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ESCOLA DAS ARTES

PORTO

INDUSTRIAL COATINGS UNDER THE SPOTLIGHT:
COMPOSITION OF PAINT LAYERS OF COATED SCRAP
METALS IN CONTEMPORARY ART

Dissertation submitted to the Catholic University of Portugal
for the master's degree in Conservation and Restoration of Cultural Heritage

Christianne Grace L. Mendoza

Porto, September 2024



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Work carried out under the supervision of:

Professor Nuno Camarneiro, PhD

And the co-supervision of:

Professor Isabel Tissot, PhD

Porto, September 2024

DEDICATION

To my family, tita Missy Reyes, and myself.

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The kindness of the individuals mentioned above has helped produce this work.

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ABSTRACT

Contemporary artists are repurposing painted scrap metals as art mediums and like any materials, they deteriorate. However, sustained studies on paint coatings of industrial objects are still scarce, even within industrial heritage, which primarily focuses on heritage machines and tools. To gain an enhanced understanding of the coatings of industrial objects in contemporary art, we used two sculptures of Mozambican artist Gonçalo Mabunda, *“Eu sou das Massas”* and *“Dá ao Povo o que é do César,”* as case studies. His sculptures are made of coated scrap metals undergoing paint loss due to corrosion. This study aims to provide critical insights that will contribute to developing appropriate conservation strategies for artworks utilizing coated scrap metals. To achieve our goal, two approaches were combined for an enhanced understanding of the materiality of the sculptures, their corrosion, and the artist’s stance regarding their preservation: an artist interview and scientific analyses.

Through the interview, we discovered the motivations behind the artist's creative decisions and uncovered some of his conflicting attitudes toward conservation. For scientific analysis, we sampled the paint coatings of two of his sculptures and observed their cross-sections using optical microscopy. X-ray fluorescence (XRF) spectroscopy was employed to identify the elemental composition of the paint coatings, while Raman and Fourier Transform Infrared Spectrometry (FTIR) Spectroscopies were used for molecular analyses. The identified pigments, phthalocyanine blue and green, chrome yellow and yellow-orange, goethite, azo red, red iron oxide, and titanium white, were those that have been reportedly used on industrial heritage objects from the past two centuries. Barium sulphate, the identified filler, has also been reported. Their continued use to this day signifies their durability and effectiveness in coating systems. Meanwhile, the identification of alkyd as the binder for almost all of the coatings is in line with the coating industry’s shift to synthetic binders in the 20th Century. Investigation of the paint coatings in Mabunda’s sculptures led to the characterization of a vastly different type of coating, a multi-layered retroreflective sheet. To our knowledge, this silica-lined coating is a novel material to be analyzed in a conservation context. Meanwhile, the artist’s execution of soldering metal pieces together also enabled us to analyze some degradation processes that coatings may undergo due to extreme temperatures. The findings suggested that while pigments may not degrade at certain temperatures, the binder will, thus highlighting the importance of investigating other significant components of coatings, too. The results gathered using multi-analytical and interdisciplinary approaches are an important base for the material study of industrial paint coatings and the definition of a conservation strategy for materials recycled as contemporary artworks.

Keywords: industrial paint coatings, recycled metals, contemporary art, material studies, conservation

RESUMO

Muitos artistas contemporâneos têm vindo a reutilizar sucata metálica revestida a tinta como meio artístico e, tal como qualquer outro material, esta pode deteriorar-se. No entanto, os estudos sobre revestimentos de tinta de objetos industriais são ainda escassos, mesmo dentro do património industrial, que se centra principalmente em máquinas e ferramentas patrimoniais. De forma a compreender melhor os revestimentos de tinta dos objetos industriais, na Arte Contemporânea, foram utilizadas, como casos de estudo, duas esculturas do artista moçambicano Gonçalo Mabunda, “Eu sou das Massas” e “Dá ao Povo o que é do César”. As suas esculturas são compostas por sucata metálica revestida a tinta, que sofre a perda do seu revestimento devido à corrosão. Este estudo tem como objetivo fornecer pensamento crítico que irá contribuir para o desenvolvimento de estratégias adequadas de conservação de obras de arte que integrem sucata metálica revestida a tinta. Para atingir o nosso objetivo, foram combinadas duas abordagens, de modo a se obter uma melhor compreensão da materialidade destas esculturas, a sua corrosão, e a postura do artista em relação à sua preservação: entrevista ao artista e análises científicas.

Através da entrevista realizada, descobrimos as motivações por detrás das decisões criativas do artista e de algumas das suas atitudes conflitantes em relação à conservação. De modo a entender a materialidade das suas obras, foram recolhidas amostras dos revestimentos de tinta de duas das suas esculturas, para análise científica, e observadas as suas secções transversais com recurso a um microscópio óptico. A Espectroscopia de Fluorescência de Raios-X (XRF) foi empregue na identificação da composição elementar dos revestimentos de tinta, enquanto a Espectroscopia Raman e a Espectroscopia de Infravermelhos por Transformada de Fourier (FTIR) foram utilizadas nas análises moleculares. Os pigmentos identificados, azul e verde de ftalocianina, amarelo e amarelo-alaranjado de crómio, goethite, vermelho azo, óxido de ferro vermelho e branco de titânio, são aqueles que terão sido utilizados em objetos do património industrial dos últimos dois séculos. O sulfato de bário, a carga identificada, também foi relatado. O seu contínuo uso até aos dias de hoje demonstra a sua durabilidade e eficácia em sistemas de revestimento. Ademais, a identificação do alquídico como aglutinante é coerente com a mudança da indústria de revestimentos para aglutinantes sintéticos, no século XX. A investigação dos revestimentos de tinta nas esculturas do Mabunda levou à caracterização de um tipo de revestimento muito diferente, uma folha retrorefletora com múltiplas camadas. Até onde sabemos, este revestimento revestido de sílica é um novo material a ser analisado no contexto da conservação. Por outro lado, a execução do artista, ao soldar peças metálicas umas às outras, permitiu-nos analisar alguns processos de degradação que os revestimentos podem sofrer, quando sujeitos a temperaturas extremas. As descobertas sugeriram que, embora os pigmentos possam não se degradar a determinadas temperaturas, o aglutinante irá, realçando assim a importância de

investigar também outros componentes significativos dos revestimentos. Os resultados obtidos através de abordagens multianalíticas e interdisciplinares são uma base importante para o estudo dos materiais que compõem os revestimentos de tintas industriais e para a definição de uma estratégia de conservação relativa a materiais reciclados enquanto obras de arte contemporâneas.

Palavras-passe: revestimentos de tinta, metais reciclados, arte contemporânea, estudos de materiais, conservação

TABLE OF CONTENTS

DEDICATION	ii
ACKNOWLEDGMENTS	iii
ABSTRACT	iv
1. INTRODUCTION	1
1.1. STATE OF THE ART.....	3
1.2. OBJECTIVES AND SCOPE	6
1.3. METHODOLOGY	8
1.4. STRUCTURE OF THE THESIS	11
2. INTERVIEW WITH GONÇALO MABUNDA: THE ARTIST, HIS JOURNEY, AND HIS VIEWS	12
2.1. THE BEGINNING OF MABUNDA’S CAREER.....	12
2.2. MULTI-FACETED SCULPTURES: ARTIST’S CREATIVE PROCESS AND VIEWS	14
2.3. <i>EU SOU DAS MASSAS</i> AND <i>DÁ AO POVO O QUE É DO CÉSAR</i>	16
2.4. MABUNDA’S STANCE ON THE CONSERVATION OF HIS WORKS	18
2.5. CONFLICTS IN INTENTIONS AND ACTIONS.....	18
3. THE CASE STUDIES: “EU SOU DAS MASSAS” AND “DÁ AO POVO O QUE É DO CÉSAR”	20
3.1. DESCRIPTION AND TECHNICAL PROCESS	20
3.2. PROVENANCE, EXHIBITION HISTORY, AND STORAGE	22
3.3. THE CASE STUDIES & THE DEVESA PARK SCULPTURES: A GLIMPSE INTO THE FUTURE.....	23
4. MATERIAL CHARACTERIZATION OF THE PAINT COATINGS	25
4.1. ANALYTICAL TECHNIQUES AND INSTRUMENTATIONS	26
4.2. RESULTS AND DISCUSSIONS	29
4.3. DEGRADATION OF THE COATINGS	53
4.4. FINAL REMARKS.....	61
5. CONCLUSION AND PERSPECTIVES	63
BIBLIOGRAPHY	67
APPENDIX	77
TRANSCRIPT OF INTERVIEW WITH THE ARTIST, GONÇALO MABUNDA.....	77
ANNEX	93
REFERENCE SPECTRA	93

1. INTRODUCTION

The analysis of paint coatings on metallic heritage tools, machines, and equipment is typically part of industrial heritage conservation. However, industrial metals with paint coatings are finding their way into art as contemporary artists have been using recycled materials as art mediums. The use of repurposed painted industrial metals as artistic materials likely dates back to the beginning of the 20th century, with the rise of the Dada art movement. In that period, artists challenged the traditional definitions of high art and transformed found objects into art as a means of protest (Stribling, 1970). These found objects include tools and industrial objects alike (Trachtman, 2006). Artists have repurposed these materials as part of a collage work like in Kurt Schwitters' 1919 *Construction for Noble Ladies* (Figure 1) or have modified them as sculptures like César Baldaccini's 1961 *The Yellow Buick* (Figure 2). The influences from this period have endured, and artists of today continue to recycle industrial objects as mediums for their artistic expression.

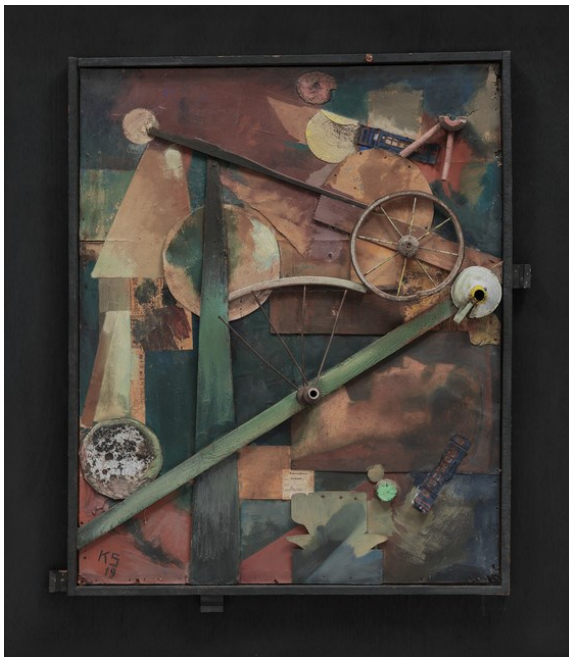


Figure 1. An example of an artwork with scrap metals from early 20th Century. "Construction for Noble Ladies." (1919). Collage by Kurt Schwitters. Oil, watercolor, gouache, wood, metal, counted on wood. 102.87 x 83.82 cm. Los Angeles County Museum of Art.



Figure 2. "The Yellow Buick." (1961). Sculpture by César Baldaccini. Compressed automobile. 151.1 x 77.7 x 63.5 cm. Museum of Modern Art, New York.

Paint coatings on industrial objects serve the dual purpose of decorating and protecting the surface of the objects from corrosion. In contemporary art context, a paint coating on a recycled material may be the element that provides color to an artwork. Its function is similar to that of the paint layer in traditional artworks, where it provides color and helps in effectively reading and appreciating a work. However, the role a paint coating might play in an artwork will ultimately depend on the artist's

intention—a crucial factor to be considered in conserving contemporary works (Foundation for the Conservation of Modern Art [Dutch abbreviation: SBMK], 1999).

Like any other materials, paint coatings deteriorate. Understanding the composition and degradation process of materials in works of art is crucial for their preservation (Anghelone et al., 2016). In non-traditional artworks, the artist's intention is also essential in conservation, as “the relationship between material and meaning is usually ambiguous” (SBMK, 1999, p. 2) in contrast to traditional works. Thus, the conservation of materials in modern artworks may involve investigating the materiality of the objects used to know their composition and researching the meaning behind the material usage to maintain the essence of the works. However, while we might know much about the characteristics and stability of traditional artistic paint mediums like oil and acrylic thanks to the number of available resources to consult from (Whitmore & Colaluca, 1995; Izzo et al., 2014a; Izzo et al., 2014b; Hagan et al., 2015; van Loon et al., 2020), comparative studies and databases regarding coatings applied to industrial heritage objects are still scarce (Tissot et al., 2021). Despite the growing interest in the paint coatings of industrial objects, the focus is usually primarily on pigments, which limits the complete understanding of paint coatings. The limited resources for identifying binders and fillers hampers the comprehensive understanding of paint systems applied to industrial objects (Tissot et al., 2021). Additionally, as far as I know, studies on recycled paint-coated metals as art materials are even fewer or nonexistent.

The lack of resources and the constant changes and developments in the coatings market (Ryntz, 2007) might mean a gap in the current knowledge and understanding of paint coatings in the industrial heritage context. New synthetic binders have been developed since the 1920s (Gordon, 2022), and cheaper ways to manufacture industrial materials have come with the rise of the competitive market (Nallicheri, 1993). Some previously used corrosion-inhibiting pigments (Gharbi et al., 2018) and solvents (Nallicheri, 1993; Ryntz, 2007) have been replaced due to health and environmental concerns. Additionally, technological advancements paved the way for innovations in the industrial paint industry, such as the development of smart coatings (Montemor, 2014). These factors suggest that coatings' composition may have evolved since their invention. Because of these, as is the case with new materials in modern artworks (SBMK, 1999), these materials' composition and aging behavior are relatively understudied. Thus, consistent investigation of coatings can be crucial in conserving coated industrial materials: “[t]he more information we have concerning the materials used and their composition, the better their condition can be determined” (SBMK, 1999, p. 6).

1.1. STATE OF THE ART

While analytical studies have been widely employed in art conservation and archaeology, the same cannot be said regarding industrial heritage (Constantini et al., 2022). Archaeological industrial heritage was a concept born in the 1970s (Costantini et al., 2022). Because of this, literature regarding scientific analysis of materials that make up industrial heritage objects is scarce (Tissot et al., 2021). However, analysis is beneficial to understanding a material's elemental and molecular components, degradation, and stability—all of which are pertinent information to the preservation of a material (Anghelone et al., 2016). Knowing this, conservators and researchers are now applying analytical tools typically used in the material studies and condition assessment of art and archaeological objects to industrial heritage objects. A material of particular interest in the conservation of industrial heritage objects is the paint coatings of industrial objects. However, while paint coatings are becoming a subject of interest in industrial heritage, there is a lack of study on their materiality, degradation, and conservation in art due to the unconventionality of coated scrap metals as art materials. To aid us in studying scrap metals in contemporary art, particularly the ones with paint coatings, we will look into what has been done in industrial heritage.

The paint coatings of industrial objects are of particular research interest because of their dual role in protection and decoration (Tissot et al., 2021). They are composed of three major components: pigments, binders, and fillers. As protective coatings, they are a vital component of a heritage object, contributing to its longevity by protecting against corrosion and enhancing its aesthetic appeal as a color-bearing medium. Moreover, the original coatings may bear marks and wear, which can provide information on the history of use and object degradation (Lemos & Tissot, 2020). Industrial coatings are a rich source of information that can aid in diagnosing and preserving industrial artifacts. Several works have been published in the past four years focusing primarily on the pigment component of paint coatings (Tissot et al., 2021; Costantini et al., 2022; Gordon, 2022; Macchia et al., 2023; Tissot et al., 2024). However, the other main components that affect their behavior and appearance, the binders and the fillers, are seldomly investigated together with the pigments; except, to the best of our knowledge, for one study where the three main components of paint coatings were investigated altogether (Macchia et al., 2023).

Analytical strategies employed to study industrial heritage objects often mainly revolve around the usage of X-ray fluorescence (XRF) spectroscopy and scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS) to characterize paint coatings and metal alloys (Tissot et al., 2021). The first application of μ Raman analysis to identify the pigments used in the protection and decoration

of historical industrial machines has recently been reported (Tissot et al., 2021). The study aimed to explore the potentiality of vibrational spectroscopy in characterizing industrial coatings and to contribute more knowledge to the subject matter. Three generators from the 20th century were used as case studies. Through XRF and Raman analyses, pigments such as prussian blue, blue Cu phthalocyanine, toluidine red, red iron oxide, chrome yellow, and chrome orange were identified in the coating system of the historical industrial machines. The use of vibrational spectroscopy also helped in identifying corrosion products present on the machines, like magnetite, which gave clues regarding the machine's history of use. Other components of paint coatings, such as fillers and binders, were not investigated.

From here, other researchers have likewise started to use vibration spectrometry to identify pigments used in the paint systems of other industrial heritage objects for conservation purposes (Costantini, 2022; Gordon, 2022; Tissot, 2024), supplying additional information that could help build a database on techniques used in paint coat systems. Costantini et al. (2022) identified lead white, ultramarine blue, carbon black, and barium sulfate (which was used as an opacifier) in the original paint layers of 1927 Plaiko Zubixe bridge whose original colors they aim to restore in the future. The identification of Cu phthalocyanine blue and green pigments in paint coatings of 19th and 20th Century machines was once again reported in later studies (Gordon, 2022; Tissot et al., 2024) along with toluidine red (Tissot et al., 2024) and chrome yellow (Gordon, 2022). Anti-corrosive pigments like red lead, lithophone, and other lead and zinc-based pigments, too, were identified (Gordon, 2022; Macchia et al., 2023) and noted to be applied to the layers directly applied to the metal substrate (Gordon, 2022). Using Fourier Transform Infrared (FTIR) Spectroscopy, oily binders were identified as the vehicle component of paint coatings on historical objects from the same centuries (Gordon, 2022; Macchia et al., 2023). On the other hand, fillers like silicates, carbonates, and barite have been deduced to be present in paint samples from 20th Century heritage objects using SEM-EDS and FTIR spectroscopy (Macchia et al., 2023).

The current studies on industrial heritage objects with a particular focus on coatings paint a picture of the components used in the paint systems of industrial objects from the 19th to the 20th centuries. While colors of industrial objects have been consistently investigated, other components that make up a coating, such as fillers and binders, seem not to have been given the same focus, except by Gordon (2022), who also investigated binders in her thesis; and Macchia et al. (2023) who studied all three components in their paint samples. Furthermore, the case studies in existing literature often center

around heritage machines and artifacts. This focus is justified, as they serve as evidence of human accomplishments in the industrial and technological sectors (Wain et al., 2023).

There is, however, another group of industrial metals that has little to no historical significance and value: modern-day packaging, construction, and manufacturing materials, especially those that have become rubbish—scrap metals. These materials regain value and significance as a medium of expression for artists in contemporary art. In contemporary art, artists may incorporate these coated metals as a visual element to add color to their work. If intended by the artist, these coatings can be considered a vital part of a work's composition, aiding in the total understanding and appreciation of the works. These visual elements must be conserved like other heritage objects for the continued understanding of the works. Just as art conservators have studied traditional artistic paints such as oils and acrylics to understand their degradation, stability, and compatibility with conservation materials, it would also be necessary to do the same for the degrading coatings of scrap metals used in artworks.

To the best of my knowledge, little attention has been paid to the components of coatings on everyday 21st-century industrial objects, especially in the context of conservation science, apart from forensic science, chemistry, and chemical engineering. The article by Charles et al. (2022) is one of the few ones that investigated the fillers of modern-day coatings. It has also helped contribute information regarding the coating system of some of the mass-produced tools of today: unprimed and having a single layer of paint coating. Although this is certainly not a total reflection of the coatings on all industrial metals, the coating system, after all, depends on the type and value of the equipment to be protected, it is different from the 19th Century coating practices gathered by Julie Gordon (2022), who stated that industrial coatings contained 2-3 layers consisting of a base coat, an intermediate layer, and a top coat according to Bierwagen (1996).

Furthermore, there is also a lack of conservation studies of paint coatings on metal in art. While studies are made on the conservation of oil paint on copper support in art (Horovits, 1986; Pavlopoulou & Watkinson D, 2006), paint coatings on industrial heritage objects are made of different materials; they are industrial paints on usually iron-based support. Currently, the existing conservation studies on painted iron and aluminum substrates are mostly focused on historical objects, not artworks, wherein they observed and determined that the cause of the alteration of coatings in painted metals is often due to the migration and diffusion of metallic ions (Gordon et al., 2019).

The constantly changing landscape of industrial coatings (Ryntz, 2007), the entry of paint-coated industrial metals into the art museum context, the degradation of these coated scrap metals that are

turned into artworks, and the challenges of conserving composite materials all highlight the need for more studies regarding industrial coatings to gain a greater understanding of the material and its composition.

1.2. OBJECTIVES AND SCOPE

This thesis aims to understand the paint coatings of scrap metals, a group of objects that are gaining new value as art mediums. This thesis seeks to improve our understanding of the composition of industrial objects' coatings to contribute information on the coating technology used for these unconventional art objects and to investigate how they degrade. To that aim, we will use scientific analysis to identify and characterize pigments, binders, and fillers of industrial coatings in contemporary art and investigate how paint coatings interact with the metal substrate. We will also examine the meaning behind their use in an art context and the artist's intention, which can be crucial in further understanding industrial materials used in a new context. The ultimate goal is to contribute knowledge about industrial coatings that can help develop an appropriate conservation approach for coated scrap metals used as artworks.

Painted metal is a composite system that includes the paint layer and the metal substrate. Paint coatings on metals act as a decorative layer while also providing essential protection against corrosive environments (Kendig & Mills, 2017). However, mechanical damage and environmental factors can lead to cracks, allowing corrosive agents to reach the metallic substrate even through microscopic fissures (Gordon, 2022). These crevices can lead to significant damage when oxidation of the underlying metallic substrate starts. The formation of corrosion products leads to the loss of the coating's adhesion to the substrate and, subsequently, its rupture and detachment (Kendig & Mills, 2017; Gordon, 2022), as illustrated in **Figure 3**. When the metal substrate corrodes, the coating eventually detaches. The coating, meant to protect the metal substrate, is now being harmed by the corrosion it was designed to prevent.

Thus, both the paint coating and its relationship to the metallic substrate are essential in understanding how paint coats behave and degrade in a composite system. Understanding the behavior and degradation processes of coatings is crucial to ensure the longevity of metal surfaces, which in turn, also contributes to the extended life of the coatings.

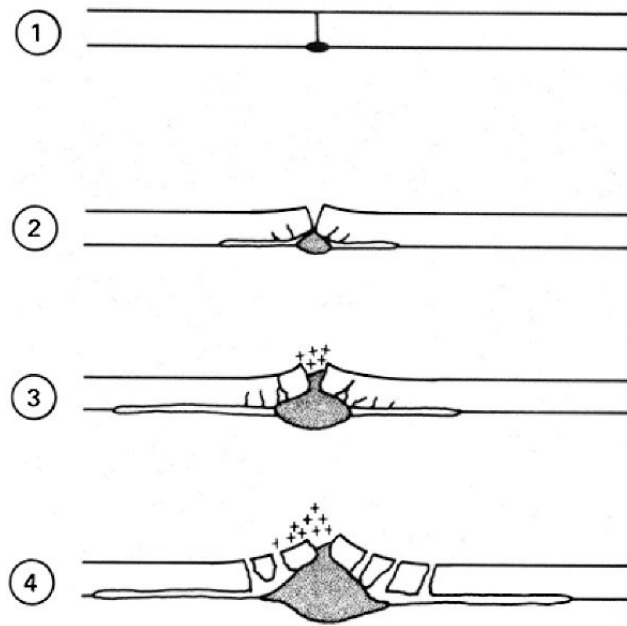


Figure 3. “Model for the role of corrosion in the destruction of a paint film” (Kendig and Mills, 2017).

When conserving composite materials, the characteristics of all components must be considered (Gordon, 2022). That is why, in addition to the interaction between paint coat and metal substrate, we aim to analyze the other significant components of coatings that are often overlooked: the binder and filler. Characterizing the materials used in each component of a composite object so that we can understand how they may behave and degrade will subsequently allow for the formulation of adequate conservation treatment.

1.3. METHODOLOGY

To achieve our objectives, which include understanding coated industrial metals repurposed as artworks and contributing to the knowledge of coating techniques, we will examine two sculptures by Mozambican artist Gonçalo Mabunda as case studies, “*Eu sou das massas*” and “*Dá ao povo o que é do César*” (Figure 4). Gonçalo Mabunda is a contemporary artist who uses discarded scrap metals as his medium. To bring color to his works, he uses coated scrap metals. However, the coatings of these metals are undergoing deterioration, such as loss of adhesion of the paint layer due to corrosion. The corrosion of the scrap metals’ metallic substrate causes the coatings to lift and flake off, threatening the overall reading of the sculptures. His artworks’ existence and deteriorating state emphasize the importance of paying attention to industrial coatings, even on discarded items, especially now that industrial objects are being displayed in museums as artistic expressions. His sculptures, which contain various colored scrap metals, offer an opportunity for an in-depth analysis of paint coatings of corroding metals. We aim to understand and characterize the coatings’ components, composition, stability, and degradation using analytical techniques.

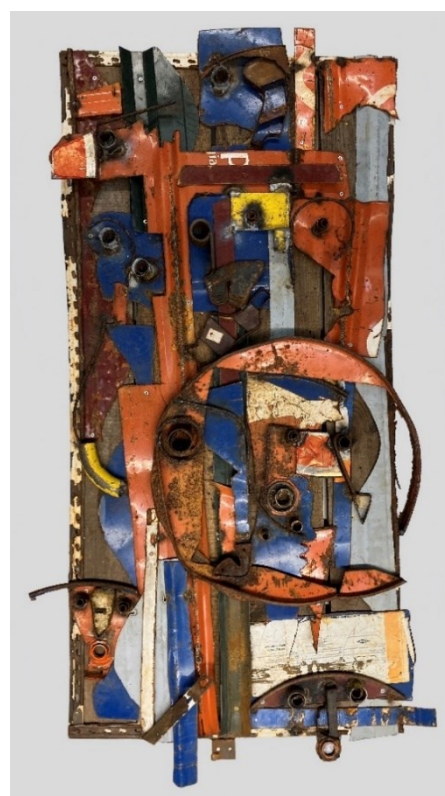


Figure 4. “*Dá ao povo o que é de César.*” (2013) Sculpture by G. Mabunda. Wood, metal, and painted metal. 165 cm x 90 cm x 14 cm.

However, as the scrap metals in his works have departed from their original intended usage as practical tools and have become art materials, other aspects beyond the materiality of the components of the sculptures and corrosion need to be considered. The usual means of employing analytical studies on industrial objects may not be enough to understand the coatings in this new context. The artist’s execution and intentions will also raise issues to consider when investigating industrial metals in the context of art. Modern theories in the conservation of heritage objects understand that the return to the original state, or even the preservation of the current state, halting any deterioration, may not always be the best conservation treatment and that artists’ intentions, among others, must also be considered (Muñoz Viñas, 2005; Pye, 2016). Thus, while conservation studies on materials used in industrial heritage objects are available, applying these findings to industrial objects in contemporary art is more complex as it requires an understanding of the artist’s intent. Therefore, a new

methodology was developed to address this challenge. To better understand coated industrial objects that were repurposed as artworks and the concerns that may arise when using them as art materials, two approaches were combined:

- a. *Online interview with the artist*- this was conducted not only to understand better the objects we are working with but also to learn about the artist’s creative process, artistic intentions, and conservation stance. Existing interview guidelines for the conservation of contemporary artworks by Jonathan Debik and Sarah Giering (2023) and by Samantha Sheesley (2007) were consulted in the formulation of interview questions. These guides would help ensure that information pertinent to the conservation of modern artworks will be gathered. **Figure 5** shows the diagram of a partially structured interview that Debik & Giering (2023) adapted from Beerkens et al.’s (2012) “The Artist Interview.”

