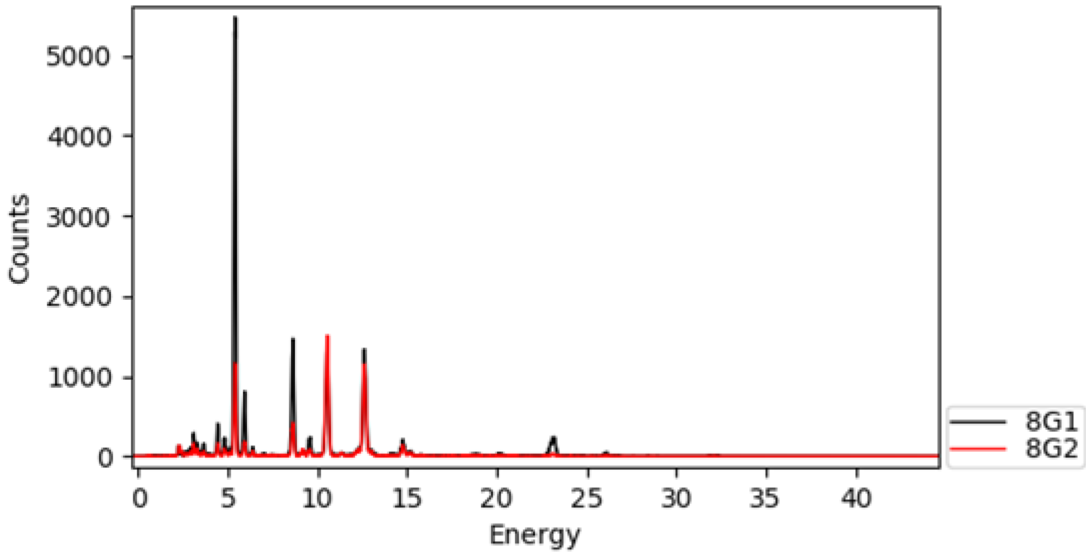
8R1-2



8R1 to 8R2 was taken on the red belt of the leftmost cyclist, the points collected in this area showed clear peaks for zinc, lead or possibly selenium, calcium, chloride, cadmium, Iron, and sulphur.