The structure starts with an opening question that encourages the interviewee to discuss his work. It is followed by questions about the creative process, materials, techniques, meaning, and context, which is considered the central part of the interview. Here, the artist's intentions are also asked. Next is an integral part of an interview done with conservation objectives in mind. It is geared towards understanding the artist's thoughts and stance on conserving his works, the deterioration of his works, and how the degradation may affect the meaning of his works. The final part wraps up the interview; it provides opportunities for asking clarifications and follow-up questions that may lead to unexpected information (Debik & Giering, 2023). The transcript of the artist interview done for this thesis is available in the Appendix.

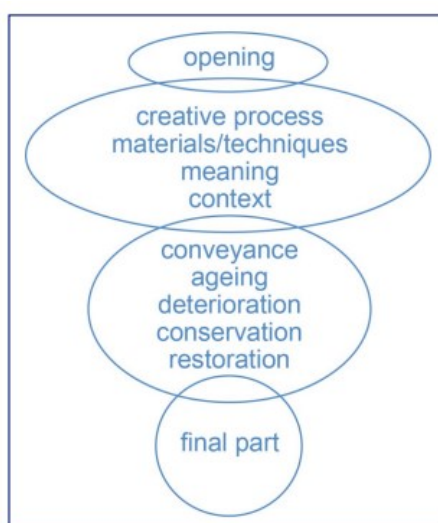


Figure 5. A diagram presenting the structure of the interview (Debik & Giering, 2023).

- b. *Material studies of the paint coatings of Mabunda’s sculptures using analytical techniques-* these were employed to understand the materiality of the coatings. Small samples were taken and observed under optical microscopy for the morphological analysis. After this, they were analyzed using XRF spectroscopy to identify the elemental composition of the samples. Raman Spectroscopy was employed to identify the molecular compounds of pigments and corrosion products, and Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR) was used to analyze the molecular compounds of fillers and binders. These techniques were also used to investigate the degradation processes of coatings that had been exposed to heat due to the artist’s execution of soldering metal pieces together. More information about the techniques will be discussed in *Chapter 4.1.: Analytical Techniques and Instrumentations.*

An artist interview offers valuable insights into the creative choices that the artist made. It could give context to some of the conditions of the materials and artist techniques used that cannot be obtained through scientific analysis alone. Scientific analysis provides an objective understanding of the materials (their chemical make-up, molecular composition, and how they degrade) chosen by the artist that even he may not be familiar with. By combining these two approaches, we aim to gather critical insights that will contribute to developing appropriate conservation strategies for artworks utilizing coated scrap metals (**Figure 6**).

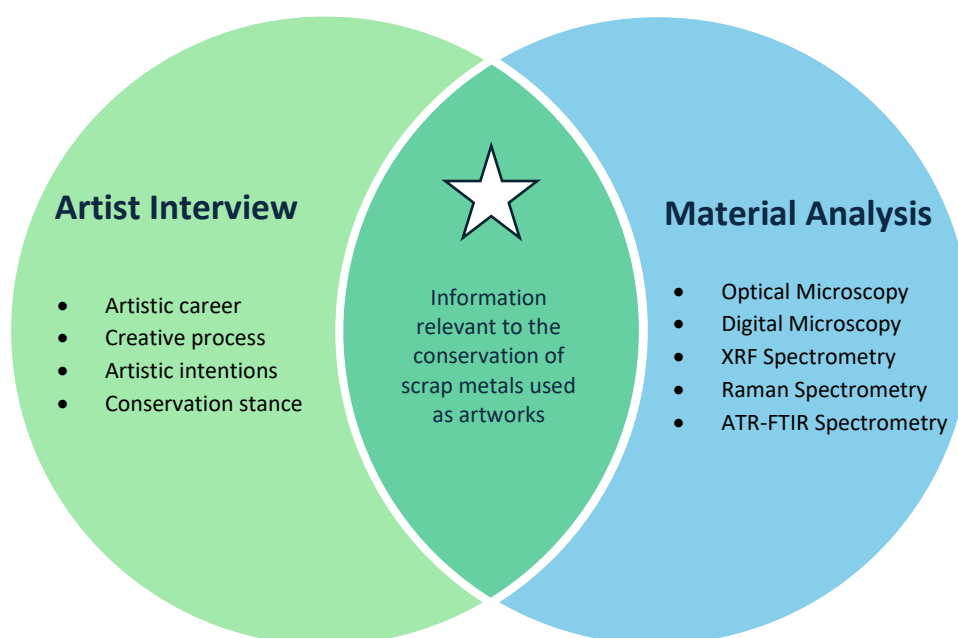


Figure 6. Diagram presenting the methodology employed for studying recycled paint-coated industrial materials in contemporary art context.

1.4. STRUCTURE OF THE THESIS

This work will consist of three chapters. The first chapter will focus on the interview conducted with the artist, providing insights into his creative process, intentions, and views on conservation. It will also delve into the influences in his artworks and his journey as an artist to give a comprehensive background on his works.

The next chapter will present the case studies "*Eu sou das massas*" and "*Dá ao povo o que é do César.*" It will focus on the sculptures' characteristics, origins, and the intentions and meaning behind them. Following this is the chapter dedicated to the scientific analysis of the coatings in Mabunda's sculptures. This chapter will provide details about the analytical techniques used to understand the coatings of the scrap metals, their degradation, the corrosion products present, and a discussion of the results obtained during the analyses.

Lastly, the conclusion will summarize the findings, interpret and combine the results from both the interview and analytical components, and contemplate future perspectives on the conservation approaches to recycled paint-coated metals in art.

2. INTERVIEW WITH GONÇALO MABUNDA: THE ARTIST, HIS JOURNEY, AND HIS VIEWS

Although the materials we are studying are inherently industrial in nature, as were their original function, it cannot be ignored that they now exist in an entirely different context as contemporary artworks. Modern theories in conservation, such as Muñoz Viñas's "Contemporary Theory of Conservation" (2005), express the importance of other concerns beyond the materiality of the artwork to be preserved; for instance, the artist's intentions, the object's meaning, and the role of the audience must also be taken into consideration. Recognizing this, we facilitated an online interview with the artist (**Figure 7**) to better



Figure 7. Gonçalo Mabunda. Photo from the artist's profile on RDN arts. <https://rdnarts.com/artist/mabunda/>

understand his intentions, creative process, and conservation stance. This would help tailor our scientific investigations' aims and analytical strategies accordingly, aid in understanding the conservation state of his works, and ensure that the artist's intention will be properly respected in developing a conservation approach. The questions were structured following existing guidelines for interviewing artists for conservation research (Sheesley, 2007; Debik and Giering, 2021). The objective of the interview, in addition to learning more about the historical and technical background of the case studies, was to understand Gonçalo Mabunda's philosophies as an artist and his stance on the conservation of his works.

2.1. THE BEGINNING OF MABUNDA'S CAREER

Gonçalo Mabunda was born on January 1, 1975, in Maputo, Mozambique. Mozambique experienced a decade-and-a-half-long Civil War two years after his birth from 1977 to 1992. Growing up amidst the war between different African social factions greatly influenced the art of Mabunda, from his material choices to the topics of his works. His artistic career began when he joined the *Nucleo d'arte* Association in Mozambique as a caretaker. This position allowed him to learn from established artists and launch his career as a visual artist. At *Nucleo d'arte*, he studied the works of renowned artists such as Malangatana Ngweyana, Joan Miró, and Victor Sousa. Mabunda not only gained exposure to their art, but he also received art materials from some of the artists, which helped him practice and improve his skills.

While he initially explored his creativity through painting, Gonçalo Mabunda eventually focused exclusively on creating metal sculptures after assisting South African artist Andries Botha with a project in 1994. After studying and training under Botha, Gonçalo abandoned painting and focused exclusively on metal sculptures from that point forward. He would be internationally known for his throne sculptures (**Figure 9**) made of discarded weapons, making him the first Mozambican artist to participate in the Venice Biennale (Martina, 2020). These unique and thought-provoking sculptures were created as part of a project initiated by the Christian Council of Mozambique in 1995. The council collected weapons from the community and exchanged them for practical tools to promote peace after the devastating war (Baldwin, 2012). Some of these deactivated weapons were then given to artists like Mabunda to challenge them creatively. His works reflect the violence that his country experienced during the war and the struggles it is currently experiencing due to the present political climate in Mozambique. His motto: *“mais balas na arte menos balas na rua”* [more bullets in art, fewer bullets in the streets] (Futuros Criativos, n.d.). His creative activism led to international success, including former US President Bill Clinton's commissioning the artist to make trophies for the 2017 Clinton Global Initiative summit (**Figure 8**).



Figure 8. Mabunda with Bill Clinton, who commissioned the artist to create trophies for the annual Clinton Global Initiative summit in New York. Photo from: Gonçalo Mabunda. *Wikipedia*.



Figure 9. *“O Trono do Mineral.”* (2014). Sculpture by Gonçalo Mabunda. Metals and deactivated weapons. 93 x 78 x 66 cm. Photo provided by Oliva Art Center.

Even though he initially began with painting, he now follows a philosophy of not painting his sculpture works. In his own words: *“Nunca quero pintar. Prefiro não pintar. Pintar não funciona. Para mim, funciona quando é uma coisa que tem uma certa vida que eu não conheço”* [I never want to paint them. I prefer not to paint them. Painting does not work. For me, it works when a thing has a certain life that I do not know about] (full interview transcripts presented in Appendix).

2.2. MULTI-FACETED SCULPTURES: ARTIST’S CREATIVE PROCESS AND VIEWS

Mabunda’s works can be divided into several categories, including thrones, masks, and totems (Figure 10). While they vary in form, they always reflect influences from African culture and identity. Gonçalo Mabunda’s sculptures almost always incorporate anthropomorphic elements. Faces, which are thematic in his metal sculptures, are the focal point of his work. This motif is a manifestation of his artistic style as an African artist. He also uses African tribal elements, such as traditional masks and thrones, to juxtapose his culture’s past and present realities. His works serve as social commentaries on Mozambique’s contemporary political and social climate. Filled with symbolism, his sculptures are multi-faceted in both literal and figurative senses.



Figure 10. Set of images from Mabunda showcasing the various types of sculptures that he makes. There are anthropomorphic sculptures (a & b), masks (c), , and totems (d). Source: Personal communication with Gonçalo Mabunda.

2.2.1. MABUNDA'S CREATIVE PROCESS AND INTENTIONS

Mabunda typically begins his process with a sketch (Figure 11) for certain types of sculptures. However, he acknowledges that he may change his mind during the creation process, especially when working with colored metals. Thus, while he starts by sketching his ideas for his throne sculptures, the colorful sculptures made from various scrap metals are created spontaneously, without a pre-prepared sketch. The only preparatory work he says he probably does for the colored sculptures is planning the colors he needs. Mabunda works in a workshop surrounded by various materials. He finds this environment filled with possibilities, inspiring design changes during creation.

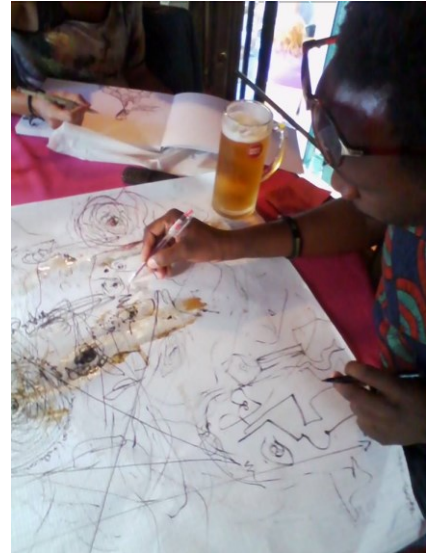


Figure 11. Mabunda sketching out his ideas. Photo from the artist's official website.

Mabunda's deliberate decision not to paint over the gathered scrap metals reflects his ideology that each piece of metal carries its own unique narrative. As an artist, he helps write and tell these stories, even if they are unknown to him. He relies on the original paint coating of the metals to give life and color to his artworks.

Since he works with used scrap metals, some pieces he finds will inevitably be corroded. When asked about the role of corrosion in his work, Mabunda explains that corrosion is an integral part of his aesthetics. Sometimes, he deliberately leaves metal pieces in humid areas to promote rust development. He clarified, however, that while corrosion during the creation process is intentional, any future corrosion that the artwork may undergo is not.

When it comes to cutting metal into the desired shapes, he uses a circular saw. He prefers it over other metal-cutting equipment, such as torches, which can alter the color of the metal. After cutting the pieces, he solders them together to create a cohesive final piece.

Once he completes assembling his sculptures, he cleans (Figure 12) the finished works and applies matte varnish as a protective layer.



Figure 12. From the artist's website with the caption: cleaning the weapons. Photo from the artist's official website. <https://goncalo-mabunda.com/en/case-studies>.

2.2.3. SOCIAL, SOCIO-ECONOMICAL, AND POLITICAL ASPECTS

The richness in meaning does not start and end with the physical elements in his sculptures, which allude to different aspects of life. The creation of his artworks has a social aspect, particularly in sourcing the scrap metal used. The process of collecting the metals also holds some social and socio-economic significance.

The artist often collaborates with his friends and street kids in his town to gather materials for his sculptures. These street kids typically roam around town with their two-wheeled carts called *tchova* to salvage scrap metals for a living. To help these kids, Mabunda purchases his materials from them who usually sell their findings to scrapyards that pay very little. The artist will pay the kids more for their goods, and they, in turn, will help him find specific-colored metals for his sculptures if needs arise. The collaboration in the procurement of materials is also imbued with social and socio-economic meaning. As such, the resulting works of art will often have local, political and social connotations as well.

2.3. EU SOU DAS MASSAS AND DÁ AO POVO O QUE É DO CÉSAR

The case studies, "*Eu sou das massas*" and "*Dá ao povo o que é do César*," are just two of the sculptures Mabunda made while he was in Famalicão, Portugal for an artistic project in 2013. These sculptures were commissioned by José Lima, a prominent Portuguese entrepreneur in the footwear industry and an art collector. They are made from scrap metals that Mabunda collected from the businessman's

pile of old metals from his shoe factory. Old shoe molds that were replaced with the arrival of new types of machinery for shoemaking can also be found in the sculptures.

The sculptures have social and political implications, as indicated by their titles, “*Eu sou das massas*” [I am from the masses] and “*Dá ao povo o que é do César*” [Give to the people what is Caesar’s]. When asked to explain the meaning behind them, the artist stated that the first sculpture represents ordinary individuals like Azagaia¹ (Figure 13) who moved the hearts of the masses by speaking to politicians through his songs. The second sculpture reflects the irony of politics and capitalization of Earth’s resources, which should belong to the people. However, due to the government, only a group of people benefits from Earth’s minerals.



Figure 13. Mozambican activist and rapper Azagaia (1984-2023), a friend of Gonçalo Mabunda. Both artists speak of social justice and political issues through their craft. Photo source: <https://mznews.co.mz/rapper-azagaia-homenageado-pela-unita-no-parlamento-angolano/>

Since he mentioned that he does not paint over the colored metals he collected because they have their own stories to tell, we asked him what these metals from Famalicão say or, rather, what he wanted to convey with them. He said he wanted to pay homage to the workers who had sacrificed much for the company. He is incorporating the lives of people into his work.

¹ Azagaia was a Mozambican rapper and a friend of Mabunda known for his socially and politically charged songs that moved the masses. They had worked together occasionally when the rapper was still alive. Three of his music videos were shot in Mabunda’s house. Mabunda said they were in the same fight. Azagaia died on March 9, 2023 at 38 years old.

The two sculptures will be discussed in more detail in the following chapter as case studies.

2.4. MABUNDA'S STANCE ON THE CONSERVATION OF HIS WORKS

Mabunda believes in a more preventive than a restorative approach to the conservation of his artworks. While he aims to minimize paint loss due to corrosion, he understands that it is inevitable. He believes in maintaining the original color of the scrap metals he uses, as it respects the history and stories they may carry. As a storyteller of untold stories, he never wants to paint over or even repaint his works to recover paint loss.

Given that he works with corroded materials and values the rustic appearance of his works, corrosion poses a significant risk. Corrosion can lead to the detachment of paint layers and eventual paint loss, affecting the overall reading of his sculptures. To hinder further loss, he recommends regular cleaning or dusting of the sculptures of his indoor sculptures and the application of matte varnish as a protective measure against corrosion if collectors so wish to place his works outdoors.

2.5. CONFLICTS IN INTENTIONS AND ACTIONS

It is interesting to note that Mabunda's intentions seem to be paradoxical to his actions. On the one hand, he uses corrosion and respects the losses in life, but on the other hand, he tries to prevent them by applying a protective layer of varnish after completing his work. This paradox is intriguing, as corrosion is a fundamental aspect of his aesthetic approach, which harms the paint coatings. The original paint coating of the scrap metals, which is meant to protect the substrate from corrosion—the very corrosion integral to his works, is also important to the meaning of his works since it tells a story. Corrosion, however, is a process that cannot be reversed or stopped; it can only be slowed down (Artesani et al., 2020). Corrosion will eventually result in the detachment of paint layers and, ultimately, paint loss.

The importance of coatings for him is also evident in his decision not to paint over them and his conscious avoidance of using any cutting equipment that may burn off the coatings and thus affect their colors. This is again contradicted by his use of soldering, which produces tremendous heat to combine the coated metal pieces and discolors the coatings.

One of the reasons for the conflict probably stems from materials (scrap metals) influencing the artist's creative process, intent, and ideas at the beginning (Wharton, 2015). And then, his relationship with his works subsequently changing now that they have been bought by a collector who invests and finds

value in his art (Wharton, 2015). Glenn Wharton, who wrote an insightful article entitled “Artist Intention and the Conservation of Contemporary Art,” has observed in his interviews with artists that their “responses reflected other concerns in their mind, including their present career advancement and their future reputation” (2015, p. 2). Mabunda’s act of placing a protective varnish upon completing his works and suggesting the same when asked how to care for his works may be a manifestation of this. He probably takes into consideration the collectors’ continued enjoyment of his works.

Wharton (2015) also showed instances when artists’ ideas and interests change over time, including how they respond to new circumstances. He concludes that conservation based on understanding artists’ intentions, or however it may be appropriately called, “should be based on an understanding of the complex relationships between ideas in artists’ minds, diverse influences on their work, and the art that they create” (2015, p. 10).

Another reason for the contradiction probably stems from the artist’s incomplete understanding of how his chosen unconventional art materials may behave over time. Varnish, a protective means available to artists to help them protect their works, is meant for traditional artistic media and might not be adequate for repurposed materials. Additionally, the techniques he uses in creating his works might have future consequences for their conservation that he, himself, may not be aware of.

To help gain a better understanding of these unconventional art materials and to provide tools to define a proper conservation strategy, scientific analysis will be employed.

3. THE CASE STUDIES: “EU SOU DAS MASSAS” AND “DÁ AO POVO O QUE É DO CÉSAR”

Das Massas



Figure 14. “*Eu sou das massas.*” (2013) Sculpture by G. Mabunda. Wood, metal, and painted metal. 165 cm x 95 cm x 10 cm.

Do César

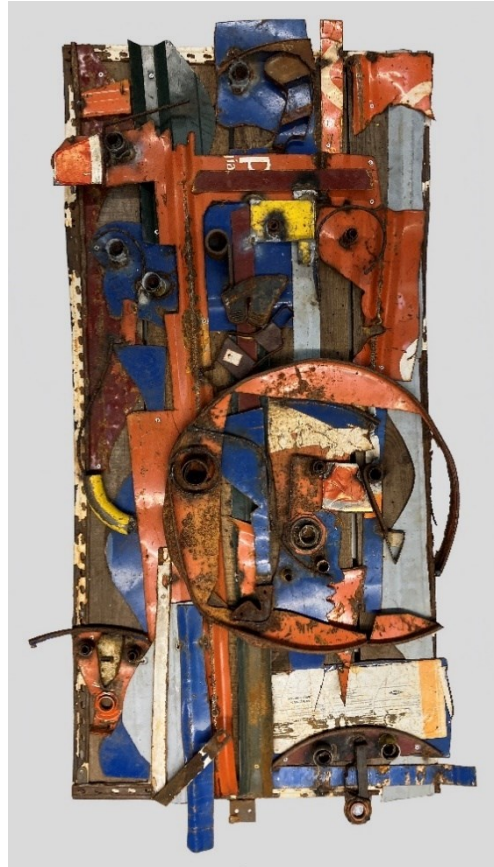


Figure 15. “*Dá ao povo o que é do César.*” (2013) Sculpture by G. Mabunda. Wood, metal, and painted metal. 165 cm x 90 cm x 14 cm.

3.1. DESCRIPTION AND TECHNICAL PROCESS

“*Eu sou das massas*” (Figure 14) and “*Dá ao povo o que é do César*” (Figure 15) are assemblage type of sculptures made in 2013 during the Mozambican artist’s stay in Famalicão, Portugal. They are roughly the same size and are made of different colored scrap metals mounted on wooden supports. The types of scrap metal identified in the sculptures include pieces of orange Galp² steel drum, blue DOW³ steel drum, unlabeled red coated metal drum, cut up yellow aluminum metal pipes, parts of white coated metal rack system, corroding metallic shoe molds, scraps of green roof sheeting, red traffic sign, and corroding iron rods. According to Mabunda, all these materials were sourced from the pile of scrap

² Galp Energia is a Portuguese petroleum company.

³ DOW is an American chemical company based in Michigan, USA.

metals in a shoe factory belonging to José Lima, thus providing clues as to what brands of raw materials may have been used in shoe production practices.

José Lima is an entrepreneur and part of the Lucília, Vieira & Lima, Lda. business, which manufactures a Portuguese shoe brand called *Storm* (Crespo & Dias, 2023). The business and the brand were both established in 2001. Thus, it could probably be assumed that the scrap metals from these works were from approximately the beginning of the year 2000 to 2013.

The found metals in Mabunda's sculptures were haphazardly cut in various shapes and sizes. The metals were joined together by soldering and attached to the wooden support using screws. While most of the metals are dominated by one color, some of them bear a part of a company logo and other markings, such as product descriptions, which are in another color. For example, the scraps of the orange drum will also have a white color from the Galp logo design.

The exposed parts of the scrap metals where paint layers have detached are corroded, contributing to the sculptures' visual aesthetics. Apart from the wooden board on which the metal pieces are mounted, the corrosion of the uncoated part of the metals gives the sculptures their brown color and characteristic rustic appearance. Besides brown corrosion products, white ones were also found around the galvanized metal pipes.

As with his other works, Mabunda did not paint over these two sculptures and thus relied on the original coatings of the materials to bring life to his works. He cut the metals into shapes using a circular saw, an equipment he prefers over other ones that use heat, which damages the color of the coated metals. He then assembled and fixed the pieces into place by soldering pieces together, made evident by the presence of burn marks around the joined areas, and screwing them into panels of wood. After this, he cleaned the finished artwork and put matte varnish as a protective coating for the works.

The assemblages form a series of faces reminiscent of African art. The various colors and shapes of the metals soldered together help make these features stand out, delivering an artist's rendition and "modern incarnations of the African mask," which has great cultural and ceremonial importance across the African continent (Bailey, 2023, par. 5). The styles of the formed shapes and anthropomorphic features are considered modernist, reminiscent of Picasso and Braque (*BIOGRAPHY | Gonçalo Mabunda*, n.d.). The fusion of Western and African influences is evident in his works.

3.2. PROVENANCE, EXHIBITION HISTORY, AND STORAGE

The artworks are owned and were commissioned by José Lima, a Portuguese shoe business owner and art collector (Crespo & Dias, 2023). They are currently part of the Norlinda and José Lima Collection of Modern and Contemporary Art at Centro de Arte Oliva in São João de Madeira, Portugal, and have been in their care since April or May of 2014⁴.

“*Dá ao povo o que é do César*” has been showcased at Centro Cultural de Cascais (Fundação D. Luis I) as part of an exhibition called “Between the words and the silences, works from the Norlinda and José Lima Collection,” curated by Luísa Soares de Oliveira. The exhibition (**Figure 16**) ran from October 30, 2021, to February 6, 2022. As for “*Eu sou das massas*,” it has not been exhibited since it was deposited at the Oliva Museum.

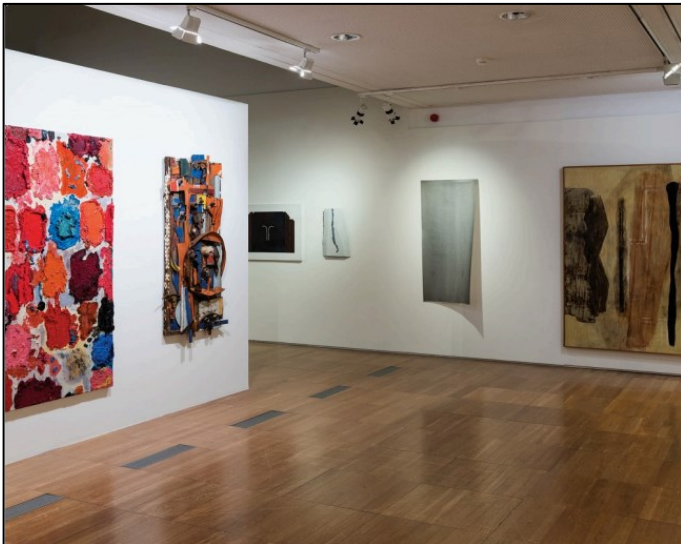


Figure 16. “*Dá ao povo o que é de César*” exhibited at Centro Cultural de Cascais (Fundação D. Luis I). Photo from online flipbook by Fundação D. Luis I. 2021. *Entre as palavras e os silêncios*. FlipHTML5. <https://fliphtml5.com/kyoil/rbor/basic>.

Currently, and when the sculptures are not in exhibition, the sculptures are in Centro de Arte Oliva’s storage. The building that serves as the museum is a former metallurgical plant converted into an art space. According to Dr. Andrea Magalhães, the artistic director of the museum, the storage of the museum was initially designed to house 1,000 objects, with drawings and paintings that can be hung on pull-out racks primarily in mind (personal communication, April 17, 2024). The museum now has over 3,000 artworks (most are long-term loans) that include sculptures and other three-dimensional objects. Due to the big collection and small museum team, Andrea Magalhães has expressed that there are challenges in regularly monitoring the state of each artwork in storage. Usually, an artwork will only be checked when it is about to be exhibited or loaned.

⁴ This information was gathered from the object data sheet from Oliva Art Museum.

Despite the challenges in space, regular monitoring, and manpower, the building itself is equipped with an HVAC system and modern dataloggers from Conserv[®] to ensure that the optimal conditions for storing artworks are met (personal communication, April 17, 2024).

3.3. THE CASE STUDIES & THE DEVESA PARK SCULPTURES: A GLIMPSE INTO THE FUTURE

The two sculptures we are using as case studies are indoor sculptures. While Mabunda was in Famalicão creating these, he also made two other outdoor sculptures. The outdoor sculptures are located at Devesa Park in Famalicão. The sister sculptures, *“Verticalidade”* and *“Surge et Ambula,”* were installed in 2013 to commemorate the first anniversary of the park’s inauguration. They were created for Architect Arminda Costa, the Mayor of Famalicão at the time. They were produced as part of the same project in the same year, using materials from the same pile of scrap metals donated by benefactor José Lima.