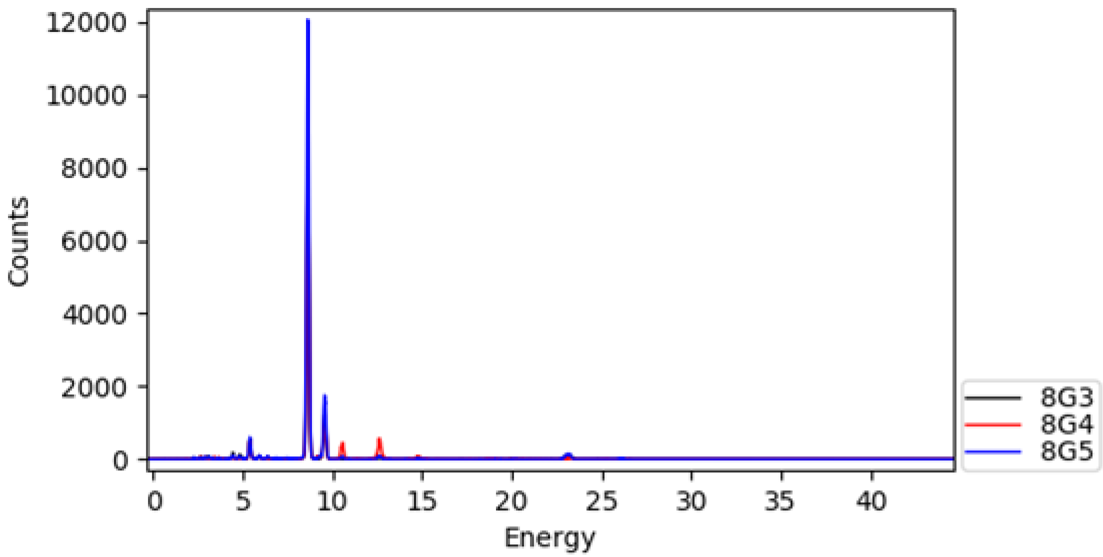
Greens

8G1-2



8G1 and 8G2 was taken in the dark green colour used in the shadows of the cyclists, the points collected in this area showed clear peaks for chromium, zinc, lead, cadmium, barium, sulphur, iron, strontium and chloride.

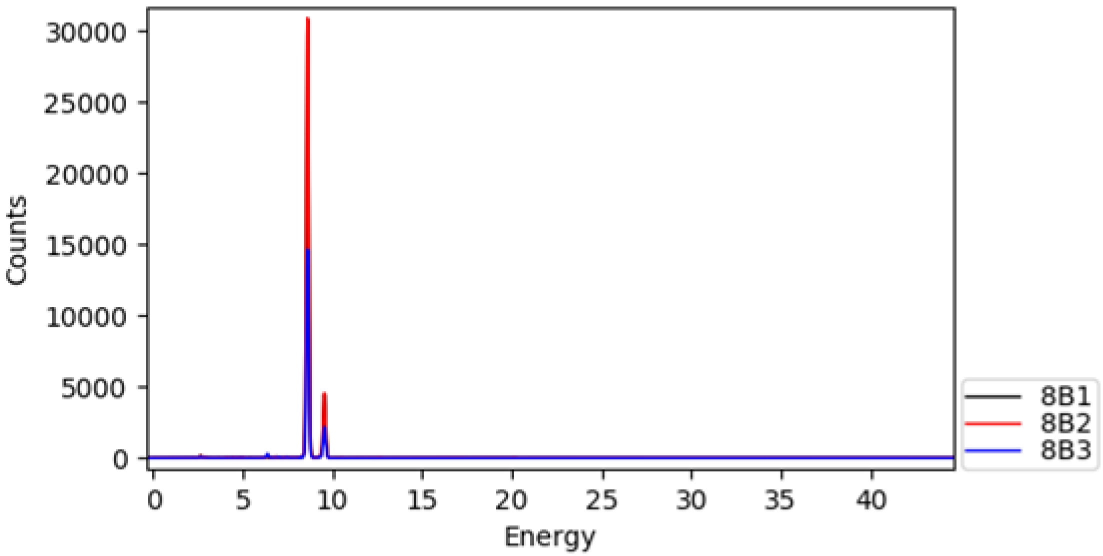
8G3-5



8G3 to 8G5 was taken in greenish yellow spots in the background, the points collected in this area showed clear peaks for chromium, zinc, cadmium, barium, sulphur and chloride with weak peaks for iron and slight elevations suggesting cobalt, and nickel