Figure 17 and 18. *“Surge et Ambula”* (left) and *“Verticalidade”* (right) by Gonçalo Mabunda. (2013). Devesa Park in Famalicão.

According to the artist, he also applied varnish to these sculptures upon completion. As the outdoor sculptures are of the same materials and are exposed to different environmental conditions, they can provide a glimpse into the accelerated degradation (**Figures 19-22**) of the indoor sculptures. It would be interesting to compare how the materials behave in different environments.



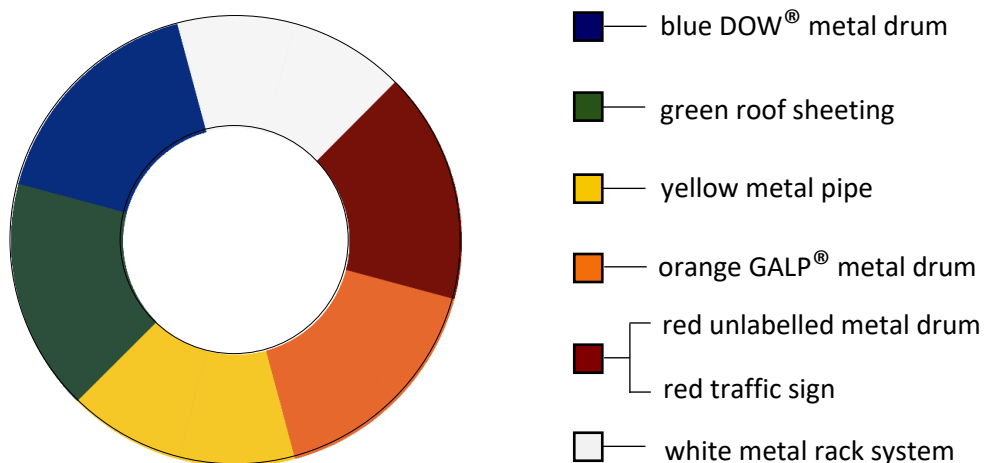
Figures 19, 20, 21, and 22. Close-up picture of the Devesa Garden sculptures to show the extent of degradation.

4. MATERIAL CHARACTERIZATION OF THE PAINT COATINGS

The original coating of the scrap metals is an essential part of Mabunda’s sculptures, facilitating the reading and overall understanding of the artwork. However, the characteristic vivid colors of his sculptures are at risk due to the corrosion of the metal substrate. To better understand the coatings of industrial objects in an art context, we complemented the information gathered through the artist interview by analyzing the components of the coatings in Mabunda’s sculptures using scientific analysis. We analyzed the paint coatings’ pigments, binders, and fillers to characterize them and understand their degradation. Besides studying the components of the paint coatings, we investigated the effects of the corrosion of the metal substrate and the artist’s execution (cutting and soldering) on the paint coatings.

The two sculptures share the same colors, except for the colors from the traffic sign which is present in “*Dá ao povo o que é do César,*” which will now be called “*do César*” for simplicity. A sample of each color from both sculptures was collected. To control the magnitude of the work, we selected a set of samples that are representative of the existing coatings (**Figure 23**).

Figure 23. The colors of paints sampled and the type of object they were from.



The artist’s technique of soldering metal pieces together exposed some parts of the coatings to heat. To compare them to parts not exposed to heat, heat-exposed samples were taken. In total, 15 samples

were collected and examined under optical microscopy for morphological analysis. They were also analyzed using XRF spectroscopy to gather elemental composition information to help in pigment and filler identification, Raman Spectroscopy to identify pigments' molecular fingerprints, and ATR-FTIR to identify the binders molecularly.

Table 1. Location and assigned name to the seven samples taken from *das Massas* sculpture.

Location	Sample ID
blue metal drum	dm_blue
green roof sheeting	dm_green
yellow metal pipe	dm_yellow
yellow metal pipe (heat-exposed)	dm_yellow*
orange metal drum	dm_orange
red metal drum	dm_red
white rack system	dm_white

Table 2. Location and assigned name to the eight samples taken from *do César* sculpture.

Location	Sample ID
blue metal drum	dc_blue
blue metal drum (heat-exposed)	dc_blue*
green roof sheeting	dc_green
yellow metal pipe	dc_yellow
yellow metal pipe (heat-exposed)	dc_yellow*
orange metal drum	dc_orange
red metal drum	dc_red
traffic sign	dc_trafficsign

4.1. ANALYTICAL TECHNIQUES AND INSTRUMENTATIONS

OPTICAL MICROSCOPY

Optical microscopy allows for the visual inspection of small samples taken using visible light and magnification lenses. For our investigation, the morphology of the samples was observed under a LEICA M205 C stereomicroscope with a zoom range between 7.8 x and 160 x. We were able to take micrographs of the samples and also choose which would be beneficial for stratigraphic analysis since most of the samples appeared to have only one layer. Samples that were thought to have multiple layers were mounted on epoxy resin and examined using an Olympus BX51 microscope with Jenoptik ProgRes C5 camera technology.

A handheld digital microscope, Dino-Lite Edge digital microscope, with a magnification range of 20 x to 200 x, was also used for non-destructive local analysis and documentation of the conservation status of the paint coatings on the artworks.

X-RAY FLUORESCENCE SPECTROSCOPY

XRF is an analytical technique that utilizes the interaction of a photo beam, usually X-rays, with a material to determine its elemental composition. The incident radiation causes ionization of the atom's inner shells through the photoelectric effect. The ionized atom returns to its ground state by transitioning electrons from outer to inner shells. The differences in binding energies between the shells involved in these electron transfers result in excess energy, which is often emitted as X-rays. Since each chemical element has distinct binding energy levels, the emitted X-rays are characteristic of that element (Bruker AXS, 2016). These transitions produce X-rays with energies corresponding to the differences between the shells, enabling the identification of each element in the material. Typically, XRF detects elements with $Z > 13$. Being an elemental technique, further information is often needed for the complete characterization of the chemical compounds, thus requiring molecular techniques such as Raman spectroscopy or Fourier transform infrared spectrometry (Wehling et al, 1999).

XRF analysis produces rapid and efficient results, which is ideal for analyzing objects of artistic and historical nature (Janssens et al., 2000). As a non-destructive and multi-elemental technique, it is beneficial to the field of conservation, where the materials to be studied are valuable and made of composite materials. In cases where a sample needs to be taken and prepared to be analyzed, samples as small as 100 μm have been sufficient (Beltran et al., 2015).

XRF analysis was conducted *ex-situ* using an M4 Tornado XRF machine from Bruker Nano GmbH and equipped with a Rh anode X-ray tube coupled to an XFlash[®]SDD detector. Spectra were collected at 50k V and 300 μ for 300 s. Spectra deconvolution, and net peak areas were determined using Bruker's ESPRIT Spectrum software.

RAMAN SPECTROSCOPY

Light can either be absorbed or scattered when it comes into contact with matter. Scattered light is the process used to identify molecules in Raman Spectroscopy, and there are two types. One is Rayleigh, which is an elastic scattering involving only the electron cloud of a molecule without any energy transfer from the incident light; and the other, Raman, a weaker and inelastic scattering process

involving nuclear motion and energy transfer either “from the incident photon to the molecule or from the molecule to the scattered photon” (Smith & Dent, 2005, p. 4). The energy of the scattered light differs from that of the incident light because of these energy transfers. If a molecule absorbs energy and moves to a higher energy state from a ground vibrational state, it is called Stokes scattering. On the other hand, when a molecule that is already in a higher excited state (because of thermal energy) scatters light and moves to a ground energy state, it is called anti-Stoke. Raman analysis usually uses Stokes scattering because of its greater intensity. In this analytical technique, molecules will exhibit characteristic spectral patterns, often called the compound’s fingerprint. These unique spectral patterns are used to identify compounds in Raman analysis (Smith & Dent, 2005).

Like XRF, Raman Spectroscopy is a non-destructive technique that requires little to no sample preparation. This analysis is more efficient for inorganic compounds than organic ones and is often used for pigment identification in art analysis (Vandenabeele et al., 2007). It is advantageous in identifying components of mixtures like paints by offering high spatial resolution, thus enabling the identification of different pigment grains in a sample (Smith & Clark, 2001).

The compounds in the sample were analyzed using a Horiba-Jobin Yvon XploRA™ confocal spectrometer with a 785 nm laser wavelength and 50 x (for the cross sections samples) and 100 x magnification objectives, a 500 µm pinhole, a 300 µm entrance slit, and a 1200 lines/mm diffraction grating. Spectra deconvolution was performed using LabSpec (V5.78) software. Pigments and primer identification were performed using the Spectral ID TM and referenced literature.

ATTENUATED TOTAL REFLECTION - FOURIER TRANSFORM INFRARED SPECTROMETRY (ATR-FTIR)

Infrared Spectroscopy (IR) is another identification technique that relies on molecular vibration. While Raman spectroscopy uses scattered light from a monochromatic source, FTIR measures the range of infrared energy absorbed by a sample (Smith & Dent, 2005). When a certain frequency in the infrared range matches that of a sample's vibrational energy, it will be absorbed, and the molecules of a sample will be promoted to an excited vibrational state (Smith & Dent, 2005). The computing program in infrared spectroscopy will measure this absorbed light and produce a spectrum that will help identify the materials sampled.

A fast and convenient technique used in Infrared Spectroscopy is ATR-FTIR (Specac, 2022). In ATR-FTIR, an evanescent wave is used to measure a material's IR spectrum (Specac, 2022). It is a wave that happens when light is totally reflected in the contact area between two touching objects. A sample is

placed in direct, firm contact with a crystal or prism through which the IR beam will pass. When an IR beam is directed from the prism side, the sample in contact with the prism will absorb this wave, and an attenuated light will be reflected and measured by a spectrometer (Specac, 2022).

IR is best suited for identifying organic compounds. Because of this, it has mainly been used in the area of art conservation to identify binding mediums, which show strong absorption bands, in works of art (Learner, 1998). The challenge with FTIR, as mentioned by Learner, is analyzing samples with multiple components. Pigments and extenders tend to exhibit strong absorption bands, which will also be shown in the analysis. The existence of literature regarding the spectrum of individual pigment and filler would aid in distinguishing the specific spectra of the binder (Learner, 1998).

The FTIR spectra were obtained using a PerkinElmer Precisely Spectrum 100. The spectra were acquired in transmittance mode in the 4000 to 400 cm^{-1} range, with 7 scans at a resolution of 4 cm^{-1} . Afterwards, the spectra were processed using Spectragryph and then analyzed and compared with existing references.

The multi-analytical approach adopted in this study—combining XRF, Raman, and ATR-FTIR spectroscopies—provides a robust framework for characterizing the complex materials present in the coatings. XRF offers elemental composition data, crucial for identifying the pigments and fillers, while Raman spectroscopy provides molecular fingerprints of the pigments. ATR-FTIR complements these techniques by offering insights into the binders and potential organic components, enabling a holistic understanding of the paint's composition and degradation processes.

4.2. RESULTS AND DISCUSSIONS

4.2.1. BLUE COATING

The blue paint coat is the decorative and protective layer on one of the three metal drums found in both of Mabunda's sculptures. The blue barrels were chemical containers from the chemical company DOW.⁵ This was made evident by the partial product description still attached to the barrel. Research attempts and contact with the company were made to investigate the manufacturing details of their steel barrels, but no information was available, and no response was received.

⁵ An American chemical company based in Michigan, USA.

The paint samples (**Figure 24**) were observed under optical microscopy and noted to consist of only one layer. XRF analysis identified copper (Cu) as the key element for pigment identification. The analysis also detected other elements in the samples, namely iron (Fe), barium (Ba), calcium (Ca), sulfur (S), silicon (Si), potassium (K), and strontium (Sr). Fe, which most probably came from the corrosion products littered along the samples, especially on the substrate. Ba, Ca and S, on the other hand, were from the filler component of the paint layer. Fillers are used in paint in large amounts (Kalendova et al., 2006). This explains the higher concentration of filler elements (*e.g.* Ba, S, and Ca) compared to the pigment element (Cu) in the XRF analysis (**Table 3**) of the coating's composition. However, only barium sulfate (BaSO₄) was identified by the ATR-FTIR result (**Figure 25**). It exhibits BaSO₄'s characteristic strong absorption peaks at 1063 cm⁻¹ (with a tail at 1108 cm⁻¹) and at 603 cm⁻¹, and a weaker band at 981 cm⁻¹.

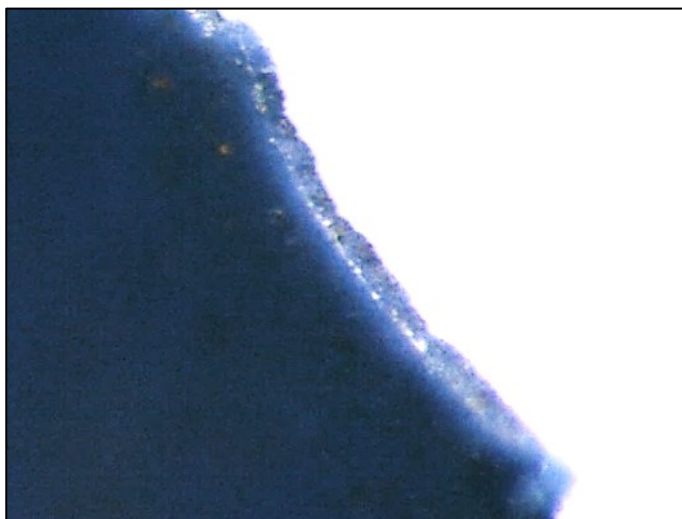


Figure 24. Micrography of the sample dc_blue.

Table 3. XRF Key Elements obtained for the blue samples, and the number of layers observed under stereomicroscope.

Sample	Key Elements	No. of layers
dm_blue	Fe > Si > Ba > Ca >> S > Cu >> K	1
dc_blue	Fe > Ba > Ca >> S > Si > Cu >> K > Sr	1
dc_blue*	Fe > Ba > Ca >> S > Cu > Si >> K > Sr	1

*exposed to heat

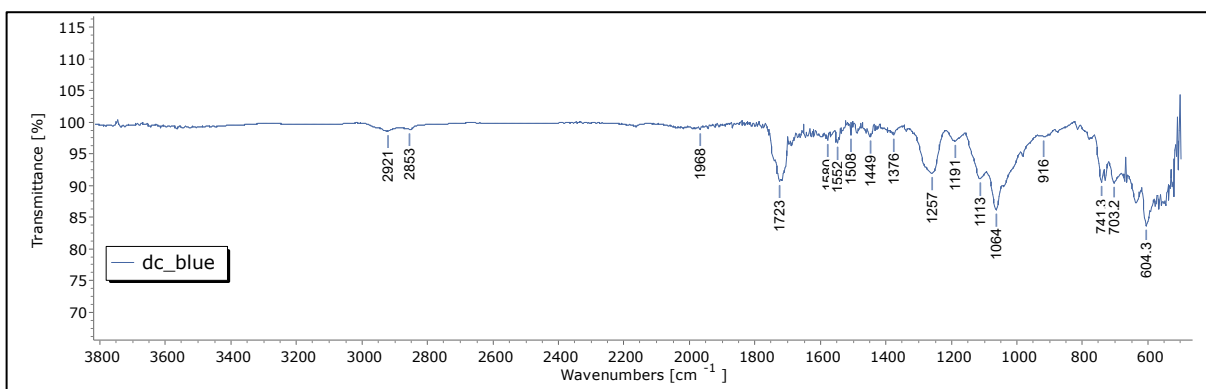


Figure 25. ATR-FTIR Spectrum of dc_blue. The characteristic bands of the alkyd binder (703, 740, 1064, 1113, 1257, and 1723 cm^{-1}), partially masked the bands of the other paint components, such as BaSO_4 (604, 982, 1064, 1113, and 1191 cm^{-1}). Reference spectrum: Alkyd (**Figure 75**), BaSO_4 (**Figure 74**).

Barium sulfate is widely used as an extender in industrial paints due to its low cost and its ability to improve various paint properties, such as ease of production, application properties of the resulting paint film, and storage stability (Kalendova et al., 2006; Beetsma, n.d.). It is chemically inert, insoluble in water, and tends not to form salts, making it an excellent choice for chemical-resistant and anti-corrosive coatings (Palasz, 2023). In addition to these, BaSO_4 also has radiation-shielding properties (Akkurt et al., 2015). Its addition to cotton-polyester fabrics as a coating in tests done (Akkurt et al., 2015) has proven its capability to improve a material's ability to withstand radiation. BaSO_4 also has tremendous heat resistance and is being used in thermal control coatings of spacecraft (Mikhailov et al., 2021). In fact, studies have shown that preheating BaSO_4 powders at 100°C and 400°C improve their optical properties and radiation stability (Mikhailov et al., 2019, 2021). Mikhailov et al. (2019) observed that BaSO_4 begins to lose its reflectance capability and radiation stability at 800°C. The use of BaSO_4 as an opacifying agent (Costantini et al., 2022) and filler agent (Macchia et al., 2023) in paint coatings of historical industrial objects has been reported.

Raman analyses were carried out to identify the structural composition of the pigments. **Figure 26** shows the typical spectrum obtained for the blue coating samples, with strong peaks at around 684, 750, 1342, and 1529 cm^{-1} and weak intensities at approximately 487, 1147, and 1452 cm^{-1} . While referencing the existing Raman pigment database (Caggiani et al., 2016; Price et al., 2009), the collected spectra showed the characteristic vibrational bands for PB15 Copper Phthalocyanine (CuPc) blue. This pigment has been commercially available since 1935 (Lomax, 2005) and has also been found in the coatings of other industrial heritage objects from the 20th century (Gordon, 2022; Tissot et al., 2021).

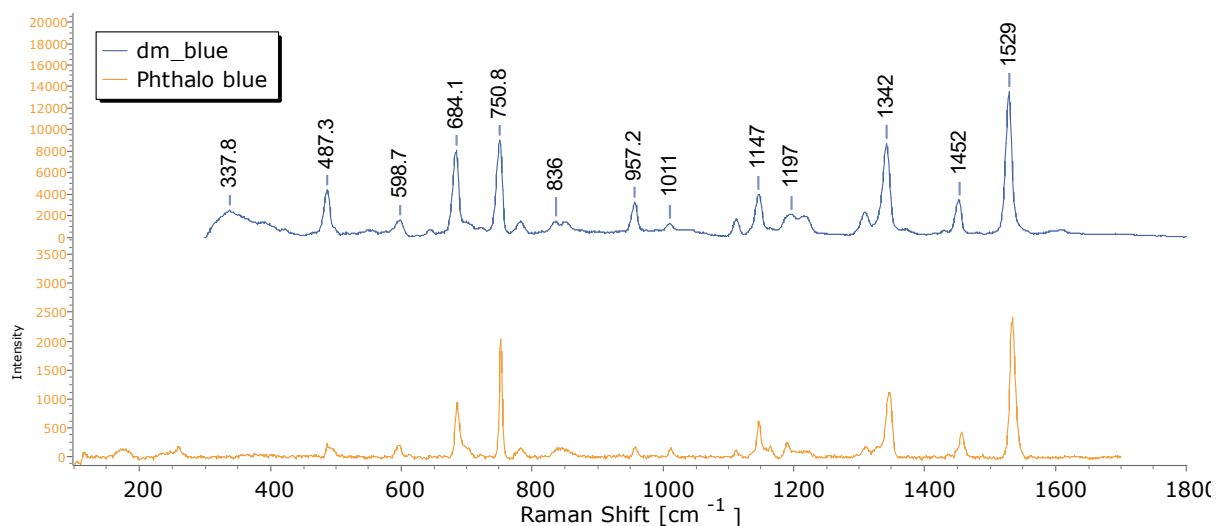


Figure 26. Raman Spectra of dm_blue, which represents the spectra of other blue samples as well, and of phthalocyanine blue from *Pigments Checker* database (Caggiani et al., 2016).

Phthalocyanine-based pigments comprise 90%-95% of blue and green pigment production and are used in the paint, inks, and plastics industry (Lomax, 2005). They are favored for their bright colors with high tinctorial strength, chemical stability, excellent lightfastness, and great resistance to heat up to 500 °C (Gregory, 2000; Tissot et al., 2021). In addition, their corrosion-inhibiting properties (Sastri, 2001) are advantageous for industrial applications. The CuPc blue pigment is considered the most important out of all phthalocyanine derivatives for its bright color and extreme stability (Gregory, 2000).

The ATR-FTIR spectrum (**Figure 25**) also shows significant bands at 703, 740, 1064, 1113, 1257, and 1723 cm^{-1} . The strong carbonyl band at 1723 cm^{-1} suggests that the material is polyester-based (Derrick et al., 1999). The binder was identified as alkyd based on references (Learner, 1998; Bumbac et al., 2017). Alkyds are made up of oil, fatty acids, and alcohol and have been one of the most used binding media for commercial paints since the 1930s (Learner, 1998; Kunduru et al., 2023). Ahmad (2006) lists its main advantages: good resistance to weather, economic value, excellent flexibility, easy application and adhesion to surfaces, and good gloss retention.

Alkyds have the same curing processes as drying oils, wherein the fatty acid portion of the resin auto-oxidizes and then cross-links (Anghelone et al., 2016). Too much cross-linking will make the film brittle (Anghelone et al., 2016). Thermal analysis conducted by Ploeger et al. in 2009 on the oxidative stability of artists' long-oil alkyd paints revealed that the binder undergoes oxidative degradation between 250 °C and 400 °C, while degradation due to combustion occurs beyond 400 °C. Interestingly, despite being

a commonly used binding medium for coatings, alkyd's main disadvantage is its inability to inhibit corrosion (Ahmad, 2006). However, this is where the pigments and fillers lend their properties, such as corrosion inhibitors, to other components like the binder (Ahmad, 2006).

Another element detected by XRF analysis is Sr. In some cases, Sr can be found together with BaSO_4 due to the occasional presence of strontium sulfate in barytes, the mineral form of barium sulfate (Charles et al., 2022). When the mineral is ground during the processing, small amounts of strontium may be integrated into the manufactured filler (Charles et al., 2022). This would probably explain the minor amount of Sr detected by XRF analysis. If the strontium did not originate from the BaSO_4 , another possible explanation could be the presence of calcium in the sample. Calcium-based fillers may contain traces of strontium as well (Namowicz et al., 2008).

Lastly, the still unaddressed elements from the XRF results, traces of Si and K, most likely originated from soil particles on the sample. This can be observed in the image taken through a stereomicroscope (**Figure 27**). While the elements might account for the soil particles, it is also important to note that Si can be used as a matting agent and as a filler to enhance coatings' scratch and abrasion resistance (Xu et al., 2018).

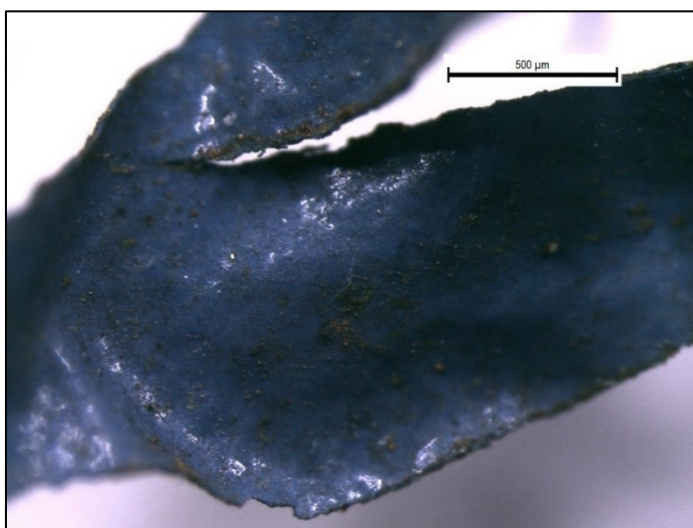


Figure 27. magnified sample of dc_blue* where specks of dirt and rust powder can be seen.

However, in FTIR analysis, the absorption bands of silica could not be detected. They may be hidden by those of other paint components, especially since it is present in small amounts. As a result, compounds containing Si and K may not be easily detected in FTIR analysis without specific extraction techniques (Learner, 1998).

4.2.2. GREEN COATING

The pieces of roof sheeting in Mabunda’s sculptures were coated in green paint. Unlike the coatings of other scrap metals, the green coating on the roof sheeting was strongly adhered to the metal substrate, mostly due to the galvanized steel substrate. Painted steel pre-treated with sacrificial metal coatings (like Zn) has superior corrosion resistance, unlike bare steel (Edavan & Kopinski, 2009). Due to the galvanized substrate, obtaining a sample without causing damage to the artwork was challenging. In fact, a sample (**Figure 28**) was only obtained thanks to the artist’s use of a circular saw to cut the metal pieces. Along the shear zone of the sheeting, there were jagged, thinned, and loose metal pieces with traces of coating. These were taken as samples. Unfortunately, only the sample taken from *das Massas* had traces of coating. The sample from *de César* was just metal.

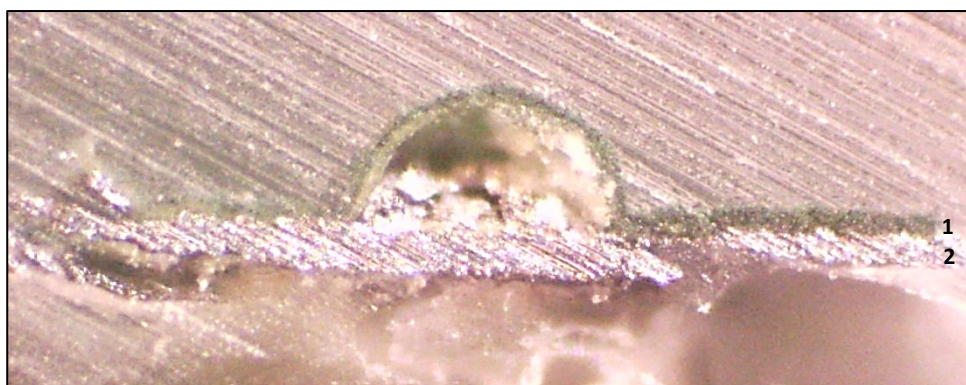


Figure 29. Micrograph of dm_green sample: a piece of metal from das Massas with a layer of green coating on top. 1 - green paint coat; 2- metal substrate.

Table 5. XRF Key Elements obtained for the green samples, and the number of layers observed under stereomicroscope.

Sample	Key Elements	No. of layers
dm_green	Zn >> Fe > Ca > Si > Cr > Mn > Ti > Sr > Pb >> Sr and Cu	1
dc_green	Fe > Zn >> Al >> Si > Mn > Ca	not observed

The XRF key element for this sample was Cu. The Raman spectrum () obtained has bands with strong and medium peaks at 338, 687, 744, 1212, 1286, 1339, and 1539 cm^{-1} . The gathered Raman spectrum matched the reported (Caggiani et al., 2016; Price et al., 2009) bands and their relative intensities of

CuPc, PG7 Phthalocyanine Green. Phthalocyanine green has been reported to be used for corrosion protection, wear resistance, and decoration purposes of several types of industrial machines (Tissot et al. 2024; Costantini et al., 2022; Gordon, 2022).

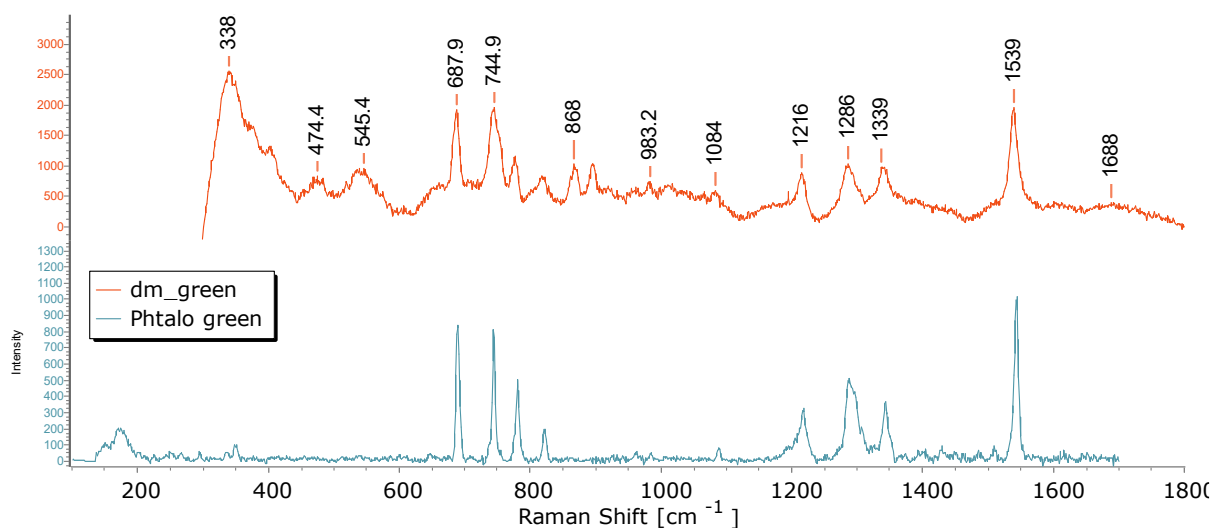


Figure 30. Raman spectrum of dm_green and phtalo green (Caggiani et al., 2016).

Copper phthalocyanine derivative PG7 shares most characteristics with the blue CuPc, but it is heat resistant only up to 150°C (Lomax, 2005). PG7 is known for its high lightfastness in watercolor, oil, acrylic, gouache, and alkyd media and its resistance to weather and solvents. However, its tinting strength is reduced due to halogenation (Lomax, 2005).

The element Ca was found in the paint layer's composition. However, no Ca-based paint additive was definitively identified in the FTIR spectrum (**Figure 31**). Similar to the previous sample, alkyd appears to be the binder for the green coating (1093, 1160, 1230, and 1723 cm⁻¹).

The XRF results revealed that the samples contain Fe and Zn, suggesting that *das Massas'* metal substrate might be zinc-coated or galvanized steel. Similar to the blue coatings, Al, Si, Mn, and K found on the sample are most likely part of the composition of dirt and soil particles found on the samples' surfaces.

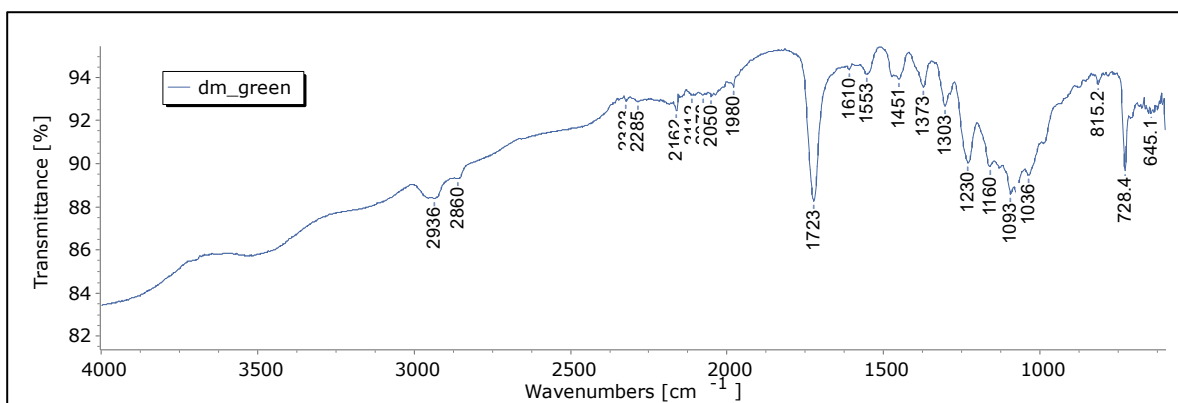


Figure 31. FTIR spectrum of dm_green. A very strong band at 1723 cm⁻¹ could indicate the carbonyl band of a polymer.

These are mere hypotheses based on deducing the elements present in the samples using XRF analysis. A more in-depth examination of the metal alloys, which is not the primary focus of this thesis, would lead to a definitive conclusion.

4.2.3. YELLOW COATING

Samples (**Figure 32**) of yellow coatings were collected from the steel pipes in Mabunda's sculptures. The key identifying elements for the pigment of the yellow samples were Pb and Cr (**Table 6**). The obtained Raman data (**Figure 33**) revealed bands at 340, 360, and 845 cm⁻¹. After analyzing the spectra, the pigments were identified as yellow chrome (PbCrO₄) using Bell et al. (2010)'s Raman Spectroscopic Library for pigments as a reference.

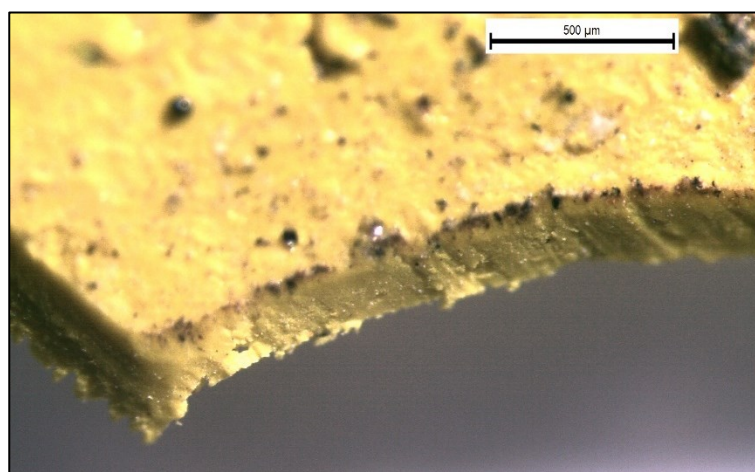


Figure 32. Micrography of dm_yellow.

Table 6. XRF Key Elements obtained for the yellow samples, and the number of layers observed under stereomicroscope.

Sample	Key Elements	No. of layers
dm_yellow	Pb > Ba > Ca > Cr > Zn >> Fe >> Sr > Si	1
dm_yellow*	Pb > Ba > Cr > Ca > Zn >> Fe >> Sr > Si	1
dc_yellow	Pb > Ba > Zn >> Cr > Ca > Fe >> Sr > Si	1
dc_yellow*	Pb > Ba > Ca > Cr >> Zn > Fe >> Sr	1

*exposed to heat

Chromates are an economical choice for preventing corrosion and have been used to protect aluminum, zinc, and steel in water (Sastri, 2001). Yellow chrome (PbCrO_4), specifically, is a synthetic pigment that was made commercially available in the 1830s. However, Cowley (1986) reports that it was not until the 1930s that lead chromate with evident improved durability and lightfastness was developed. This pigment is known for its high opacity, brightness, insolubility in organic solvents, and heat stability up to 240°C (Cowley, 1986). Its use in industrial applications as topcoats for 20th-century historical machines for said properties has been reported (Tissot et al., 2021; Gordon, 2022).

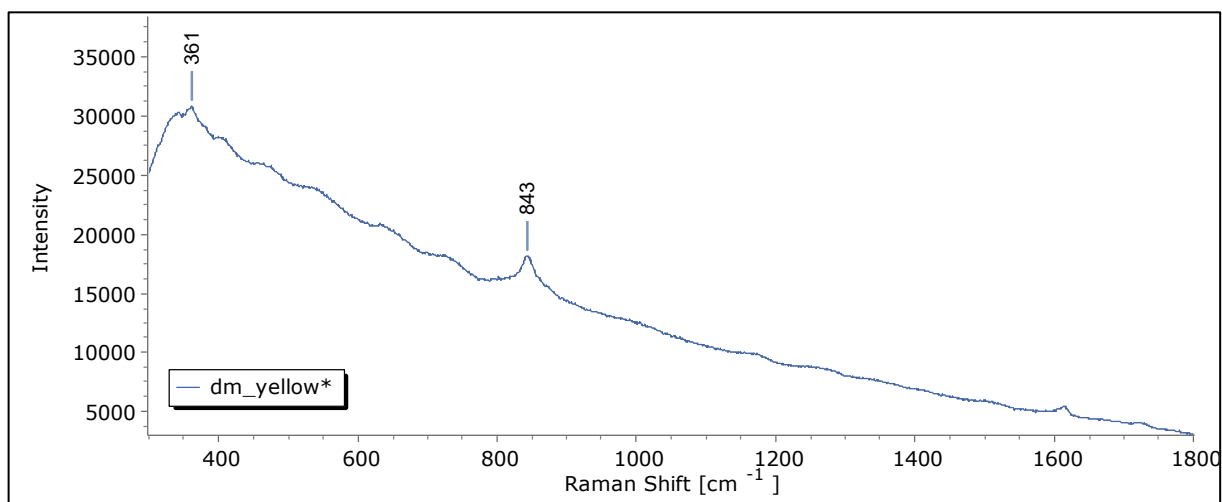


Figure 33. Raman Spectrum of dm_yellow*, which represents the spectra of other samples as well. dc_yellow* did not produce any spectrum. Results showed significant peaks at 340, 360, and 845 cm^{-1} . Reference spectrum: **Figure 68**.

Because of PbCrO_4 's unique characteristics, it has been difficult to completely eliminate its use despite its toxicity (PCI, 2015). As a result, strict legislation and workplace safety regulations have been implemented to ensure the safety of those who handle chromates in their workplaces (Cowley, 1986).

The elements Ba, Ca, and Sr were present in all samples and are likely from the paint filler used for the yellow coating. Based on FTIR analysis (**Figure 34**) and the elements detected in the sample by XRF spectroscopy, it is probable that BaSO_4 was the extender used for these coatings. The binder was identified as alkyd.

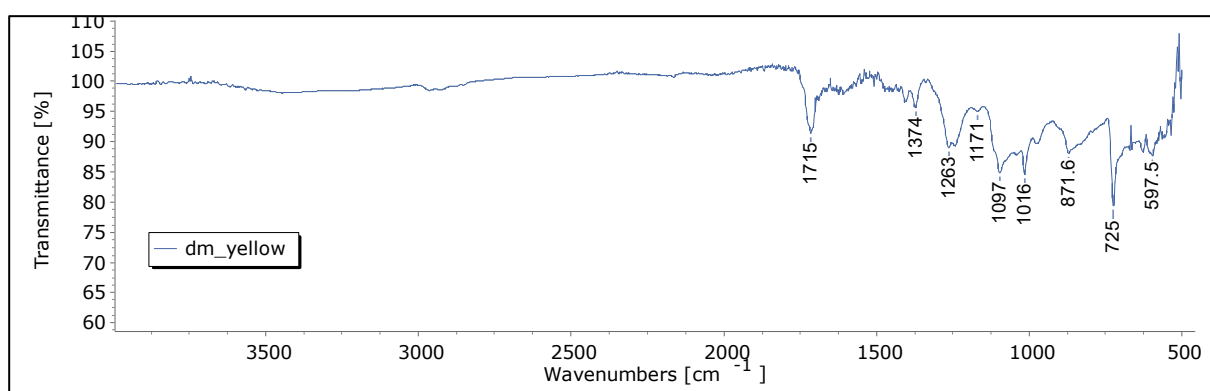


Figure 34. ATR-FTIR spectrum of dm_yellow.

Meanwhile, the presence of Fe and Zn in the XRF results likely indicates the brown and white corrosion products that originated from what appears to be a galvanized steel metal support for the yellow coatings shown in **Figure 35**. Some white and brown powder was deposited across the samples that were taken. The image also shows the influence of heat on the paint layer, where some parts have discolored, bubbled, and, even detached. This will be discussed in more detail on the next section.



Figure 35. Corroded metal with yellow coating from *das Massas* sculpture.

4.2.4. ORANGE COATING

The orange coatings were collected from the second metal drum, which bore the logo of the Portuguese Energy company, Galp. The key elements found in this sample for the pigment were Pb and Cr, with a small amount of Molybdenum (Mo) from the *das Massas* sample. Raman analysis

showed that the compounds have a strong peak at 829 cm^{-1} and a broad peak at 361 cm^{-1} with smaller peaks at 345 cm^{-1} (**Figure 37**). The obtained spectra matched the chrome-yellow orange ($\text{PbCrO}_4\cdot\text{PbO}$) spectrum in Bell et al.'s (2010) Raman Spectroscopic Library for Pigments. It has reportedly been used to coat a 20th-century historical machine (Tissot et al., 2021).

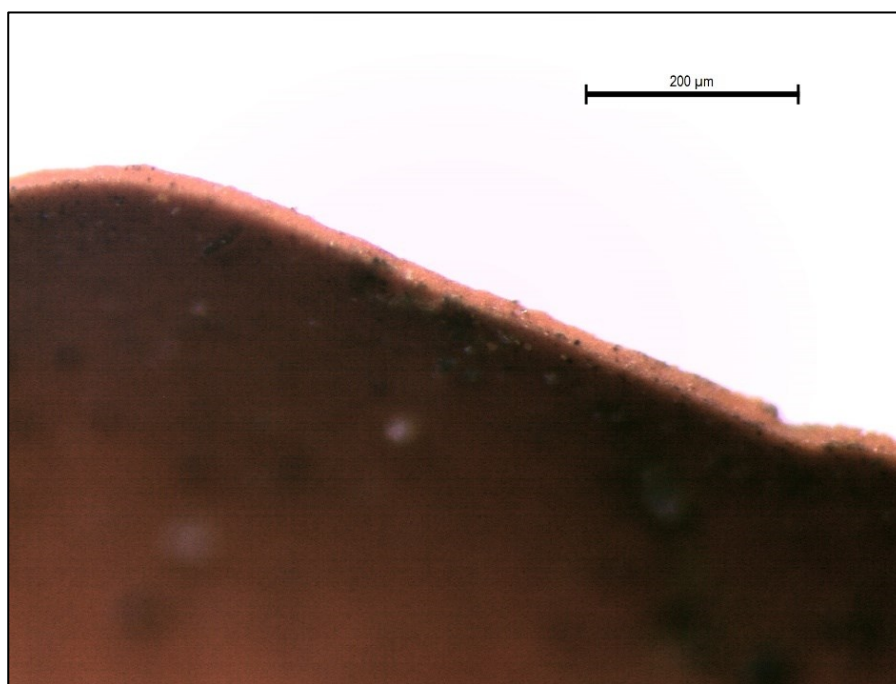


Figure 36. Micrography of dm_orange

Table 7. XRF Key Elements obtained for the orange samples, and the number of layers observed under stereomicroscope.

Sample	Key Elements	No. of layers
dm_orange	Pb > Cr > Fe >> Ba > Ca >> Si > Mo > Sr	1
dc_orange	Pb > Cr > Fe > Si > Ba > Ca >> Sr	1

The trace amount of Mo detected in the XRF analysis of *das Massas'* sample probably contributed to the orange hue of this coating. A little addition of Molybdenum (Mo) to $\text{PbCrO}_4\cdot\text{PbO}$ enables the change of hue of the pigment from yellow until red (Cowley, 1986). Mo salts are also known as corrosion inhibitors (Sastri, 1998).

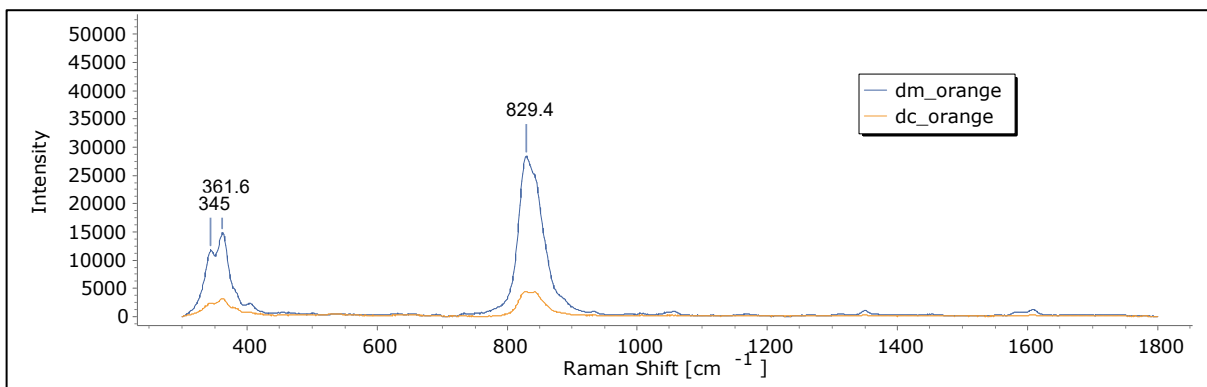


Figure 37. Raman Spectra of the orange coatings. Results show significant peaks at 345, 361, and 829 cm^{-1} . Reference Spectrum: **Figure 69**.

Once again, the sample contained Ba, Ca, Sr, Si, and Fe. The detection of the last element likely accounts for the presence of iron corrosion product on the sample's surface, while Ba suggests the presence of BaSO_4 in the paint layer as a filler. The other components could not be confidently identified from the obtained FTIR spectra (**Figure 38**). However, it appears that alkyd (703, 741, 1064, 1111, 1256, 1721 cm^{-1}) was again the binding medium for the orange coatings.

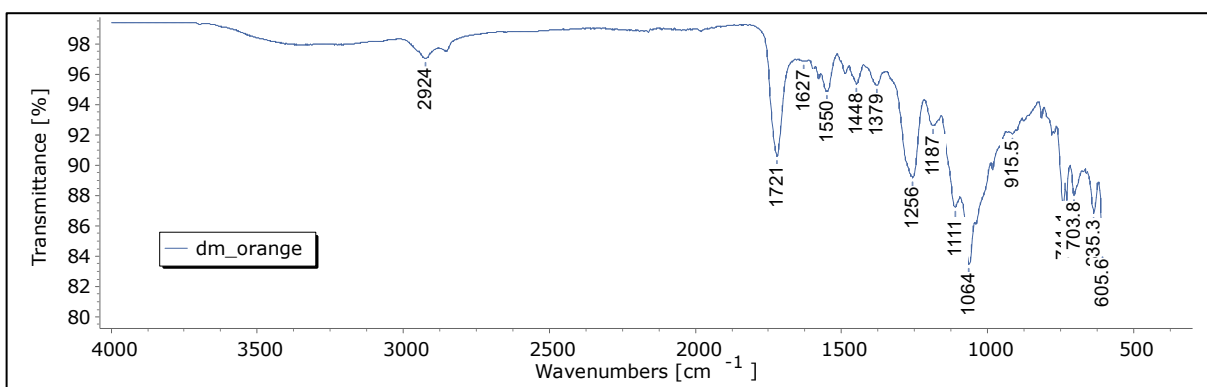


Figure 38. ATR-FTIR bands from dm_orange sample.

4.2.5. WHITE COATING

The white coating was on the edges of the sculptures and acted as a frame for them. It was the coating of what appeared to be a part of a racking or shelving system. The cross-section (**Figure 39**) of the sample was observed under an optical microscope to observe the effects of corrosion on the coating,

which was stained with rust. However, despite their presence on the surface of the paint, no migration of corrosion products into the paint layer was observed.



Figure 39. Cross-section of dm_white under stereomicroscope.

Table 8. XRF Key Elements obtained for the white sample, and the number of layers observed under stereomicroscope.

Sample	Key Elements	No. of layers
dm_white	Ti >> Ca > Fe > Ba > Si > S >> Sr	1

The XRF results (**Table 8**) showed that the main element in the sample was Titanium (Ti), suggesting that the pigment would be titanium white (TiO₂). Titanium white has three forms, but only two are used as pigments, anatase and rutile (CAMEO, 2022). Raman analysis helped identify which of the two forms it was. The Raman spectrum showed strong peaks at 452 and 614 cm⁻¹ (**Figure 40**). Based on this information, the pigment was identified as the rutile form of Titanium dioxide (TiO₂). Its use as an opacifying agent in industrial applications for 20th-century heritage bridges has been reported (Costantini et al., 2022).

Rutile is the more stable and durable form of the pigment (Oldring, 2003; Pfaff, 2022). Although it was discovered years earlier, its high price meant that TiO₂ only began to be widely used in the 1930s (Oldring, 2003). It is considered to have twice the hiding power and tinting strength of other white pigments (Oldring, 2003). Rutile has excellent chemical and heat stability due to its highly stable crystalline structure (Zhou et al., 2022). Titanium white has been observed to decompose at 453-498 °C (Ploeger et al., 2009).

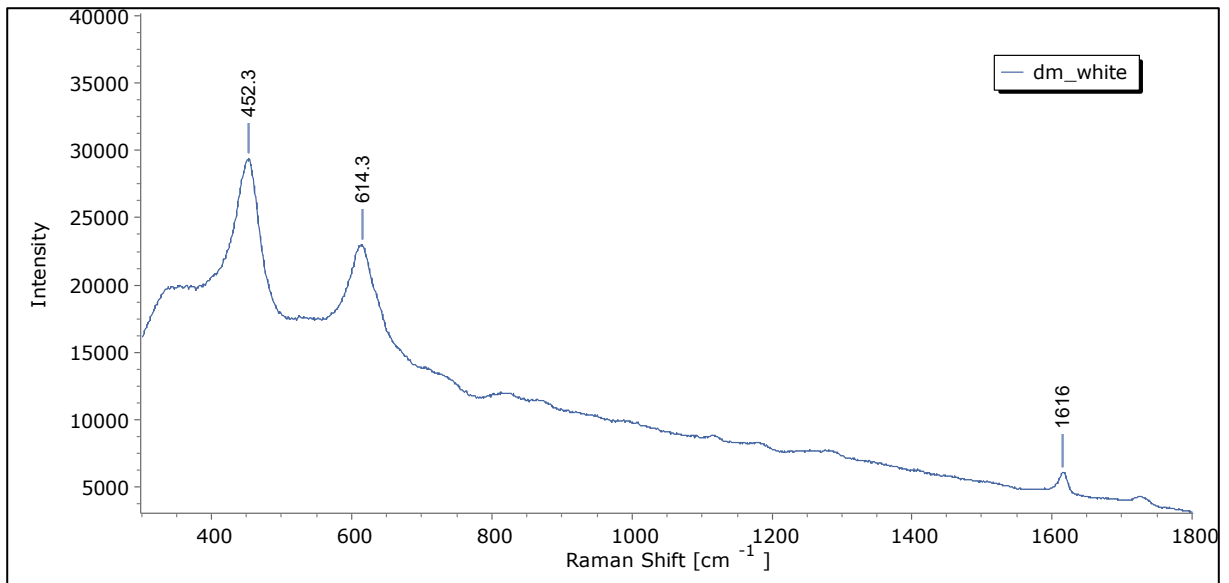


Figure 40. Raman spectrum of dm_white. Significant bands at 452 and 614 cm^{-1} . Reference spectrum: **Figure 70**

Once again, this sample contained elements often found in fillers, like Ca, Ba, and Sr. The paint layer may comprise calcite (CaCO_3), as indicated by FTIR absorption bands at 712, 874, and 1407 cm^{-1} (**Figure 41**), and possibly BaSO_4 , based on the presence of Ba in the XRF results.

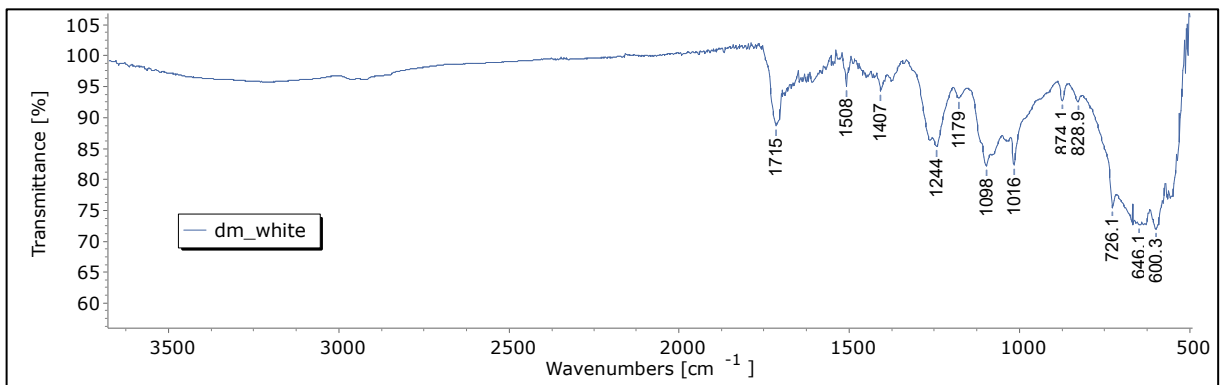


Figure 41. FTIR Spectrum of dm_white. The stronger bands of the binder probably masked some of the bands of calcite (particularly the one at 712 cm^{-1}). Reference spectrum for calcite: **Figure 76**.

Calcium carbonate (CaCO_3) is commonly used as a filler in polymers because it is abundant in nature and has favorable properties, such as being non-toxic (Othon & Paynter, 2017). Calcite was observed to decompose rapidly beyond 750°C (Karunadasa et al., 2019).

Regarding the presence of other elements detected by XRF analysis, Si and Fe probably correspond to dirt particles and iron-based corrosion products like oxides and hydroxides, respectively. Alkyd might be the binder once more.

4.2.6. RED COATING

The red samples from the third and last metal drum in Mabunda's sculptures were analyzed and found to be composed of two different pigments. The key element (**Table 9**) in *das massas'* red coating (sample dm_red [**Figure 42**]) is Iron (Fe). Raman spectroscopy revealed bands at 410 and 613 cm^{-1} from the sample (**Figure 43**). However, the collected spectra only covered the wavelength range from 300 to 1800 cm^{-1} . The spectra's bands seem to partially match the Raman bands of iron oxide, typically found around the 226, 292, 411, 496, and 611 cm^{-1} regions (Price et al., 2009).

Iron oxides are known for their excellent opacity, colorfastness, and high durability. They are resistant to alkalis and chemicals (Ryntz, 2007), as well as heat-resistant up to 1200 °C in air (Pfaff, 2021; Tissot et al., 2021). Its use in coating heat-generating historical engines has been reported (Tissot et al., 2021). Although they may have a dull color typical of inorganic pigments (Abel, 1999), they are utilized as shading colors for their strong tinting properties (Ryntz, 2007).