Blue

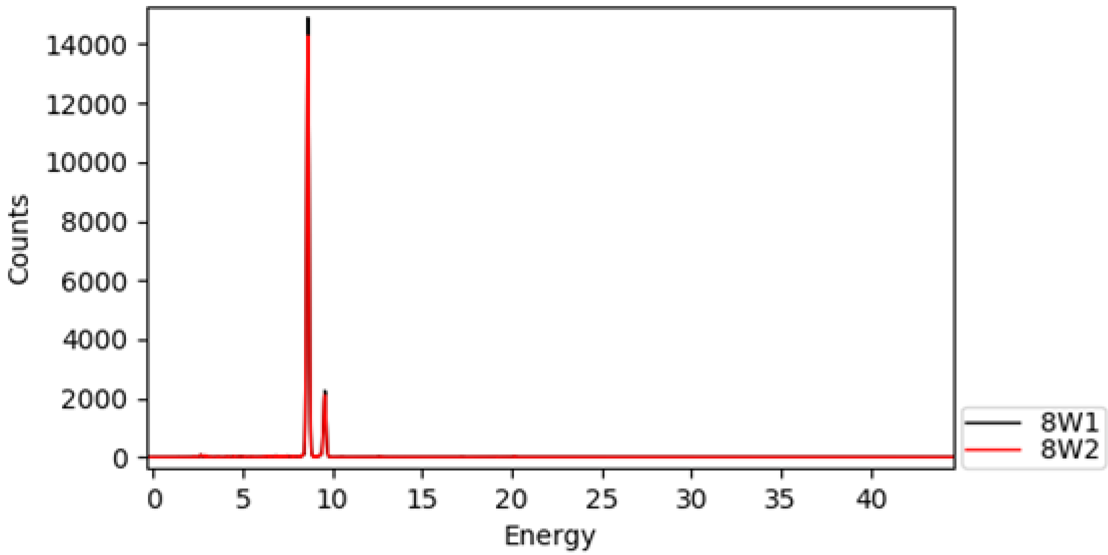
8B1-3



8B1 to 8B3 was taken on the blue shoes of the leftmost cyclist, the points collected in this area showed clear peaks for zinc, lead, sulphur, chlorine, calcium, chromium, and cadmium with weak peaks for iron with slight elevations suggesting nickel and cobalt.

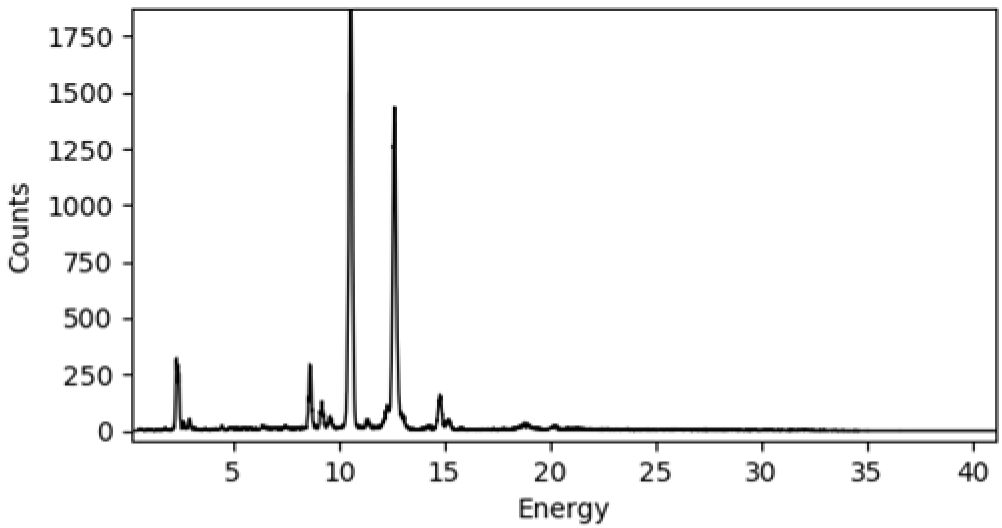
White

8W1-2



8W1 and 8W2 was taken in the white used for the shoes of the leftmost cyclist. the points collected in this area showed clear peaks for zinc, chlorine with weak peaks for sulphur and slight elevations suggesting nickel and cobalt.