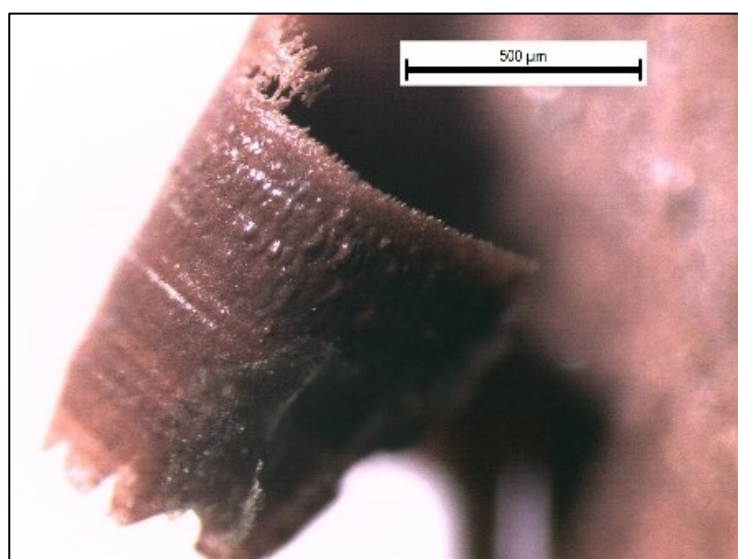


Figure 42. micrography of dm_red.

Table 9. XRF Key Elements obtained for the red samples, and the number of layers observed under stereomicroscope.

Sample	Key Elements	No. of layers
dm_red	Fe > Ca > Ti >> Si > K >> Sr	1
dc_red	Fe > Ca > Si >> Ba > Pb > Cr > Mn >> Sr > K	2

The FTIR spectrum for dm_red (**Figure 44**) shows an unusually very strong absorption band at 1686 cm^{-1} . The material that could have this characteristic band could not be identified. The spectrum also exhibits three other strong bands at 1722, 1241, and 1062 cm^{-1} , which could be associated with polyesters (Smith, 2022). The specific binder of the coating could not also be confidently identified; it could be either acrylic or alkyd resin.

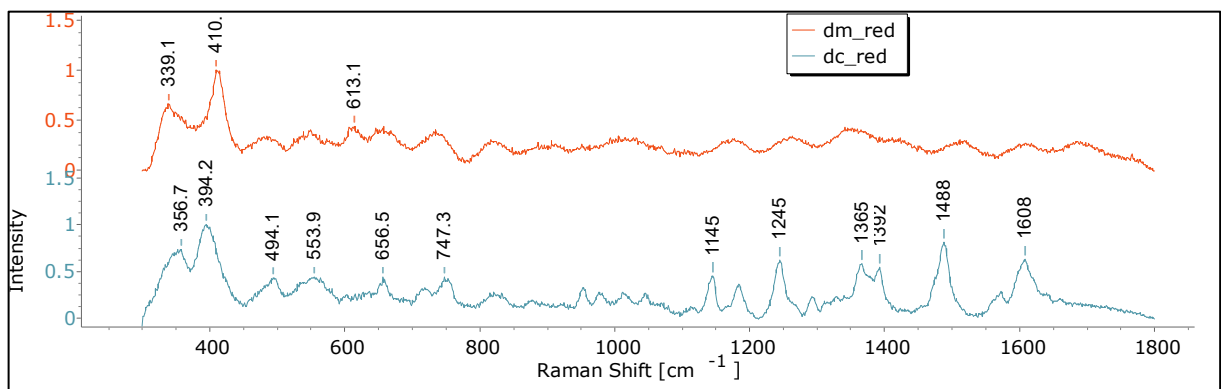


Figure 43. Raman spectra of dm_red and dc_red. The two samples have different Raman shifts, indicating they are made up of different molecular compounds and are not the same pigment. The former is identified as red iron oxide and the latter as PR48:2 Bon Azo red through reference (Price et. al, 2014). Reference spectra for iron oxide (**Figure 72**) and PR48:2 BON Azo red (**Figure 73**).

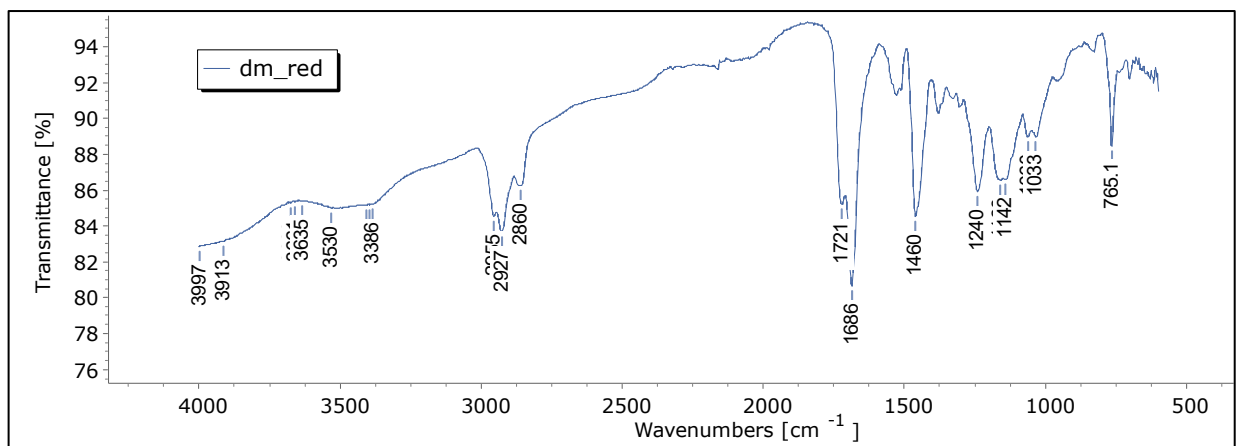


Figure 44. ATR-FTIR Spectrum of dm_red.

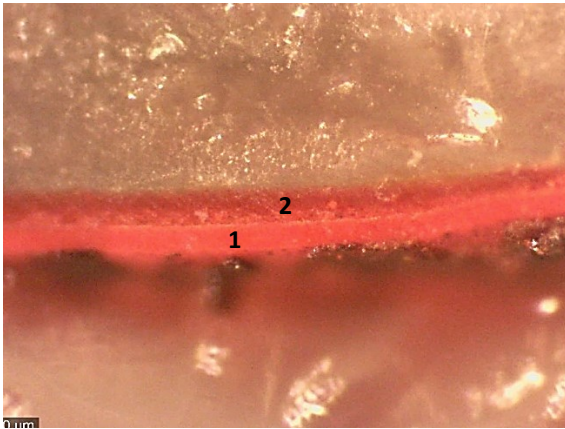


Figure 45. Cross-section of dc_red. The two layers were identified as BON Azo red pigment.

While all the previously mentioned samples only had one layer of paint, the red coating sampled from *do César* has two paint layers. The key elements in dc_red were Ca, Ba, and Mn. Raman analyses for both layers reveal characteristic bands at 394, 494, 553, 656, 747, 1145, 1245, 1365, 1488, and 1608 cm^{-1} (**Figure 43**), suggesting the pigment as Permanent Red 48:2 BON Azo (Price et al., 2009). It is typically a metal salt of either calcium, barium, or manganese. The Ca, Ba, and Mn present in the XRF analysis supported this finding.

Berrie and Lomax (1997) reported BON Azo to have a very good (scored 4 out of 5, 5 being excellent) resistance to ethanol, 2-Ethoxyethanol, and xylene despite being part of the monoazo class known for poor solvent fastness (Abel, 1999; Berrie & Lomax, 1997). Although it has very low solubility in water, it shows fair resistance to hydrochloric acid. Additionally, this pigment can withstand temperatures up to 130°C and has very good lightfastness (Berrie & Lomax, 1997).

With regards to other paint components, the FTIR absorption bands at 708, 741, 1068, 1112, 1257, and 1718 cm^{-1} suggest that the binding medium for this sample was alkyd (**Figure 46**). Based on Ba in XRF analysis, the filler might be BaSO_4 , but its absorption bands are likely masked, so it may not be detected in the FTIR spectrum collected.

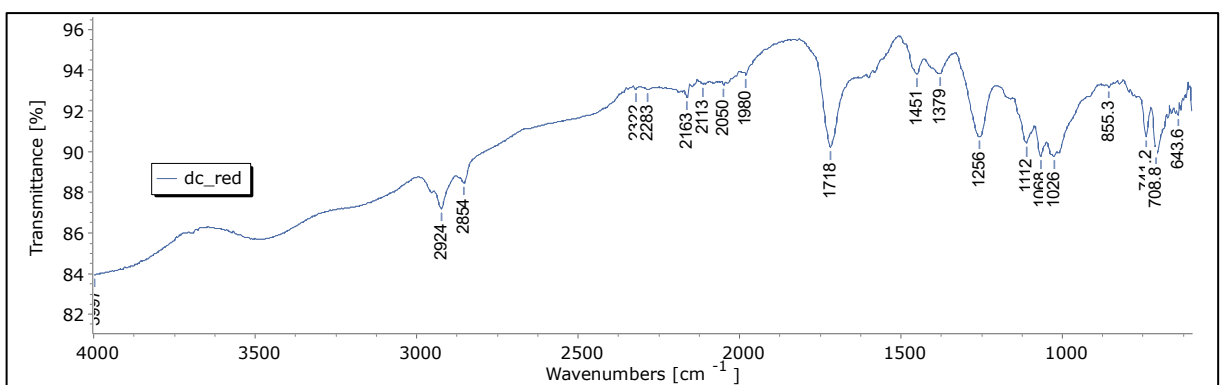


Figure 46. FTIR Spectrum of dc_red. The bands of alkyd resin in the fingerprint region (708, 741, 1068, 1112, 1257, and 1718 cm^{-1}) could be observed in the obtained spectrum.

4.2.7. RETROREFLECTIVE COATING

The last coating is an intriguing multi-system coating sampled from *do César*. The sample (**Figure 47**) was taken from what was most likely a piece of a traffic sign (**Figure 48**), which is primarily designed to warn or instruct drivers. Therefore, it has highly reflective properties so that it may be visible day and night. The red color, a universal color to issue danger and warning, indicates that this could have been a part of a stop sign or other signs that require attention or a full stop action.

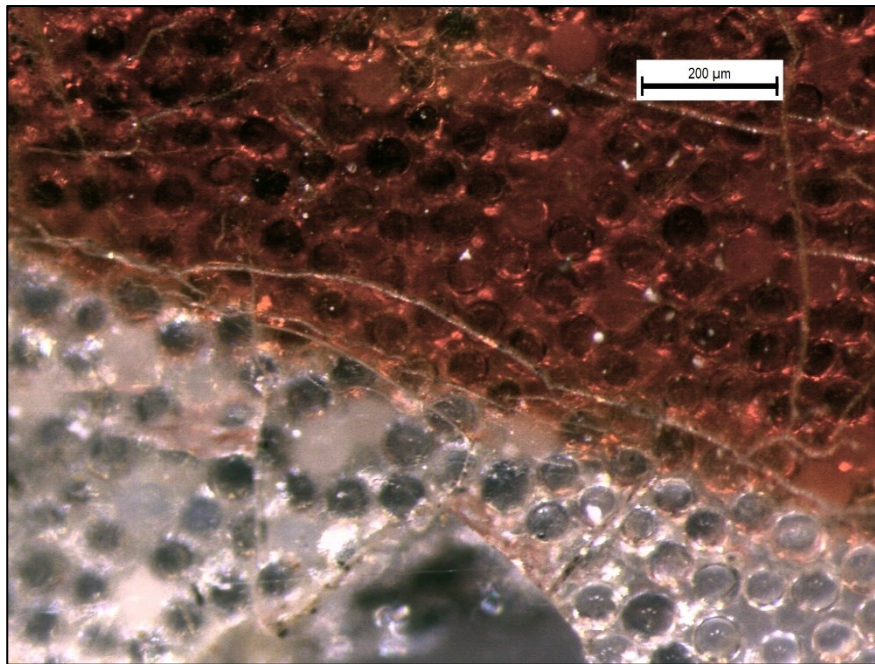


Figure 47. Micrography of dc_trafficsign.

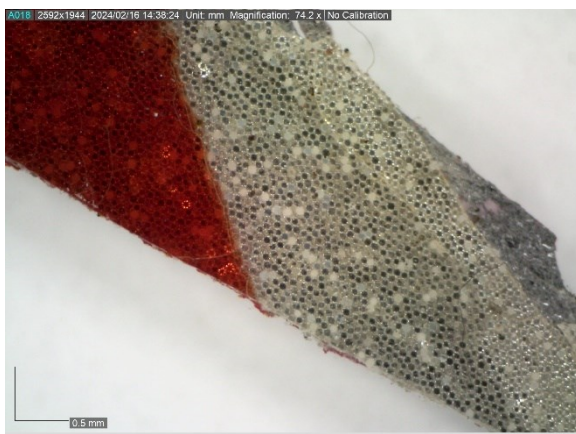


Figure 48. dc_trafficsign under digital microscope.



Figure 49. Cross section of the red part of the sample taken from the traffic sign. 1- layer of circular beads; 2- transparent adhesive layer; 3- white layer, 4- red layer, and 5- yellow layer.

The coating consists of 5 distinct layers (**Figure 49**): a layer of circular beads, a transparent layer, and a layer each of white, red, and yellow color. It likely also has a transparent topcoat, which was visible under the microscope and the naked eye but may have been made indistinguishable due to the transparent resin on which the sample was mounted for cross-section analysis. Based on morphological analysis, the coating was identified as a retroreflective sheeting.

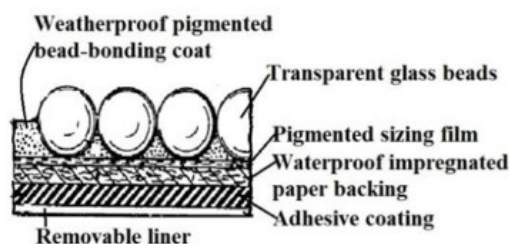


Figure 50. Cross-sectional view of retroreflective sheeting.

Source: Heltzer & Clarke (1940), as cited by (Khrapova, 2023).

The XRF data (**Table 10**) revealed that the complex material contained Ba, Zn, Si, Fe, Ca, Sr, and Pb. Si is one of the major components in the coatings. So far, this element has only been present in minor amounts in other samples, which is a stark contrast and makes this coating greatly unlike the others. The high amount of Si in this coating is most likely responsible for its highly reflective property, a property not present in the previously characterized paint coatings. The Si in the coatings led us to believe that the circular beads on the top layer, which did not produce any Raman signal, are probably silica glass beads (**Figure 50**). Glass beads in road signs were first used in the 1930s (Khrapova, 2023).

Table 10. XRF Key Elements obtained for the traffic sign sample, and the number of layers observed under stereomicroscope.

Sample	Key Elements	No. of layers
dc_trafficsign	Ba >> Zn > Si > Fe > Ca > Sr > Pb	5

Meanwhile, the red layer is composed of PR48:2 Azo Red (bands at 493, 751, 1238, 1362, 1488, and 1597 cm^{-1}) and lead chromate (PbCrO_4) pigments (bands at 360 and 840 cm^{-1}), as identified by the characteristic Raman bands (**Figure 51**) and the detected elements in XRF analysis.

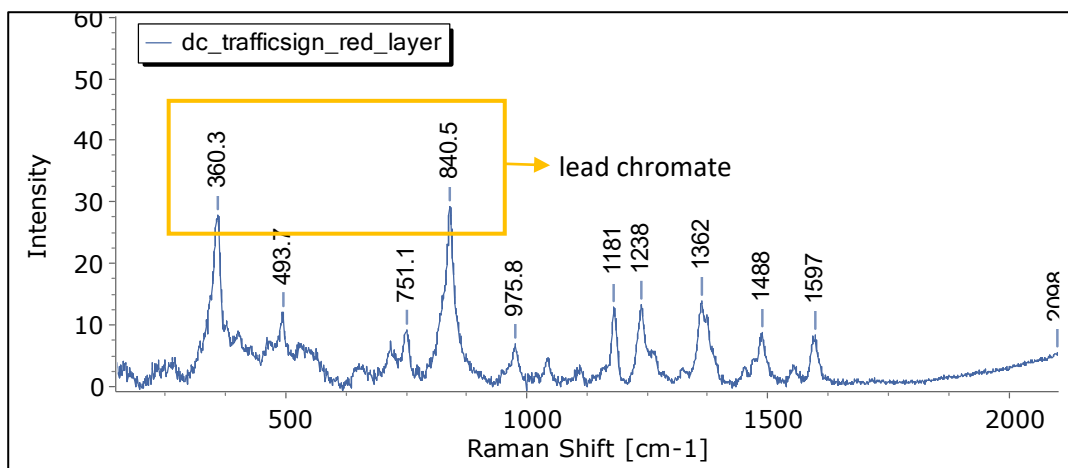


Figure 51. Raman Spectrum of the red layer in the traffic sign. A mixture of lead chromate and BON Azo red had been identified. The Raman bands at 360 and 840 cm^{-1} match the reference spectra for yellow chrome (Bell et al., 2010 [Figure 68]), while the other shifts match the reference spectra for PR48:2 Azo Red (Price et al., 2014 [Figure 73]).

In the yellow layer, pigment goethite (Raman bands at 392 and 553 cm^{-1} [Figure 52]) had been identified through reference (Holclajtner-Antunović et al., 2015). Natural goethite, otherwise known as iron (III) oxyhydroxide ($\alpha\text{-FeOOH}$) or ochre, has been used as a pigment since pre-historic times (Böhland et al., 2005). Iron oxide hydroxide pigments are considered important due to their economic value, optical properties, chemical stability, and non-toxicity. The pigment is used for exterior and interior painting in construction (Streltsova et al., 2013). When heated between 140°C and 500°C, iron oxide hydroxides lose water and can be converted to red iron oxides such as hematite or maghemite (Mayhew et al., 2014). It's use in industrial heritage coatings have been speculated (Macchia et al., 2023)

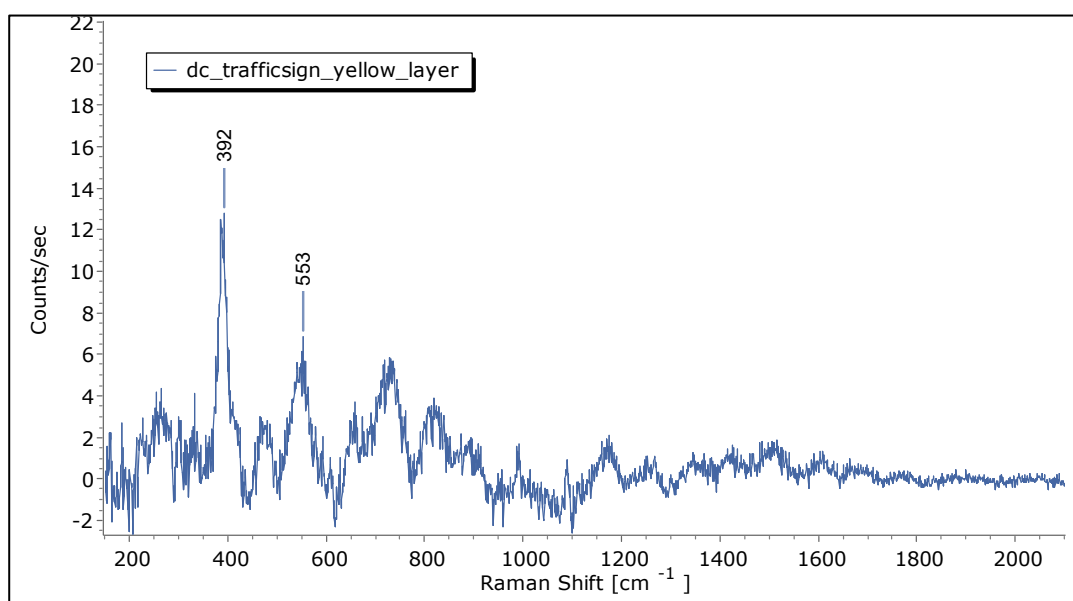


Figure 52. Raman Spectrum of the yellow layer in the traffic sign. Reference spectrum: Figure 71.

The sample's surface was also subjected to ATR-FTIR analysis to identify the fillers and binders in the coating. The characteristic peaks, FTIR bands at 733, 1017, 1238, 1264, 1406, and 1727 cm^{-1} (**Figure 53**), seem to correspond to the IR spectrum of a polyethylene terephthalate (PET) material (Price et al., 2014). A transparent layer of plastic is typically used to protect the topmost layer of the retroreflective sheeting from rain and dirt, as these elements reduce the reflectivity of exposed glass beads (Khrapova, 2023).

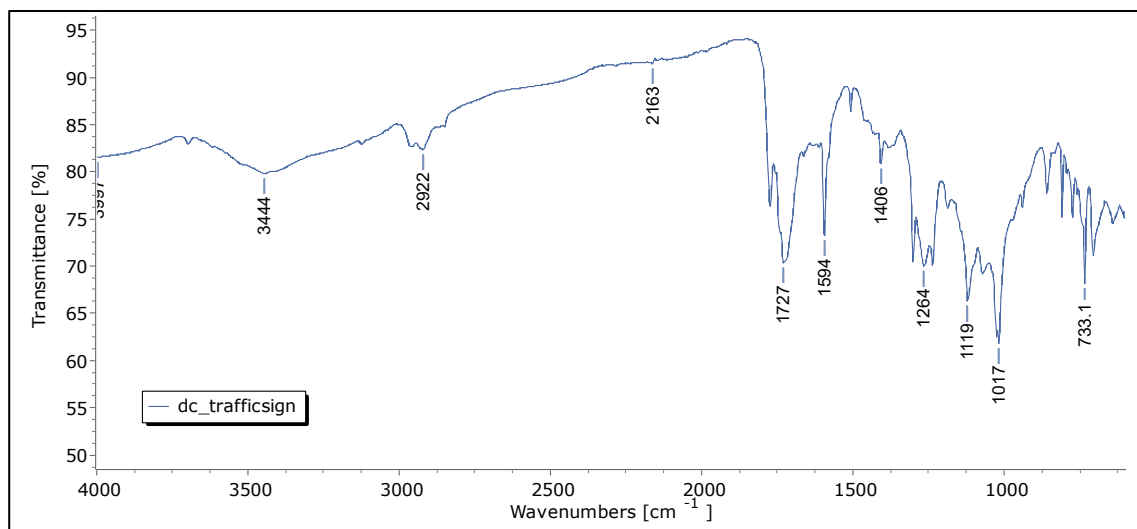


Figure 53. FTIR Spectra of the retro-reflective sheet. Reference spectrum for PET film: **Figure 77**

Due to time constraints, the sample's cross-section was not analyzed, and the material for each layer remains to be identified. Despite this, the coating taken from what is presumed to be a traffic sign evidently presents an entirely different kind of coating that sets it apart from the other coatings found in Mabunda's sculptures. It consists of multiple layers made of different materials, with the most characteristic layer being silica glass beads on the topmost layer. To the best of our knowledge, this is the first time that this type of material has been materially characterized in the context of a contemporary work of art.

To summarize the findings gathered from the analyses, **Table 11** lists all the samples taken and the corresponding key elements, pigments, binders, and fillers identified from each. Pigments were conclusively identified thanks to the homogeneity of the pigments in the samples, the ability of XRF analysis to identify the key elements in the sample, and the ability of Raman spectroscopy to analyze pigment grains. While the majority of the binders and fillers have been identified through XRF and ATR-FTIR analyses, a few remain inconclusive due to the absorption bands of other components in the

samples showing in the analysis and masking other bands, thus inhibiting a confident identification of some components. Nevertheless, the analyses produced good results overall.

Table 12 compiles the general characteristics of the pigments discussed in the previous sections to organize all the information gathered about the pigments. This table was mainly adapted from Abel's (1999) comprehensive data about the general properties of different pigment types. It is modified with some information from Barrie and Lomax (1997). Details about the specific temperature range the pigments could withstand are also added, as they will be helpful references for the next section of this chapter. The next section will discuss heat-related degradation of the paint coatings and will refer to the information about the heat stability of some components collated on the next page. For this same reason, **Table 13** was made to compile information regarding the heat stability of the identified filler and binder components.

Table 12 shows that different pigments have different levels of heat stability. Some can withstand heat of up to 1000°C, while others will start to degrade below 200°C. In contrast, **Table 13** shows that the identified fillers have higher resistance to heat than almost all the identified pigments. The binder component, alkyd resin, on the other hand, degrades at 250°C. This information has implications for the degradation of a paint coating, which is comprised of different components, when heat is applied. These will be analyzed and explored in the next section.

Table 11. Summary of results.

Coating	Sample	Elements	Pigment(s)	Binder	Filler
blue metal drum ⁺	dm_blue	Fe, Si, Ba, Ca, S, Cu, K	phthalo blue	alkyd	barium sulphate
	dc_blue	Fe, Ba, Ca, S, Si, Cu, K, Sr	phthalo blue	alkyd	barium sulphate
	dc_blue*	Fe, Ba, Ca, S, Cu, Si, K, Sr	phthalo blue	alkyd	barium sulphate
green roof sheeting ⁺	dm_green	Zn, Fe, Ca, Si, Cr, Mn, Ti, Sr, Pb, Cu	phthalo green	alkyd	barium sulphate
	dc_green	Fe, Zn, Al, Si, Mn, Ca	<i>n/a</i>	<i>n/a</i>	<i>n/a</i>
yellow metal pipe ⁺	dm_yellow	Pb, Ba, Ca, Cr, Zn, Fe, Sr, Si	chrome yellow	alkyd	barium sulphate
	dm_yellow*	Pb, Ba, Cr, Ca, Zn, Fe, Sr, Si	chrome yellow	alkyd	barium sulphate
	dc_yellow	Pb, Ba, Zn, Cr, Ca, Fe, Sr, Si	chrome yellow	alkyd	barium sulphate
	dc_yellow*	Pb, Ba, Ca, Cr, Zn, Fe, Sr	<i>n/a</i>	alkyd	barium sulphate
orange metal drum ⁺	dm_orange	Pb, Cr, Fe, Ba, Ca, Si, Mo, Sr	chrome yellow orange	alkyd	barium sulphate
	dc_orange	Pb, Cr, Fe, Si, Ba, Ca, Sr	chrome yellow orange	alkyd	barium sulphate
white metal rack ⁺	dm_white	Ti, Ca, Fe, Ba, Si, S, Sr	titanium white	alkyd?	calcite and barium sulphate?
red metal drum ⁺	dm_red	Fe, Ca, Ti, Si, K, Sr	red iron oxide	alkyd? or acrylic?	?
	dc_red	Fe, Ca, Si, Ba, Pb, Cr, Mn, Sr, K	BON Azo red	alkyd	barium sulphate
retroreflective sheet traffic sign ⁺	dc_trafficsign	Ba, Zn, Si, Fe, Ca, Sr, Pb	red layer: monoazo red & chrome yellow yellow layer: goethite		

Legend: * sample exposed to heat
⁺ type/function of the coated metal support
n/a no Raman and FTIR signal was obtained
? inconclusive

Table 12. General properties⁷ of chemical pigment type found in Mabunda’s sculptures

Properties in Paint	phthalocyanine	lead chromate	titanium dioxide	iron oxide	BON Azo
color	E	E	E	F	E
opacity	P	E	E	E	F-G
tinting strength	E	F	E	F	F-G
heat stability up to	500°C (blue) ⁸ 150°C (PG7) ⁹	240°C ¹⁰	453-498°C ¹¹	1200 °C ¹² 140°C-500°C ¹³	130°C ¹⁴
solvent fastness	E	E	E	E	E
resistance to					
acids	E	F-G	E	E	F
alkalis	E	P	E	E	E
chemicals	E	G	E	E	<i>n.a.</i>
lightfastness	E	G	E	E	E
price	low-medium	low	low	low	medium-high

Legend: P Poor
F Fair
G Good
E Excellent

Table 13. Thermal stability of other paint components identified in Mabunda’s sculptures

coating component	heat stability	reference
barium sulphate	up to 800°C	(Mikhailov et al., 2019)
calcite	up to 750°C	(Karunadasa et al., 2019)
alkyd	up to 250°C	(Ploeger et al., 2009)

⁷ (Abel, 1999; Barrie & Lomax, 1997)

⁸ (Gregory, 2000; Tissot et al., 2021)

⁹ (Lomax, 2005)

¹⁰ (Cowley, 1986)

¹¹ (Ploeger et al., 2009)

¹² For red iron oxide, (Pfaff, 2021; Tissot et al., 2021)

¹³ For goethite, (Mayhew et al., 2014)

¹⁴ (Berrie & Lomax, 1997)

4.3. DEGRADATION OF THE COATINGS

Oil paints degrade due to environmental factors such as heat, water, light, and pollutants (Gordon, 2022). Although not much study has been done about it yet to confirm it, it is assumed that alkyd resins also have stability properties similar to natural drying oils since they are 70 wt% in oil (Ploeger et al., 2008). The degradations they undergo are made visually evident through blistering, cracking, and discoloration of the coatings (Gordon, 2022).

Being a part of a composite system, such as a painted metal system, can also further complicate matters (Gordon, 2022). The deterioration of one system component (*e.g.* the formation of corrosion products on the metal substrate) can impact the other component (*e.g.* coating detachment). Understanding the degradation processes and assessing the conditions of the sculptures could help in identifying the source of alterations in coatings (Gordon et al., 2019)

In this section, degradations of the coatings observed through observations and analyses will be discussed to understand their processes.

4.3.1. HEAT-RELATED DEGRADATION

The artist uses soldering to join different pieces of coated metals together (**Figure 54**). Soldering is a process that requires applying high heat of up to 600 °C to join metals together, depending on the metals. Due to the process of soldering metal pieces together, areas surrounding the joint area can also be affected by heat. In welding, this area is known as the heat-affected zone (HAZ) (Lomozik, 2000). The part of the metal substrate directly adjacent to the weld area, or the zone of partial melting, can reach up to 1500 °C (Lomozik, 2000). On the other hand, soft soldering, which does not require melting the metals being joined, only needs a temperature of up to 450 °C to melt the solder alloys, mainly Sn and Pb. Hard soldering, also known as brazing, can require temperatures of up to 600 °C, depending on the metals to be soldered (Sharma, n.d.).

Since the artist soldered coated metals together, it would be interesting to see how heat has affected the chemical structure of paint coatings and if degradation products have been formed. To study the impact of heat on the coatings in the HAZ, samples of coatings near heat-exposed areas and coatings of the same color but far from any HAZ were collected for comparison. Using the FTIR analysis, the

spectra of the heat-exposed samples were compared against their counterparts to understand how the heat affected the molecular structure of the coatings' components. Specifically, only the yellow coatings from *das Massas* and *do César* and the blue coatings from *do César* were examined for thermal degradation.



Figure 54. The artist soldered two metal pipes, a shoe mold piece, and the mouth of a drum to other pieces of metals to form an anthropomorphic feature.

Comparing the spectra of the heat-exposed samples to those of the unexposed ones (an example is **Figure 55**) showed that the frequencies and shapes of the absorption bands did not exhibit any significant changes. Additionally, no new formation of FTIR bands was observed, suggesting that the samples' molecular structures did not alter and that the formation of new molecular bonds and by-products did not occur. However, it is worth considering that the heat-exposed coatings may not have been close enough to the HAZ to exhibit significant changes in these two band attributes.

Conversely, the FTIR spectra of the samples show significant changes in the intensities of the bands representing the functional groups present in an alkyd resin. The heat-exposed samples showed weaker band intensities throughout the spectra than those not exposed to heat.

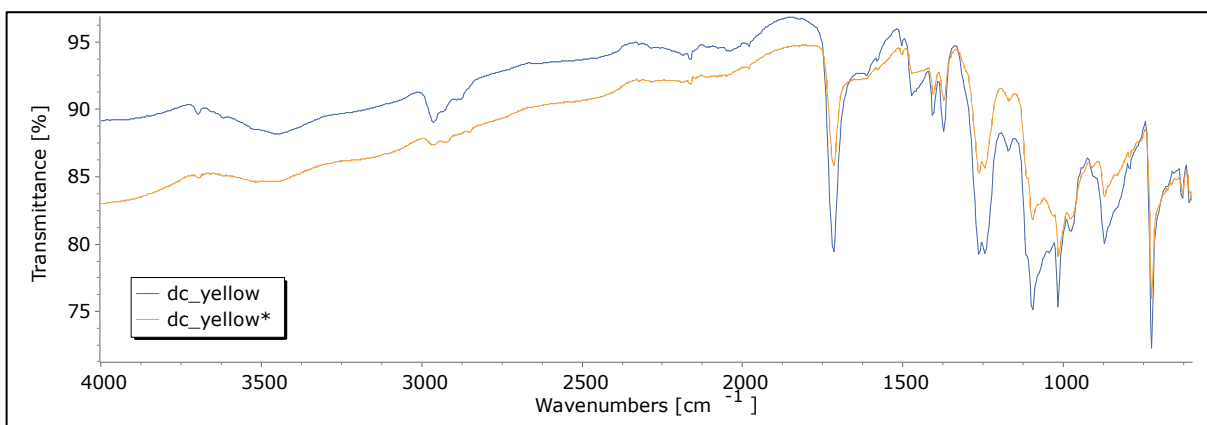


Figure 55. FTIR Spectra. Comparison of the *heat-exposed yellow coating from de César to the unexposed one.

Samples prepared under the same conditions should produce identical spectra (Derrick et al., 1999). The disappearance and decrease of specific bands in the heated samples, particularly the characteristic carbonyl (C=O) band of alkyd at the 1720 cm^{-1} region, may indicate the degradation of the alkyd (Pagnin et al., 2020) and the deterioration of the binder structure (Grabowska, 2010). Two bands in the $2960\text{--}2870\text{ cm}^{-1}$ regions, which correspond to the C-H stretching of oil portion in alkyd resin (Anghelone et al., 2016), most notably almost disappeared in the heated samples. This is likely due to oxidation (Pagnin et al., 2020). The oil portion provides the plasticization of the resin (Bentley, 1999); its decomposition might lead to the brittleness of heat-exposed coatings.

On the contrary, Raman spectra of the heat-exposed samples and their unexposed counterparts remain identical. This suggests that no molecular change had occurred for the pigments. For instance, yellow chrome (PbCrO_4) reduces from Cr (IV) to Cr (III) (Gordon, 2022) at $300\text{ }^\circ\text{C}$ (Cowley, 1986). However, no shifts in the Raman bands of dm_yellow* occurred (**Figure 56**). This might imply that the heat-exposed sample was only subjected to temperatures sufficient to start the oxidation of the alkyd binder but not enough to degrade lead chromate.

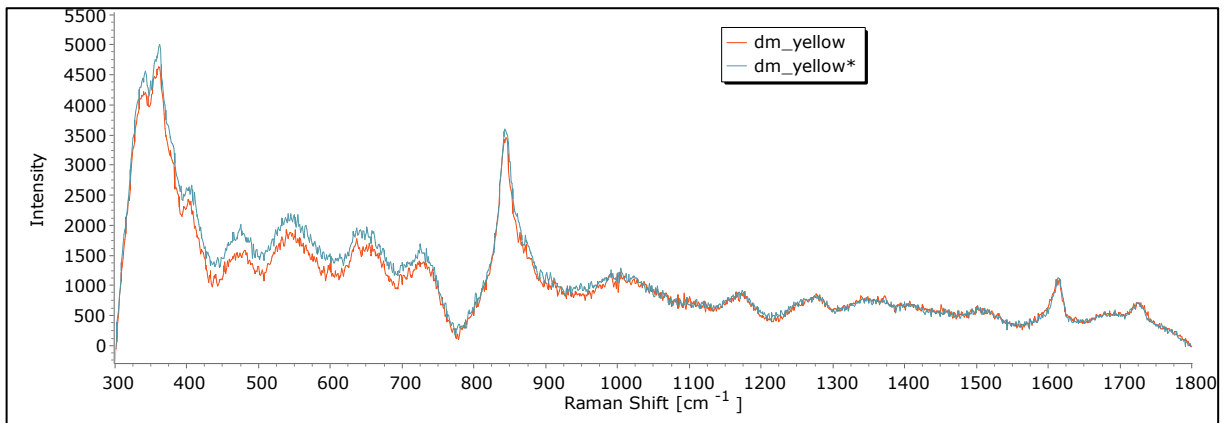


Figure 56. Raman spectra of yellow heat-exposed and un-exposed samples from *das Massas*.

A visual change that coatings may undergo due to extreme heat is discoloration (Gordon, 2022). Pigments, which are responsible for a coating’s color, can only withstand heat up to a certain degree (Table 12). Inorganic pigments are considered to have “superior heat stability” (Abel, 1999). Going back to yellow chrome as an example, the reduction of lead chromate to lead chromite may result in the darkening of the pigment due to elevated temperatures (Cowley, 1986). While this change might not have happened or not visible in the samples that were taken, **Figure 57** and **Figure 58** shows the darkening of a coating that was extremely close to the soldering area.

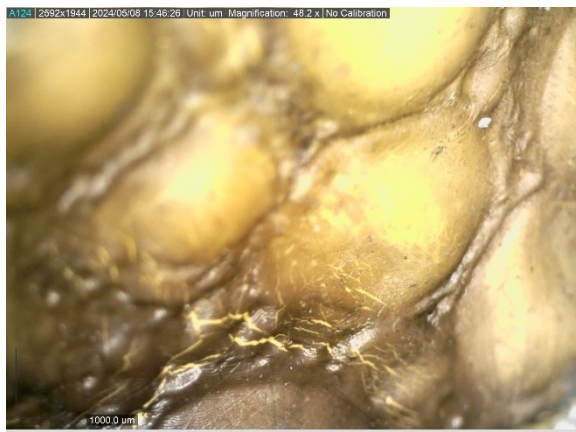


Figure 57. Discoloration and blistering of the yellow coating due to extreme heat as observed under digital microscope.

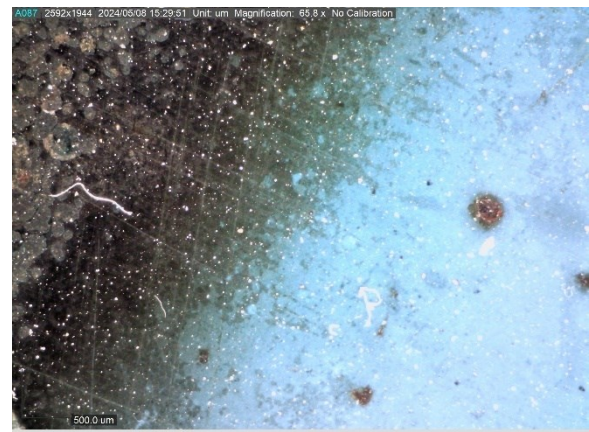


Figure 58. Discoloration of the blue coating due to extreme heat as observed under digital microscope

The presence of blisters where heat was applied (**Figure 57**) is an additional visible sign of the coating deteriorating (Gordon, 2022). These blisters could create a gap between the metal substrate and the coating, potentially compromising the adhesion of the coating. A strong adhesion of the coating to the substrate is crucial for protecting the metal substrate from corrosion (Kendig & Mills, 2017).

Cutting the coated metals into his desired shapes was another artist's execution that generated high temperatures. Circular saws, the artist's chosen cutting equipment, do not generate heat, but the friction between the metal saw and the object being cut produces heat. Tests conducted (Abukhshim et al., 2006) to measure the temperature during metal cutting, found that the temperature along the cutting area can reach up to 950 °C. Although this thesis did not investigate the coatings along the shear zone, this could be an interesting aspect to consider in the future.

4.3.2. DEGRADATION OF COATINGS AS PART OF A PAINT SYSTEM

The type of coating system used can lead to a loss of coating adhesion to the substrate, resulting in degradation. Most of the sampled coatings only consisted of a single layer of paint. As said by Gordon (2022), citing (Lyon et al., 2017), "no coating can completely prevent the occurrence of corrosion." This is due to the imperfections and pores that a coating may have through which water and air could pass through. One way to provide additional protection against corrosion is to implement a multi-layer coating system (Gordon, 2022; Bierwagen, 1996) (**Figure 59**). If the outermost layer fails and there are no additional layers, the substrate will be left vulnerable to water and air, leading to the formation of corrosion on the metal substrate.

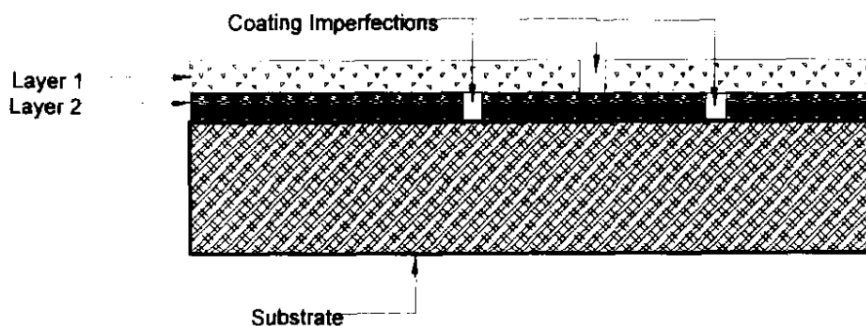


Figure 59. Schematic showing how multiple layers of coatings can prevent water and oxygen from reaching the metal substrate despite coating imperfections. (Image source: Bierwagen, 1996).

Figure 60 demonstrates the effectiveness of a multi-layer coating system. In Mabunda's sculptures, the blue-coated metal has only one paint layer, while the red-coated metal has two layers. Damage to the single paint layer on the blue-coated metal allowed corrosion products to form on the metal substrate. On the other hand, the red-coated metal, which has an intermediate layer below the topcoat, showed minimized corrosion formation in areas where the topcoat was damaged.



Figure 60. The formation of corrosion in the locations where the blue coatings were damaged can be seen. Meanwhile, the red coated metal shows that the existence of an intermediate layer protected the metal substrate where the topmost red coat have disappeared.

However, the number of coatings, of course, would not matter if a coated metal is cut, exposing the metal's cross-section to the corrosive environment (**Figure 61 & Figure 62**). This is part of Mabunda's technical process as well. His fondness for creating anthropomorphic images by cutting metals into specific shapes and sizes affects the stability of paint coatings in the long run if or when corrosion eventually forms. The images in **Figure 63** show some of the cut metal pieces present in his works and the formation of corrosion that mainly occurred along the shear zone.

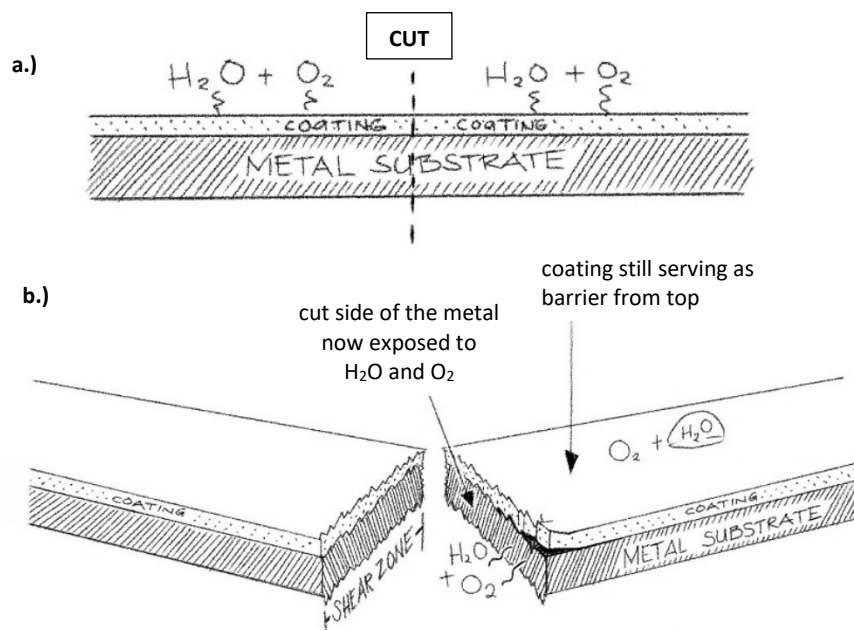


Figure 61. Diagram showing how coated metal can form corrosion along the cut line. **a.)** shows the coated metal before being cut, while **b.)** shows that the shear zone of the cut metal is now exposed to oxygen and water. Source: author.



Figure 62. Shear zone under a digital microscope. Corrosion can be seen along the cut.

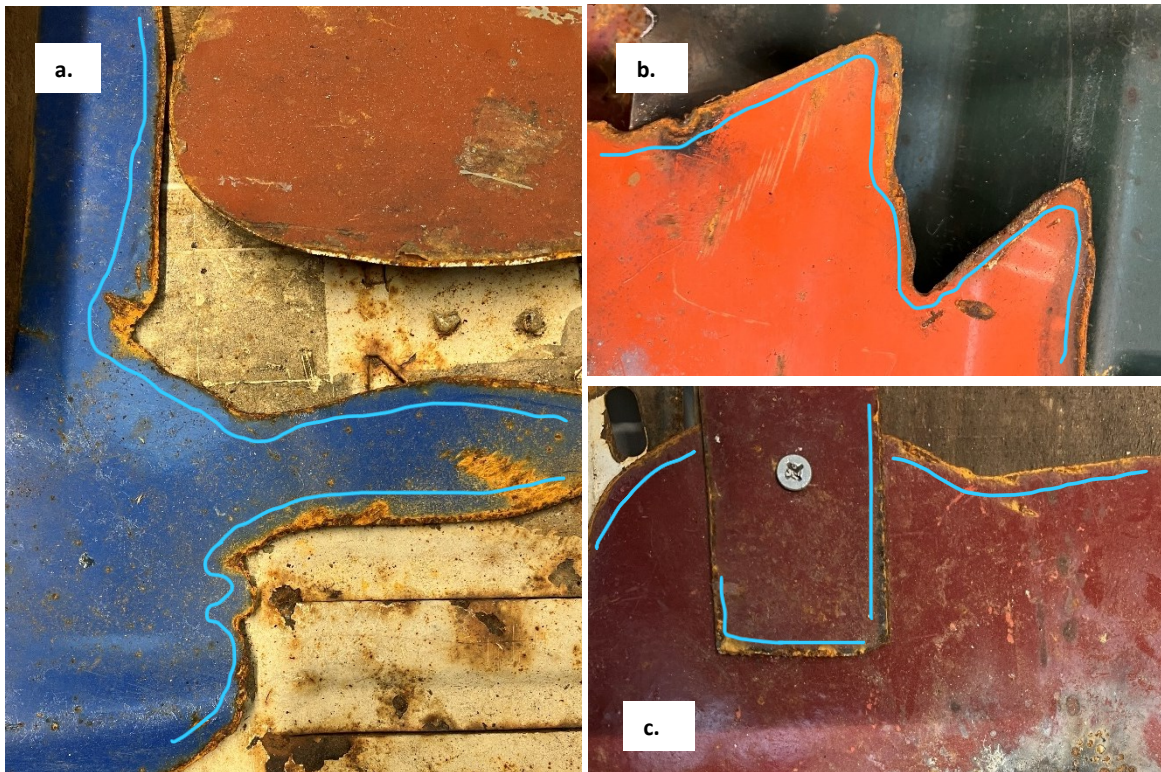


Figure 63. Three images show corrosion occurring along the cut lines of the coated metals. Blue lines were drawn to emphasize the cut lines. a. and b. have a single-coat system, while c. has a multi-layer coating system.

The formation of corrosion will eventually lead to coating detachment. Detachment of coatings in Mabunda's sculptures is more widespread on steel substrates (**Figure 64** & **Figure 65**) than on galvanized steel (e.g. Zn coated) and aluminum substrates. The green coatings, which we had difficulty taking samples from, are examples of a paint system applied to a galvanized steel and aluminum

substrate, which have superior stability. Due to the substrates' strong resistance to corrosion, the green coating remains firmly adhered to the surface. On the other hand, paint coatings on Fe-based substrates are undergoing detachment due to the corrosion of the less stable steel substrate. When corrosion occurs on a steel substrate, a coating is at risk of various degradations due to the migration of Fe^{2+} ions from the corrosion (Gordon, 2022; Kendig & Mills, 2017). These ions may oxidize the binder and the pigment, causing the loss of coating adhesion due to the former (Kendig & Mills, 2017), and coating staining due to the latter (Gordon, 2022). Unfortunately, a good stratigraphic sample that may provide visual evidence of pigment staining due to the migration of corrosion products into the paint layer from Mabunda's sculpture was not obtained.



Figure 64. Loss of adhesion, and discoloration of the coating due to the corrosion of the metal substrate in Mabunda's sculptures.



Figure 65. Substrate of a sampled white coating, on which Fe was detected by XRF Analysis, an element not found in Titanium white pigment. The formation of corrosion products, which most likely explains the presence of Fe on the metal substrate, resulted in the subsequent detachment of the coating.

4.4 FINAL REMARKS

Pigments, binders, and fillers of the sampled coatings from Mabunda's sculptures were identified using analytical techniques. Observation under optical microscopy revealed that most coatings consisted of a single layer of paint. However, the red coating from *de César* had two layers, and the retroreflective sheet, which is likely a new material to be studied in the field of heritage conservation, had five layers.

The pigments in the samples were identified using XRF and Raman Spectrometries. These were phthalocyanine blue and green, chrome yellow and yellow-orange, yellow goethite, BON azo red, red iron oxide, and titanium white. The pigments mentioned have reportedly been used in the coating systems of other industrial heritage objects from the 19th and 20th centuries (Costantini et al., 2022; Gordon, 2022; Tissot et al., 2021, 2024). This signifies the consistent use of these pigments in techniques employed in the paint systems of industrial objects.

The fillers were identified using XRF and ATR-FTIR spectroscopies. Most samples contained barium sulfate as a filler and calcite for the white coating. The binder, which displays strong absorption bands in ATR-FTIR spectroscopy, was mostly alkyd for all the samples except for the red coating from *das Massas*, which might be either acrylic or alkyd.

The successful identification of the components enabled their characterization thanks to the wealth of existing literature dedicated to pigments, binders, and fillers. It was discovered that the components possess their own physical and chemical properties, giving them varying tolerance levels against elements such as UV radiation, solvents, and heat. The components of the paint coatings in Mabunda's sculptures were compared to those identified from the 19th-20th centuries of industrial heritage objects. While most of the pigments and binders used remain the same, the industry's shift from oily binders to alkyd resins was made evident.

Each component's varying heat tolerance levels became evident when comparing Raman and FTIR spectra of coatings exposed to heat (due to the artist's technique of soldering to join materials) with those not exposed. The analysis showed that while degradation was observed in the binder of the heat-exposed samples using FTIR spectroscopy, no degradation was observed in the pigments using the Raman spectra gathered, especially in lead chromate, which would change molecular structure at

300 °C. This suggests that the yellow samples exposed to heat had been subjected to temperatures enough to degrade the binder but not the pigment, lead chromate.

Each analytical technique provided helpful information and results about the sampled coatings. The combination of analytical techniques allowed for a definitive identification of the coatings' components and a better understanding of their composition and degradation. The analysis of the paint samples from Gonçalo Mabunda's sculptures has provided important insights into the composition and degradation pathways of industrial coatings used in contemporary art. Identifying the key pigments, binders, and fillers not only helps in preserving these works but also contributes to a better understanding of how industrial materials behave when used in art. The analysis also highlights that artist's technical processes that modify coated metals will affect the stability of the coatings in the future. The zones where coated pieces had been cut and exposed to heat are areas that are now made vulnerable to the corrosive environment and pose a concern for the conservation of the objects. These findings will be crucial in developing preservation techniques that honor both the materials and the artistic intent behind the works.

5. CONCLUSION AND PERSPECTIVES

This thesis aimed to understand the material composition and degradation mechanisms of scrap metal coatings in contemporary art. The ultimate goal was to produce a contribution that would be beneficial in conserving artworks that use scrap metals as a medium. Two artworks of Gonçalo Mabunda were used as case studies to analyze coatings of numerous ordinary industrial materials. His sculptures, made from various scrap metals exposed to different conditions during the artist's execution, provided invaluable insights into the components used in coatings and their degradation. These insights were obtained through an interview with the artist and by using scientific tools for material and degradation studies, underscoring the importance of interdisciplinary collaboration in art conservation.

In contemporary art, an artist interview is essential and invaluable. It can help better understand the artist's work and serve as a guide on approaching a work to be cared for. Interviewing Gonçalo Mabunda led to acquiring information about the artworks that would not have been available elsewhere, such as his preference for employing preventive measures over restorative ones in the conservation of his works, his openness to accepting losses, and his contradicting intentional use of corroding materials for aesthetic purposes and his use of varnish to mitigate corrosion and protect his works. Despite his use of varnish, it does not seem to have the intended effect. His sculptures, made up of corroded scrap metals, continue to degrade. It is probable that the artist himself does not have a holistic understanding of his materials since recycled coated metals are unconventional artistic media. To understand these materials as artworks, scientific analyses were employed to complement the artist interview. From the interview, it was determined that taking detached coating samples for ex-situ analysis would be acceptable. Optical microscopy, XRF, Raman, and ATR-FTIR spectroscopies were deemed sufficient and practical for the scope of this thesis. The depth of understanding achieved through the interview is a testament to its importance in the research process.

The combination of XRF and Raman spectroscopies effectively identified the components of the coatings, allowing for their subsequent characterization. The pigments identified in the case studies, phthalocyanine blue and green, chrome yellow and yellow-orange, yellow goethite, azo red, red iron oxide, and titanium white, have been previously reported (Costantini et al., 2022; Gordon, 2022; Tissot et al., 2021, 2024; Macchia et al., 2023) to have been used to protect and decorate industrial artifacts from the 19th-20th Century. Their continued use to this day, despite the toxicity of some,

demonstrates their durability and effectiveness as protective and decorative coating for industrial objects. Through the successful identification of the pigments, their subsequent characterization and history of use had been possible with the help of existing literature. Through them, we learned that some pigments are more durable than others, implying that one may degrade faster than the other under certain circumstances. Characterizing the pigments, which are primarily responsible for coatings' properties, highlights the importance of pigment identification in conservation.

Meanwhile, XRF and ATR-FTIR spectroscopies were employed to analyze the fillers and binders used in industrial coatings. The study revealed that the fillers used in industrial coatings are barium sulfate and calcite. These compounds are commonly used across various industries due to their abundance and chemical inertness, and their use (BaSO_4 most notably) in the coatings of historical objects has been reported (Costantini et al., 2022; Macchia et al., 2023). Meanwhile, cost-effective alkyd was identified as the binder in almost all the samples, replacing traditional oil-based binders such as linseed oil, which were historically used for coating metals until the development of synthetic binders in the 1920s (Gordon, 2022; Macchia et al., 2023).

The identification of the binder and filler and their subsequent characterization using existing literature proved that looking into the other components of paints, too, and not just the pigments, would be beneficial in understanding the behavior of coating and its degradation. The pigments, after all, comprise only a part of the coating components. XRF analysis has shown that multiple elements compose the paint coatings. The average distribution of ingredients in paints is 29.5 % binder, 27.4 % solvent, 18.7 % pigment, 12.3 % fillers, 10.6 % water, and 1.5 % additives (Bieleman, 2000). Of course, these ratios can be modified depending on the paint appearance needed and the tinctorial strength of pigments. (Abel, 1999; Beetsma, n.d.). Typically, pigments are present in larger quantities than fillers in paints wherein vibrant colors and opacity are essential, especially in high-quality artists' oil, acrylic, and gouache paints wherein pigment distribution can reach up to 60 %¹⁵.