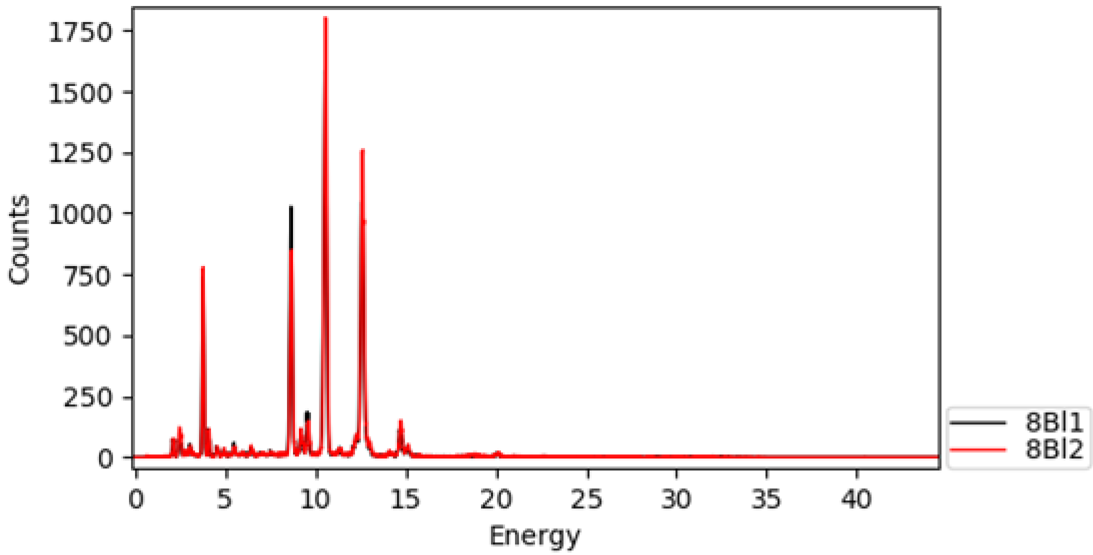
8W3

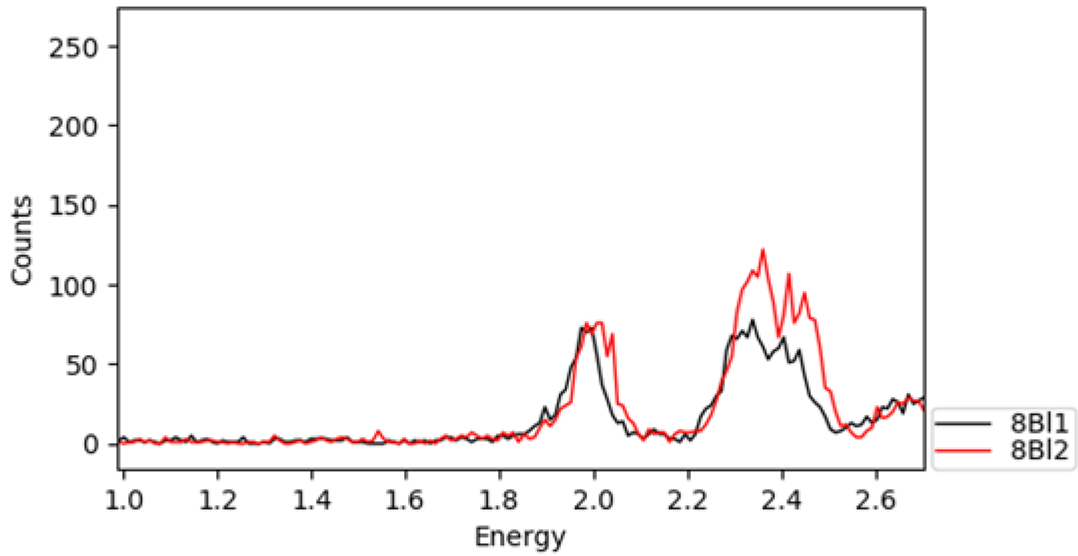


8W3 was taken in areas of exposed ground. the points collected in this area showed clear peaks for zinc, sulphur, chlorine, and lead with weak peaks for titanium.

Black

8Bl1-2





8Bl1 and 8Bl2 was taken in the black used for the shoes of the rightmost cyclist. The peak at 2 keV is attributed to phosphorus K_{α} peak. the points collected in this area showed clear peaks for zinc, calcium, chloride, lead, and sulphur, weak peaks for chromium and Iron.