While pigments mainly determine a coating's visual appearance and properties, other paint components can also influence coating properties, such as its ability to adhere to a surface. Strong surface adhesion is essential for the effectiveness of a protective coating. A successful coating can help

¹⁵ *M. Graham & Co.* brand of acrylic paints reports that their pure acrylic emulsion contains 60% solids, with no fillers, bulking agents, or whiteners. Product site: <https://mgramham.com>

prevent or minimize paint degradation caused by corrosion. This was made evident by the green scrap metals in Gonçalo's sculptures, from which we had difficulty taking samples because of the strong adhesion of the coating to the metal substrate. The green-coated metals looked less degraded than the other coated metal pieces. This was most likely due to the type of substrate the green paint was applied to, galvanized steel, which is more stable than regular steel. The deterioration of the binder component is one of the factors that can lead to loss of coating adhesion, no matter how durable pigments may be. Such degradation was observed when the heat-exposed coatings were investigated. Raman and FTIR analyses allowed for the molecular comparison of heat-exposed coatings against unexposed ones. The results from the analyses suggest that while the binder of heat-exposed coatings appeared to have deteriorated, the pigment did not. The comparison supported the fact that different components degrade differently. It also highlighted the importance of investigating other coating components besides the pigments in conservation.

Aside from characterizing the components' coatings, the analyses also showed that modifying coated materials as raw materials repurposed into art materials has conservation implications. Cutting, fixing, and soldering coated metals may affect their longevity. Gonçalo Mabunda is fond of using different shapes of metals to create his sculptures. Modifications that coated metals were not meant to undergo compromise the coatings' performance, made evident by the degradation of the coatings adjacent to the shear lines and soldered pieces. The refashioning of the coated metals can increase mechanical damage to the coatings, in addition to the scratches and damages that these metals already have as scrap metals. Corrosion could and would eventually form under damaged coatings and rapture the coatings from underneath. Thus, Mabunda's recommendation of using varnish to protect his work is a superficial technique that is insufficient against degradations happening in the substrate. The disconnect probably stems from the artist's unfamiliarity with the behavior of recycled coated objects as an art medium and his being accustomed to using varnish as protection for traditional artworks.

Nonetheless, it would be interesting to see if the varnish had slowed down the corrosion of already corroded metals at all, and to compare the behavior of varnish on outdoor and indoor coated metals, considering the existence of the sister sculptures in Famalicão.

By combining two approaches to conserving contemporary art and industrial objects, we have gathered information that would benefit conservators, and artists who experiment with and prefer

unconventional art materials. Artists typically use varnish to protect their works as it is what is customary and what is readily available to them. However, the case of Goncalo Mabunda's sculptures showed that traditional means of protecting artworks may not apply to unconventional art materials. A superficial treatment is insufficient against degradation occurring on the substrate. More importantly, the study shows that it is imperative to know not only the composition of the materials but also how they were repurposed as raw materials. The artist's working methods, such as using heat on painted surfaces, can impact and even exacerbate future conservation challenges.

This calls for a conservation strategy that would protect artworks whose degradation happens in the substrate and along the areas of modification. It would help artists and caretakers of recycled artworks to whom the preservation of which is important if so intended. Serving as both a protective and aesthetic layer, the longevity of paint coatings in artworks is essential for preventing corrosion and ensuring prolonged enjoyment and effective reading of the pieces.

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APPENDIX

TRANSCRIPT OF INTERVIEW WITH THE ARTIST, GONÇALO MABUNDA

Purpose: To research the artist's career history, his works, specifically about *Eu sou das Massas* and *Da ao Povo o que é do César*, his creative process, and intentions.

Interviewee: Gonçalo Mabunda

Interviewers: Prof. Doutor Nuno Camarneiro and Christianne Mendoza.

Date of interview: March 4, 2024 done online via Zoom.

List of Acronyms: GM= Gonçalo Mabunda
NC= Nuno Camarneiro
CM= Christianne Mendoza

[Interview starts at 00:00:47]

CM: You are mostly known for your artworks that were made from recovered war paraphernalia which we learned was promoted by a project initiated by the Christian Council of Mozambique. And we read in this interview that it reflects mostly your life experiences and the collective memory of Mozambique. But we would like to know how you developed your art style and which artists influenced you. [00:01:21]

GM: When I was young, I went to *Nucleo d'Arte* Association for artists, I went to that place to work. And then, that place where the men artist work, most of famous artists from Mozambique work there but I didn't work there as an artist—I learned from them there. I started to paint and then in '94, the organization *nucleo d'arte* organized a big workshop, international workshop. That workshop we had an artist from South Africa, his name is Andries Botha. And then he was looking for someone to help him make his work. Because he was supposed to work for two weeks but his work it was huge. And then he needed someone and my boss from the association, he asked me if I wanted to help him, and I said yes, why not. And then I helped him. He's my mentor, one I really like. I learned many things from him because after the workshop, he took me to the university where he is a teacher there to train me more [for] three months. And then, when I came back, I forgot the painting and I started making sculptures with metal. [00:02:58]

NC: Gonçalo, can you just repeat the name of the artist from South Africa? [00:03:04]

GM: Andreis. Andreis. Botha. If you go [to] google, you can see him. [00:03:19]

CM: Okay. Thank you very much. So, you started with painting and then this project which with you assisted/ [00:03:29]

GM: //My process, I started to be as someone who cleans for the association, and then I learned from those artists [in the association]. I was painting because I was learning from [other] artists like, Malangatana [Ngwenya], [Joan] Miró, Victor Sousa, because they [were working] there

and I looked at them when they do their work—that's why I started to paint because they give some materials. [00:03:55]

CM: My second question will be, you almost always have anthropomorphic elements like human figures which are I think reminiscent of African masks, African elements, and thrones. Would you consider this your signature artistic style, incorporating African motifs and integrating them into your works. [00:04:48]

GM: When I started, I made different things, different figures. And then slowly when—because my first piece, it was [a] big motorbike with weapons. It was [a] big motorbike. Because in our association we had a lot of weapons there and different ones. And when they showed us those weapons-- because the idea is not our idea. It was Christian Council of Mozambique who created the idea. They came to us and challenged us if we want to use these materials. For me, (unintelligible 00:05:37) but emotional it was something different because we came from civil war and we never used these materials, but all of us, we said yes. And from there I started to make different sculptures, motorbikes, people. And then slowly I started to change, after (*ascar mix* ? [00:06:09]). I started to have different philosophies, like masks and thrones. Masks, I am talking about the people, how they are fake people. They have this face, and behind is another thing. Because we have all those things and different parts and sometimes, I like to do that because our culture, the mask is one of the important things, but not for the fake people. The difference before, they were making masks for traditional dance, they were great tools. But today, especially, I use those materials as the fake people. And the thrones, I am talking about the African presidents. The weapon to go (unintelligible 00:07:14) the old people [people of the past], the king, they didn't fight, didn't use weapon, they didn't make war to get into power. But today to get into power, I talk about how presidents use force to get into power. [00:07:54]

CM: Interesting. So there's this political and more realistic contemporary meaning to these African motifs. [00:08:08]

NC: Christianne, may I? *Portanto, há aí uma ideia da diferença entre o passado do país e do povo e o presente que mudou a forma das pessoas serem, do poder ser exercido— É um pouco sobre isso?* [00:08:30]

(Therefore, there is an idea of the difference between the past of the country and the people and the present that changed the way people are, the way power is exercised— Is that a little about that?)

GM: *O poder agora é fetiche. É tudo força. Por exemplo, agora nós vamos ter eleições, eles vão fazer propaganda, vão chamar todo o povo, vão prometer mudar coisas e, quando chegarem ali, vão trocar. Então, vão esperar mais 4 anos e, quando chegarem as eleições, vêm de novo. Portugueses têm um sistema muito louco. Eles podem virar a estrada aqui, agora porque é tempo das eleições. Depois dão camisete, dão capulana.*

Por exemplo, o povo moçambicano, agora, já começou a reclamar, a dizer que não queremos mais camisete, não queremos mais capulana. Queremos é realidade. Especialmente, quando Azagaia tocou— conhece o Azagaia? Azagaia agitou povo. O povo trocou todo. Toda a gente,

cada música de Azagaia— teve (velhotes?? 00:09:32). Quando ele morreu, foi uma confusão. Tiveram de o pôr cheio de carros blindados— porque tava cheio! Tás a ver? Então, tem essa separação das máscaras, dos tronos: o passado era diferente. Agora, o presente é tudo de corrupção, essas coisas. [00:09:56]

(Power is now a fetish. It's all strength. For example, now we're going to have elections, they're going to carry out propaganda, they're going to call all the people, they're going to promise to change things and, when they get there, they're going to change them. So, they will wait another 4 years and, when the elections come, they will come again. Portuguese have a very crazy system. They can turn the corner here, now because it is election time. Then they give a shirt, they give *capulana*.

For example, the Mozambican people have now started to complain, saying that we don't want shirts anymore, we don't want *capulana* anymore. What we want is reality. Especially when Azagaia played—do you know Azagaia? Azagaia stirred up the people. The people, they all changed. Everyone, every Azagaia song— There were old people(?). When he died, it was a mess. They had to fill it with armored cars— because it was full! Do you see? So, there is this separation of masks, of thrones: the past was different. Now, the present is all about corruption, these things.)

NC: *Então, e há aí uma brincadeira... Esse trono feito de armas e também essa máscara que é posta, não é? [00:10:05]*

(So, there is this play... this throne made of weapons and also this mask that is put on, isn't it?)

GM: *Exatamente. [00:10:07]*

(Exactly.)

CM: For your next question, you were known for these thrones, the recovered weapons that became sculptures. I wanted to ask what prompted you to experiment with the sculptures with colored scrap metals? [00:10:35]

GM: I do. I'll show you now [GM prepares to send photos of his works]. I do many different—if you would. But the people— most of the museums/ [00:10:52]

NC: //Gonçalo you are showing but we cannot see you. Do you have your camera on? [00:10:57]

GM: On where? On the computer? Ah, okay. I'll send to you by message now. But sometimes I do the totems, but I use the face— you'll see now because I will send to you. [00:11:27]

NC: *Então, Gonçalo, tavas a dizer? Em relação é isso dos materiais— [00:12:30]*

(So, GM, you were saying? Regarding the materials—)

GM: *O ferro velho pintado— porque sempre que o fui trabalhando como um material velho, toda a gente sempre perguntou: “Éh pá, Gonçalo, quando trabalhares ele, vais fazer o quê?” Eu disse a eles: “Éh pá..., antes, eu trabalhava com metal, vou fazer metal. Então eles começaram a desafiar, eu comecei a fazer metal. Mas, nesse caso, o metal que eu uso—eu uso, por aqui, tem—sabe o que é tchova? Tchova é um carrinho de dois rodas. Aqui, fazer negócio de ferro. Fazer, né? Então, aqui, em Moçambique, fazer negócio de ferro. Então, comecei a usar esse material, comecei a falar com os miúdos da rua que vendem aquele material porque eles vão andado para cidade e vão comprando o ferro, e levam o ferro, vão vender na sucada. E a sucada paga até um pouco. Então, eu comecei a falar com alguns, que tenho umas ideias: eu quero um ferro com cor assim, cor assim, cor assim. E eles andam e, quando encontram aquelas coisas, sempre eles guardam para mim e vêm e vendem a mim. Entendes? Tão, aí, é onde eu faço esse trabalho com esse material reciclado e, no meu entender, eu acho, eu digo que estou a escrever uma história. Porque eu estou a escrever uma história? É uma história que eu mesmo próprio não conheço. Porque eu não sei como aquele todo material vai parar naquele sítio. Se foi acidente, se é porque alguém deitou fora. Entendes? Porque cada metal tem a sua história, de como foi para lá no—então, eu digo que é uma maneira de escrever sem tudo saber, tás a entender? É uma maneria de escrever com a vida. Porque é a vida de muita gente, não sei quantas pessoas pegaram isto. São várias pessoas na mesma obra, entendes? [00:14:53]*

(The painted scrap metals— because whenever I worked on an old material, everyone always asked: “Hey, Gonçalo, when you work on it, what are you going to do?” I told them: “Oh man..., before, I worked with metal, I’m going to make metal.” So, they started to challenge me, I started doing metal. But, in this case, the metal that I use—I use, because around here, there is—do you know what *tchova* is? *Tchova* is a 2-wheeled cart. Here, we do business with iron. We do, right? So, here, in Mozambique, we do iron business. So, I started using this material, I started talking to the kids on the street who sell that material because they go to the city and buy the iron, and they take the iron and sell it in the scrapyard. And the scrapyard pays little. So, I started talking to some of them, and I have some ideas: I want an iron with a color like this, a color like this, a color like this. And they go around and, when they find those things, they always save them for me and come and sell them to me. Do you understand? So, that’s where I do this work with this recycled material and, in my opinion, I think, I say I’m writing a story. Why am I writing a story? It’s a story that I don’t know myself. Because I don’t know how all that material ended up in that place. If it was an accident, if it’s because someone threw it away. Do you understand? Because each metal has its own story, how it got there in—so, I say it’s a way of writing without knowing everything, do you understand? It is a way of writing with life. Because it is the life of many people, I do not know how many people took this. There are several people in the same work, you know?)

NC: *Falaste em tchova? Tchova é o quê? [00:14:58]*

(You said *tchova*? What is *tchova*?)

GM: *Tchova. Tchova é um carrinho. Tem 2 rodas de carro. Não é feito na fábrica, é feito nas casas. [00:15:13]*

(*Tchova. Tchova* is a little car [a cart]. It has two wheels. It is not manufactured in a factory; it is made at home.)

NC: *Essa ideia é muito boa. Então, tu falas com os miúdos e dizes o quê? “Quero metais com cor. Quero— ” O que é que tu dizes?* [00:15:40]

(This idea is good. So, you talk with the kids and say what? “I want metals with color. I want— ” What do you say to them?)

GM: *Dependendo da obra o que eu vou fazendo porque a empresa quer a obra com uma cor, com muito preto— então, eu faço isso com eles. Vou-te mandar algumas obras. Quando eu tiver lá em baixo, vou-te tirar a foto de tchova para tu veres o que é, até como material, e enviar para ti para vocês verem o que é tchova.* [00:16:05]

(It depends on the artwork that I will do because the company wants the work with one color, with a lot of black— so, I do that with them. I’m going to send you some works. When I get it down there, I’m going to take a photo of *tchova* for you so you can see what it is, even as material, and send it to you so you can see what *tchova* is.)

NC: *Então, é como se eles fossem teus colaboradores, é isso?* [00:16:11]

(So, it’s as if they were your collaborators, is that it?)

GM: *São. Muita coisa que eu preciso. Porque como eu pago um pouco mais que a socada, eles guardam para mim. Disso, digo, procurar as minhas coisas. São colaboradores, mas também é uma ajuda mútua, não é?* [00:16:28]

(They are. Lots of things that I need. Since I pay a little more than the scrapyards, they save [the metals] for me. Of that, I say, look for my things. They are collaborators but also it is a mutual help, right?)

NC: *Sim, há aí quase um aspeto social também, não é?* [00:16:33]

(Yes, there is almost a social aspect to it as well, right?)

GM: *Claro.* (Of course). [00:16:34]

NC: *[Then Prof Nuno translates for Christianne]* Gonçalo work with these kids for scrap metals. But they are very low paid by the market. So, Gonçalo pays a little bit more and they go fetch the materials he needs for his works. [00:17:03]

CM: *Okay, there’s a collaboration between you and the kids—you pay them more so, that’s nice.* [00:17:15]

GM: *Yeah, because the scrap metals are big and they pay very low money. These boys fight a lot to catch these— it’s too hot, they push, it’s too heavy.* [00:17:39]

CM: That brings me to my next question which is about your creative process like how you create your sculptures. Do you do a sketch beforehand that's why you know what kind of scrap metals that you want beforehand, is that it? [00:17:56]

GM: It depends, sometimes I do a sketch. When I travel, I like to do a sketch. Because when I am travelling, sometimes I have ideas, and I put in sketch and save it. Even when I am at home, I do sketch with my book. My way to do sketch, I do it quickly, because I want to understand what I want to do. [00:18:29]

CM: That makes me curious, do you still keep the sketches of your sculptures? [00:18:38]

GM: Yes, I save. [00:18:45]

CM: During this sketch, do you already know the color you want? [00:18:52]

GM: For example, for the colored things, I don't use sketch. For the weapon I use sketch because I know exactly what I want to put there. Because for the colored things, it changes a lot. When I start to put the metal there, they can give you different options, maybe even better options. Even when I do sketch, when I am working, many things change, because better options come when I work. [00:19:35]

NC: *Então, ou seja, podes começar com um desenho, mas, depois, vai mudando muito ao longo da obra. É isso? Tem muito a ver com o que encontras—?* [00:19:45]

(Then, you may start with a design, but after it will change throughout the work, it's this? Does it have a lot to do with what you find—?)

GM: *Exato. Ya, quando tou no atelier, muita coisa muda. Porque ali está cheio de coisas e vão te puxando para outras opções.* [00:19:55]

(Exactly. Yeah, when I'm in the studio a lot of things change. Because, there, it is full of things and they pull you towards other options.)

NC: *Não dá para programar tudo, não é?* [00:19:59]

(You can't program everything, right?)

GM: *É, não. Por exemplo, também gosto de incorporar as obras de armas com cor também, às vezes meto cor lá. Estás a perceber?* [00:20:17]

(Yes, I can't. For example, I also want to incorporate colors to the weapon artworks, sometimes I put color on them. Do you get me?)

NC: *Não, desculpa, podes repetir? Não percebi, Gonçalo.* [00:20:23]

(No, sorry, can you repeat? I didn't understand, Gonçalo)

GM: *As obras com as armas também introduzo cor dentro delas, coisa que não tem a ver com armas.* [00:20:29]

(The artworks with weapons, I also introduce color in them, something that you don't see in weapons.)

NC: *Ok. Mas quê? Mas pintas, é isso?* [00:20:32]

(Ok. But what? You paint them, is that it?)

GM: *Não, não, não, não. Nunca quero pintar. Prefiro não pintar. Pintar não funciona. Para mim, funciona quando é uma coisa que tem uma certa vida que eu não conheço.* [00:20:43]

(No, no, no, no. I never want to paint them. I prefer not to paint them. Painting doesn't work. For me, it works when it is a thing that has a certain life that I don't know about.)

NC: *Então, tá a dizer que misturas armas com outros metais que têm cor, é isso?* [00:20:49]

(Then you are saying that you mix the weapons with other metals that has color, right?)

GM: *Ya, quando quero dar um pouco de vida. Ei-de te mandar algumas imagens.* [00:20:56]

(Yeah, when I want to give a little life. I'll send you some images.)

NC: *Porque, nas armas, não há cor, não é? Então, vais misturando—* [00:21:02]

(Because, in weapons, there is no color, right? So, you mix—)

GM: *É tudo um pouco morto, tá a ver?* [00:21:05]

(It's all a bit dead, you know?)

CM: My next question would be if you have any specifications when you choose these metals to work with. For example, when you have piles of metals, how do you choose which kinds of metals to use? Like, "Oh, I'll go with this metal, not this metal—" [00:21:28]

GM: The metals with colours? [00:21:32]

CM: Yes, the metals with color. Because, actually, I forgot to tell you, my thesis is about "Eu sou das massas" and "Dá ao povo o que é de César." [00:21:58]

GM: For example, I like gas containers. *Por que tem boticas pequenas por que ele tem formato redondo. Uso tanto. Tenho um amigo que trabalha na fabrica. Eu sempre digo como eles trabalham que—* (Because there are little gas containers that are rounded. I use them a lot. I

have a friend who works in a factory. I always say as they work—) I [was saying] to him that I have a friend who work in the place where they have most of those things. I ask him all the time to collect those for me and give them to me. And my friend, when he sees those people who work for him, he says: “save this for Gonçalo, save this for Gonçalo.” That one I like all the time because they give me nice proportions. [00:22:54]

CM: That’s nice, so he gives them to you for free? [00:23:00]

GM: Yes, for free he’s my good friend. [00:23:04]

CM: Now that we have gone to the topic of “Eu sou das massas” e “Dá ao povo o que é do César,” what did intend to convey with these pieces and how did you come up with their design? [00:23:19]

GM: *Quando eu digo “Dá ao povo o que é do César,” é uma ironia, né? Que é, eu falo dos governos. Que esses têm que dar aquilo que a terra tem, que são os minerais, ao povo. Porque é do povo, não é de um grupo de pessoas. Tás a entender? Então, aí, eu tenho essa ironia [unintelligible 00:24:00] de trocar só um pouco e dar ao povo.* [00:24:04]

(When I say “Give the people what belongs to Caesar,” it’s ironic, right? That is, I’m talking about governments. That they have to give what the earth has, which are minerals, to the people. Because it belongs to the people, not a group of people. Do you understand? So, then, I have this irony of exchanging just a little and giving it to the people.)

NC: *E o “Das massas”, também é—?* [00:24:11]

(And the “Das massas,” it is also—?)

GM: *O “Das massas?” Eu falo de uma pessoa como o Azagaia. O Azagaia era uma artista que movia massas. Ele enfrentava a política de uma maneira. Ele ficou tão famoso porque ele é uma pessoa normal, mas consegue fazer muito para as massas, consegue dar voz às massas. Porque toda a música que ele cantou, até sempre a chamada “Maçonaria” (??) porque ele falava com os políticos.* [00:24:46]

(The “Das massas?” I’m talking about a person like Azagaia. Azagaia was an artist who moved masses. He faced politics in a way. He became so famous because he is a normal person, but he managed to do a lot for the masses, he manages to give the masses a voice. Because all the music he sang, even the so-called “Freemasonry” because he spoke to politicians.)

NC: *E tu eras amigo dele... Ele morreu o ano passado, não foi?* [00:24:51]

(And you were a friend of his? He died last year, didn’t he?)

GM: *Sim, era amigo dele, eu trabalhava com ele. Três vídeos dele, ele faz na minha casa.* [00:24:59]

(Yes, I was a friend of his. I worked with him. Three of his videos, he did them in my house.)

NC: *E tinham os dois a mesma visão da realidade?* [00:25:09]

(And you both have the same vision of reality?)

GM: *Da luta, não é?* [00:25:09]

(Of the fight, right?)

NC: *E, para ti, o sentido mais político ou social das obras também está ligado os materiais que tu usas? Há aí uma relação?* [00:25:25]

(And, for you, is the more political or social meaning of the works also linked to the materials you use? Is there a relationship there?)

GM: *Eu acho que há porque— éh pá! Aos poucos ficou muito coisa. Porque, quando comecei, era diferente. Porque eu fazia esculturas de músicas, os títulos—tás a entender? Mas, depois, fazia coisas muita mais diferente com títulos muito duros. Já tava um pouco mais crescido, já não tava preocupado em arranjar dinheiro para o fim de semana, preocupado em fazer coisas e isso assim funciona mais! E eu falo também. Tento dar a minha voz, não é?* [00:26:11]

(I think there is because— eh man! Little by little it became a lot. Because when I started, it was different. Because I made sculptures of songs, the titles—do you understand? But, later, I did things much more differently with very tough titles. I was already a little older, I was no longer worried about finding money for the weekend, worried about doing things— and that works better! And I speak out, too. I try to give my voice, right?)

CM: Since prof NC has asked if your pieces are connected with your vision also, with the pieces selected [the two sculptures], remember that in your sculptures you had these containers from Galp. [00:26:39]

GM: Sorry, the what? [00:26:40]

NC: *A Galp é dos combustíveis, portuguesa.* [00:26:49]

(Galp is a Portuguese fuel company.)

GM: *Sim, a Galp, Galp. Tem o quê?* [00:26:50]

(Sim, the Galp, Galp. It has what?)

NC: *Ela tava a dizer que na tua peça usas pedaços de metal que são de Galp. Não sei se são contentores de gasolina ou algo assim—* [00:27:02]

(She was saying that in your piece you use pieces of metal that are from Galp. I don't know if they are gasoline containers or something—)

GM: *Essa peça eu fiz com material aí em Portugal. Tive em Famalicão.* [00:27:12]

(I made this piece with material from Portugal. I had it in Famalicão.)

NC: *Ah, fizeste cá, em Famalicão?* [00:27:15]

(Ah, you did it here, in Famalicão?)

GM: *Num jardim de Famalicão, tem mais uma escultura de acho que quatro ou cinco metro, mas fiz com—havia um senhor que era—era, como é que é— um maia (??) de Famalicão. Mas ele tinha uma—* [00:27:38]

(In a garden in Famalicão, there is another sculpture measuring four or five meters, I think, but I made it with—there was a man who was—was, what is it—*um maia* (??) from Famalicão. But he had a—

NC: *Presidente da Câmara.* [00:27:40]

(President of the Chamber.)

GM: *Ele tinha uma oficina. Ah não, deve ter uma fábrica grande de sapatos. Antigamente, eles usavam umas formas para fazer os sapatos. O que acontece? Essas formas também tinham cor. Tás a ver? Tem cor. Isso foi mudando— foram trocando as coisas, né? Ou passava a utilizar a tecnologia e tudo. E, quando fizeram isso, ele teve a ideia de que Gonçalo poderia fazer uma escultura para o jardim lá, Devesa, em Famalicão. Tem duas esculturas ali. Um a cor, com uma pedra grande, mais ao menos oito metro e essa outra, de metal. Lá usei, essas coisas da Galp, tudo. Porque lá, na lixeira, tem um sítio onde eles vão, guardam os carros. É que esse tambor era o do combustível que já não serviu para nada e, então, utilizei esses tambores.* [00:29:00]

(He had an office. Oh no, it must have been a big shoe factory. In the past, they used molds to make shoes. What happens? These shapes also had color. Do you see? It has color. That was changing— things were changing, right? Or started using technology and everything. And, when they did that, he had the idea that Gonçalo could make a sculpture for the garden there, Devesa, in Famalicão. There are two sculptures there. One in color, with a large stone, at least eight meters long and and this other one, made of metal. I used it there, those Galp things, everything. Because there, in the dump, there is a place where they go and store their cars. This drum was the fuel drum that was no longer useful, so I used those drums.)

NC: *E, e isso foi... Tiveste cá a fazer uma residência, é isso?* [00:29:05]

(And this was... You were here for a residency, is that it?)

GM: *Fiquei... 1 mês. Ficamos 1 mês aí.* [00:29:10]

(I stayed... one month. We stayed for month there.)

NC: *Ok. E e fizeste também estas peças é?* [00:29:15]
(And you did these pieces too, right?)

GM: *Essas peças, é, fiz aí.* [00:25:17]
(These pieces, yes, I did there.)

NC: *As duas de São João da Madeira.* [00:29:20]
(The two from *São João da Madeira*)

GM: *É... Não, Famalicão.* [00:29:22]
(Yes... No, in Famalicão.)

NC: *Não, não, mas estas peças que Christianne falou... O "Das massas" e o do "César..." Também têm partes da Galp.* [00:29:30]
(No, no, but these pieces that Christianne talked about... the "*Das massas*" and the "*César...*" they also have parts from Galp.)

GM: *Mas não têm armas, essas, não?* [00:29:35]
(But they do not have weapons, these ones, no?)

NC: *Não, estas não têm armas.* [00:29:36]
(No, these do not have weapons.)

GM: *Então, fiz aí mesmo.* [00:28:38]
(Then, I did them there.)

NC: *Então, foi aqui feito também em Famalicão, é isso?* [00:29:40]
(So, it was also done here in Famalicão, is that it?)

GM: *Sim, sim, tão tudo em Famalicão. Foi tudo feito em Famalicão.* [00:29:42]
(Yes, yes, they are all done in *Famalicão*. It was all done in *Famalicão*.)

NC: *E, depois, o Museu de São João da Madeira comprou as peças, é isso?* [00:29:49]
(And, after, the Museum of *São Joao da Madeira* bought the pieces, right?)

GM: *Sim, sim, comprou, comprou.* [00:29:52]

(Yes, yes, the museum bought.)

CM: You said that you never paint over the metals, right, because for you the original colors are important to send a message, right? [00:30:11]

GM: Exactly. [00:30:12]

CM: What kind of message did you want to send using these metals that came from western companies, for example. [00:30:22]

GM: *Tou a tentar homenagear toda a gente que utilizou aquilo ali. Porque aquilo ali era trabalho um pouco forçado, né? Então, é uma maneira de homenagear as pessoas que utilizaram aquilo. Por isso, que eu digo: É uma história que eu escrevo que não conheço. Não sei quem é que visualizou aquilo, mas eu tive a oportunidade de usar. Por exemplo, aquelas coisas que tive lá, no Famalicão, acho que é báaaa... Muita gente poderia tar morta porque acho que é de muitos anos, muitos anos. Imagina lá, mas, não sei quem pegou e eu utilizei para fazer obras. É isso, tento homenagear. Tás a entender?* [00:31:17]

(I'm trying to pay homage to everyone who used it there. Because that was a bit of forced work, right? So, it's a way to honor the people who used it. That's why I say: It's a story I write that I don't know. I don't know who viewed it, but I had the opportunity to use it. For example, those things I had there, in Famalicão, I think are— a lot of people are dead by now because I think it's been going on for many years, many years. Imagine, but I don't know who took them, and I used them to do artworks. That's it, I try to pay homage. Do you understand?)

NC: *É uma forma de pores a vida das pessoas nas tuas obras.* [00:31:23]

(It's a way of putting people's lives into your works.)

GM: *Das pessoas? Exato.* [00:31:24]

(Of the people? Exactly.)

NC: *Seja da guerra, seja do trabalho... Seja...* [00:31:31]

(Be it of war, of work...)

GM: *Exato, exato.* [00:31:33]

(Exactly, exactly.)

CM: So Prof. NC, just to clarify, it's the stories about the people in Famalicão, is that it? [00:31:42]

- NC: Yes, Goncalo was saying that whenever he uses these metals, they incorporate the stories of the people that use them: be it the war, or work, of the kids that go to look for these metals. [00:32:00]
- CM: Okay, thank you. This is still part of the creative process, when you get the materials do you prepare them, do you clean them, prepare them before using them or after— [00:32:15]
- GM: No, I clean them after, and I put varnish to protect [them.] [00:32:21]
- CM: Okay, so you have varnish [on the works]. What type of solder to connect the metal pieces, would you happen to know? [00:32:32]
- GM: A welding machine, a normal one. But I have two different ones now. One uses fire but the other one use like electron— *Como um “electron”, sabes o que é “electron”?* (As an “electron”, do you know what an “electron” is?) [00:32:53]
- NC: *O ferro que aquece, não é?* [00:32:54]
- (The iron that heats up, right?)
- GM: *Han?* (Huh?) [00:32:55]
- NC: *Tens uma máquina de soldar mesmo daquelas de—*[00:33:01]
- (You have a soldering machine like those of—)
- GM: *Um pouco antigas e tenho essas modernas que vai diminuindo. Tão certo como teres de queimar o ferro.* [00:33:07]
- (A little old and I have these modern ones that are getting smaller. As sure as having to burn iron.)
- CM: Now, for the state of your works. For example, metals corrode in the future, right? They undergo corrosion. Is corrosion part of your aesthetics and is their [the works] future corrosion part of your aesthetic[s] as well? [00:33:31]
- GM: You know, sometimes, I have materials I just put in a place where they get water to change them a little bit. They give me some things. I just go put there to get rust, you know? [00:33:48]
- CM: So they are intentional. [00:33:50]
- GM: It’s life. [00:33:53]
- CM: So, since it’s intentional on your part, how far are you willing to let corrosion spread, like how much paint loss is acceptable for you? Because the paint detaches due to corrosion. [00:34:20]

GM: I tell people all the time: you can let it work, get corrosion, but when you want [it] to stop, just protect. Because you can protect and it'll stop. *Porque as pessoas gostam de pôr as peças fora, né? Eu digo, quando vocês quiserem fazer isso parar, vocês têm que pôr o verniz, para o verniz proteger.* [00:34:55]

(Because people like to put the pieces outside, right? I say, when you want this to stop, you have to put varnish, so the varnish protects.)

NC: *Ah, okay. Então, ou seja, a corrosão faz parte, mas tu também não queres que a obra seja/* [00:35:04]

(Ah, okay. So, in other words, corrosion is part of it, but you also don't want the work to be—
)

GM: *//Exato. Há pessoas que querem aquilo assim, mas, por exemplo, eu uso a corrosão para fazer as minhas peças, tá a entender? Mas as pessoas podem de vez em quando fazer uma cosida ali para só proteger mais.* [00:35:22]

(Exactly. There are people who want it like this but for example, I use corrosion to create my pieces. But people can occasionally do a little stitching there to just protect it more.

NC: *Ou seja, tu usas a corrosão para fazer as peças, mas não é tua intenção que elas depois se destruam completamente, não é?* [00:35:31]

(In other words, you use corrosion to make the pieces, but you don't intend for them to completely destroy themselves, do you?)

GM: *Não, não.* [00:35:32]

(No, no.)

CM: Since some of the corrosion is your intention but the corrosion after, not so much. So, are you open to the idea of repainting the paint layers that were lost also? [00:35:55]

GM: Yes, they have to put varnish to protect. Varnish, matte, without colors. [00:36:05]

CM: Because sometimes the problem is that the corrosion happens between the metal substrate and the paint layers, so sometimes even with varnish, I think, the paint layers will eventually detach so I was wondering if you're open to these layers or parts which [have] the paint detachment, are you willing to repaint them after to compensate for the loss? [00:36:35]

GM: Repaint with colors? [00:36:38]

CM: Yes. [00:36:39]

GM: No, never. [00:36:31]

CM: Never. So, paint loss: don't ever repaint. [00:36:47]

GM: Yeah. [00:36:49]

GM: So, since repainting is not part of your intention. When happens when your sculptures eventually lose most of its colors? Would it matter to you or [just] let it be, let it live? [00:37:14]

GM: Sometime with the lose they become better. [00:37:21]

CM: It is much better to leave it alone. My next question was supposed to be if you wanted to be part of the restoration but since I think the part would be more on giving advice. Would that be it? [00:37:48]

GM: If I wanted to be part of the restoration? [00:37:51]

CM: Yeah, to be part of the restoration. Since you're not willing to do restoration, maybe giving advice to the— [00:38:00]

GM: To someone who has these things? [00:38:03]

CM: Yes. [00:38:04]

GM: That's why I say to you, they must have something to protect. Because you can use varnish in two ways: you can use machine like spray. But the varnish must be matte. Because matte has no color, okay? [00:38:26]

CM: Yes, it makes sense. I think those are my questions. Prof. Nuno, would you like to add something else? [00:38:37]

NC: *Então, Gonçalo, só para ver se percebi bem. Portanto, tu preocupas-te com a conservação das peças, mas o tipo de restauro não poderia implicar pintar ou nada disso, não é?* [00:38:53]

(Then, Goncalo, just to check if I understood well. Therefore, you are concerned about the conservation of the pieces, but the type of the restoration shouldn't involve painting the pieces or anything like this, right?)

GM: *Não, não, não.* [00:38:55]

(No, no, no.)

NC: *Pronto, é mais uma coisa de preventivo ou limpeza—*[00:39:00]

(It is more of a preventive thing or cleaning—)

GM: *Ya, preventivo, só limpeza, tá a ver? Isso é como uma obra de arte que esteja em casa. Se deixar só, ela pode apanhar sujidade, sujidade vai mudando também, né? Tem que ser sempre limpar um bocadinho.* [00:39:15]

(Yeah, preventive, only cleaning, you see? This is like an artwork that is at home. If left alone, it may accumulate dirt—dirt changes too, right? You always have to clean it a little bit.)

NC: *Sim, acho que ficou claro.* Christianne, is it— [00:39:25]

(Yes, I think it was clear.)

CM: I do have on last question, because one of our pieces is “Dá ao povo o que é de César,” right? But then in your website/portfolio there is another piece that is entitled the same but they look different. Is this intentional or— [00:39:44]

GM: No, [one is entitled one (I), and the other two, (II.)] [00:39:49]

CM: Okay, that’s a series. Which would be entitled “one (I)?” [00:39:55]

GM: “One (I)” is the one you have there. [00:39:57]

CM: Which is done in 2013, right? [00:40:01]

GM: Yes, this is the old one. [00:40:03]

NC: *Também foi feita lá em Famalicão?* [00:40:09]

(Was it also done there in *Famalicão*?)

GM: *Não, não, essa foi feita aqui.* [00:40:12]

(No, no, it was done here.)

NC: Okay. Is it okay, Christianne? [00:40:20]

CM: Yes, I think that’s it unless Prof. Nuno yo have—you’re also good? [00:40:24]

NC: Yes. *Sim. GM, muito obrigado. Foi muito bom, foi muito útil. Muito obrigado pela tua simpatia.* [00:40:38]

(Goncalo, thank you very much. It was very good, very useful. Thank you for your kindness.)

GM: De nada. Obrigado a vocês. [00:40:40]

(You’re welcome. Thank you.)

CM: Thank you very much. [00:40:41]

[Interview ends]

ANNEX

REFERENCE SPECTRA

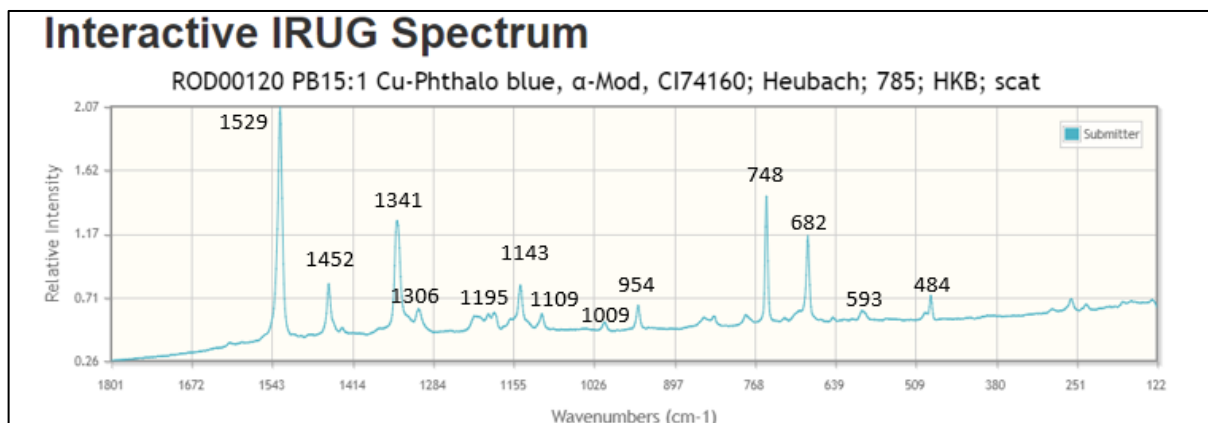


Figure 66. Reference Raman spectrum for Cu-Phthalocyanine Blue. (Price et al., 2014).

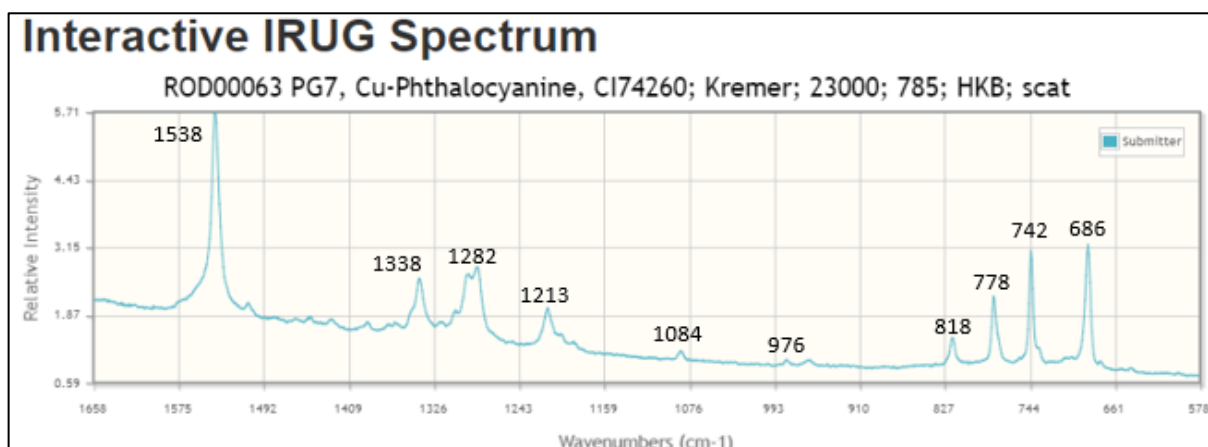


Figure 67. Reference Raman spectrum for Cu-Phthalocyanine Green. (Price et al., 2014).

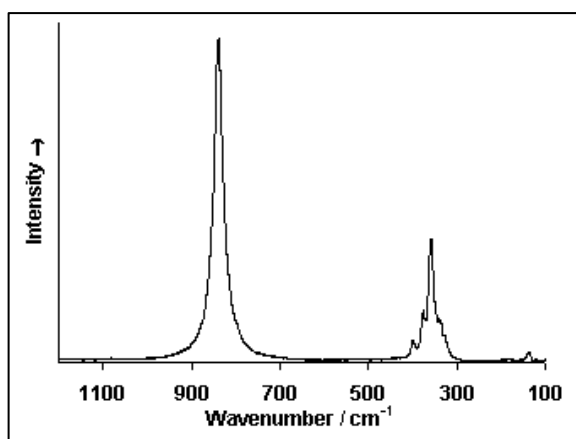


Figure 68. Reference Raman spectrum for yellow chrome (Bell et al., 2010).

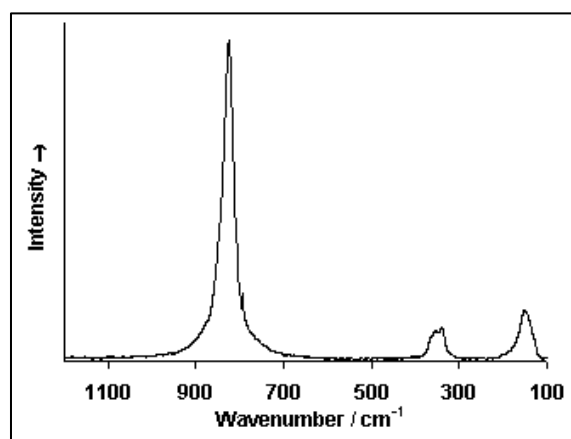


Figure 69. Reference Raman spectrum for chrome yellow orange (Bell et al., 2010).

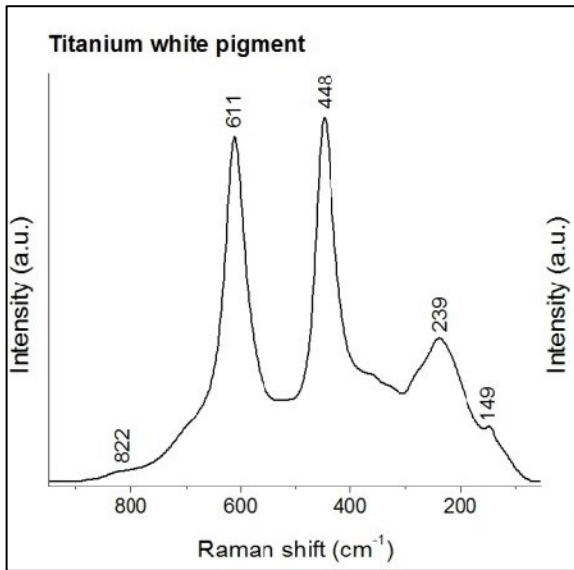


Figure 70. Reference Raman spectrum for titanium white, Rutile form (Domingues et al., 2010)

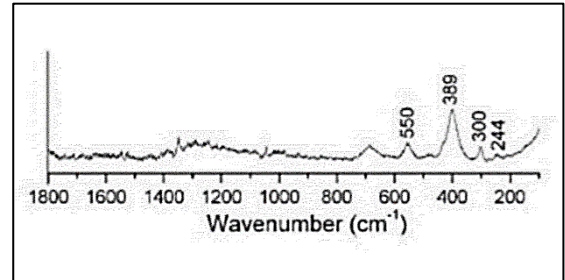


Figure 71. Reference Raman spectrum for yellow goethite (Holclajtner-Antunović et al., 2015).

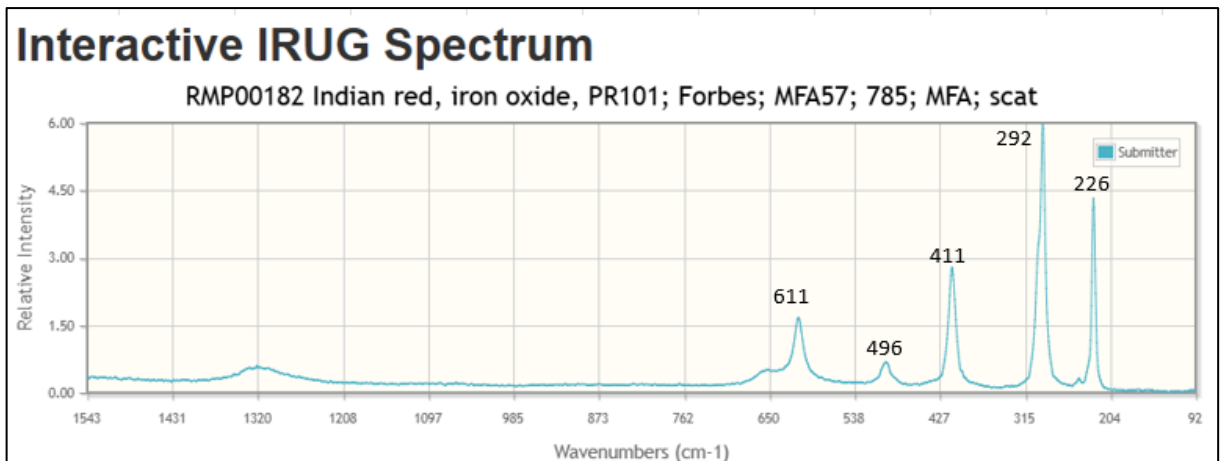


Figure 72. Reference Raman spectrum for red iron oxide. (Price et al., 2014).

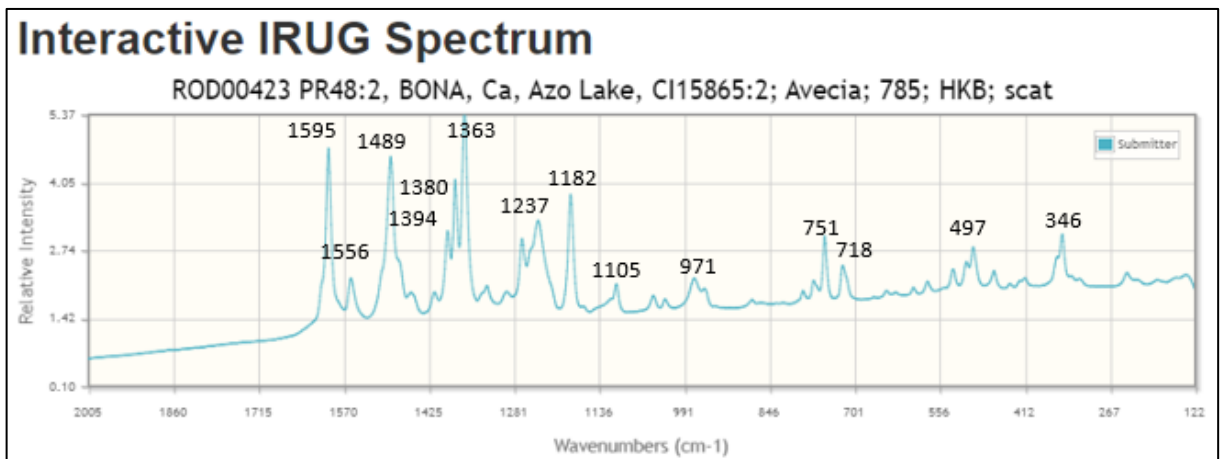


Figure 73. Reference Raman spectrum for PR48:2 Azo Red. (Price et al., 2014).

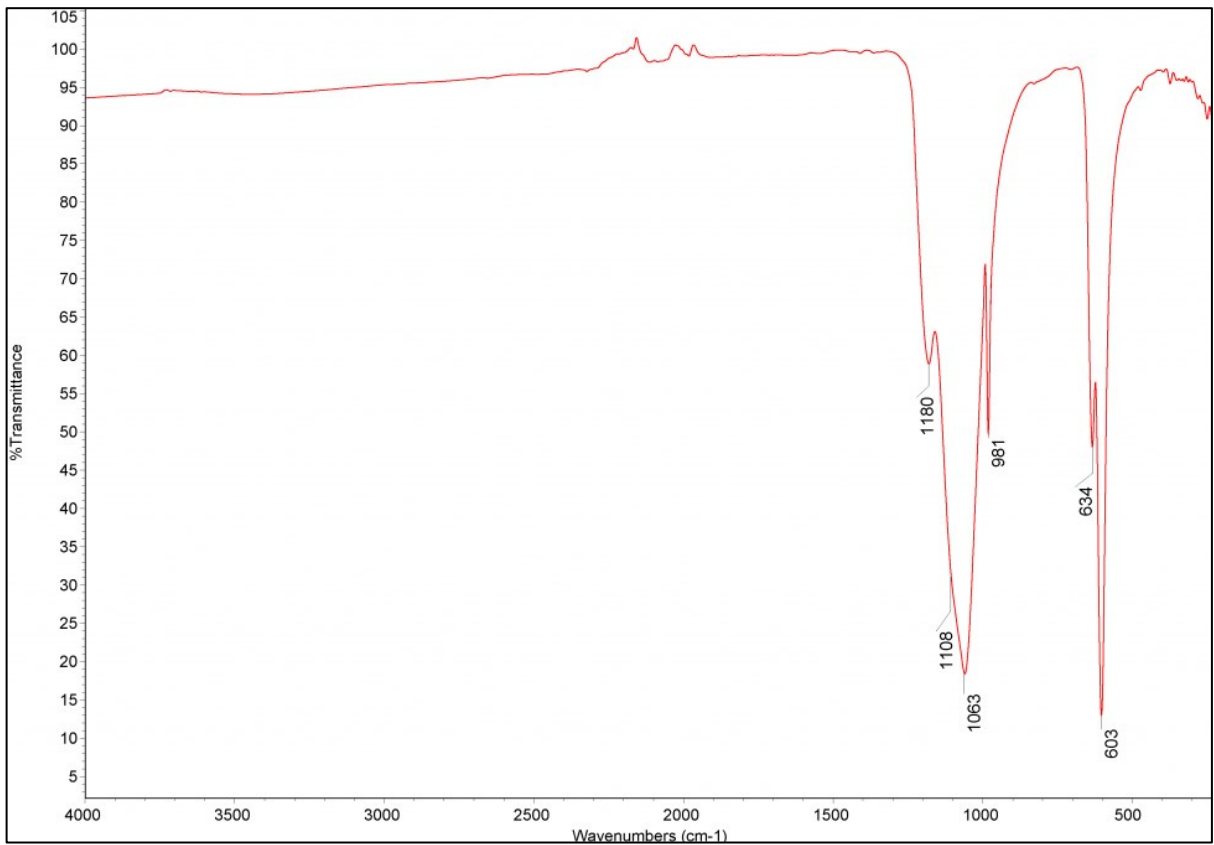


Figure 74. Reference FTIR Spectrum of BaSO₄ (Vahur et al., 2016).

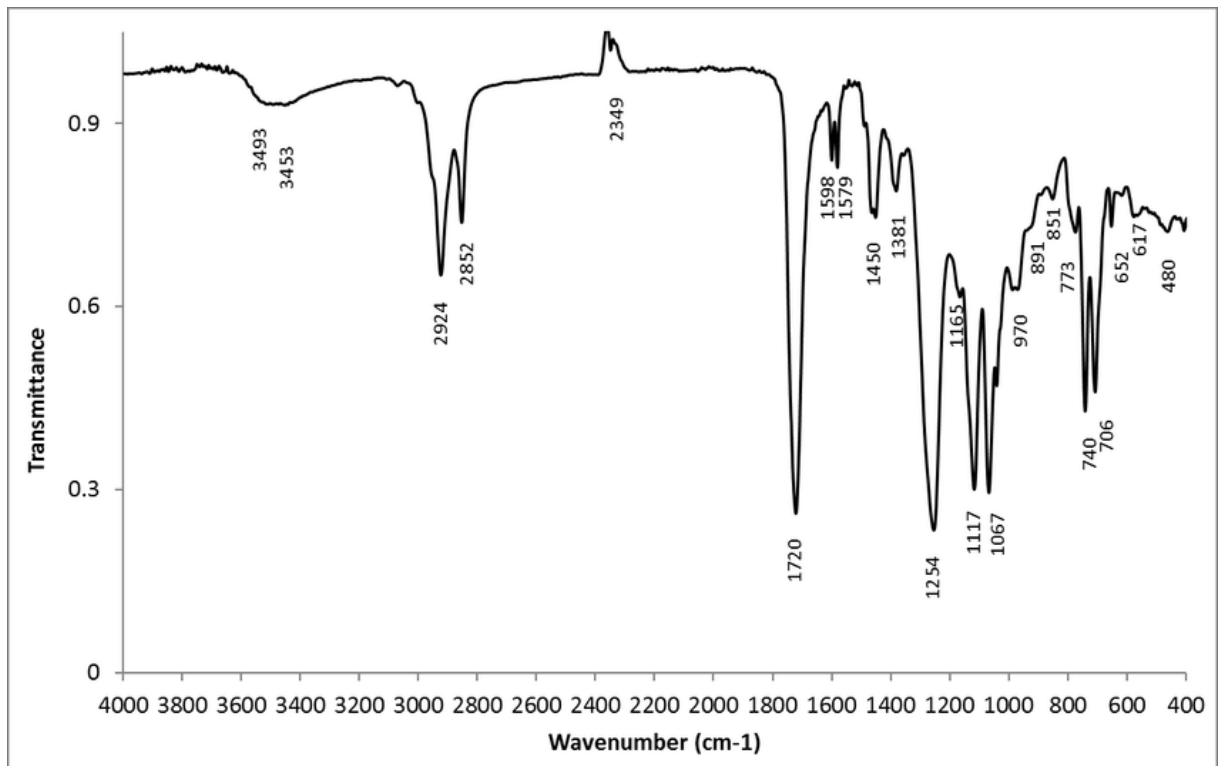


Figure 75. Reference FTIR Spectrum of cured alkyd resins (Bumbac et al., 2017).

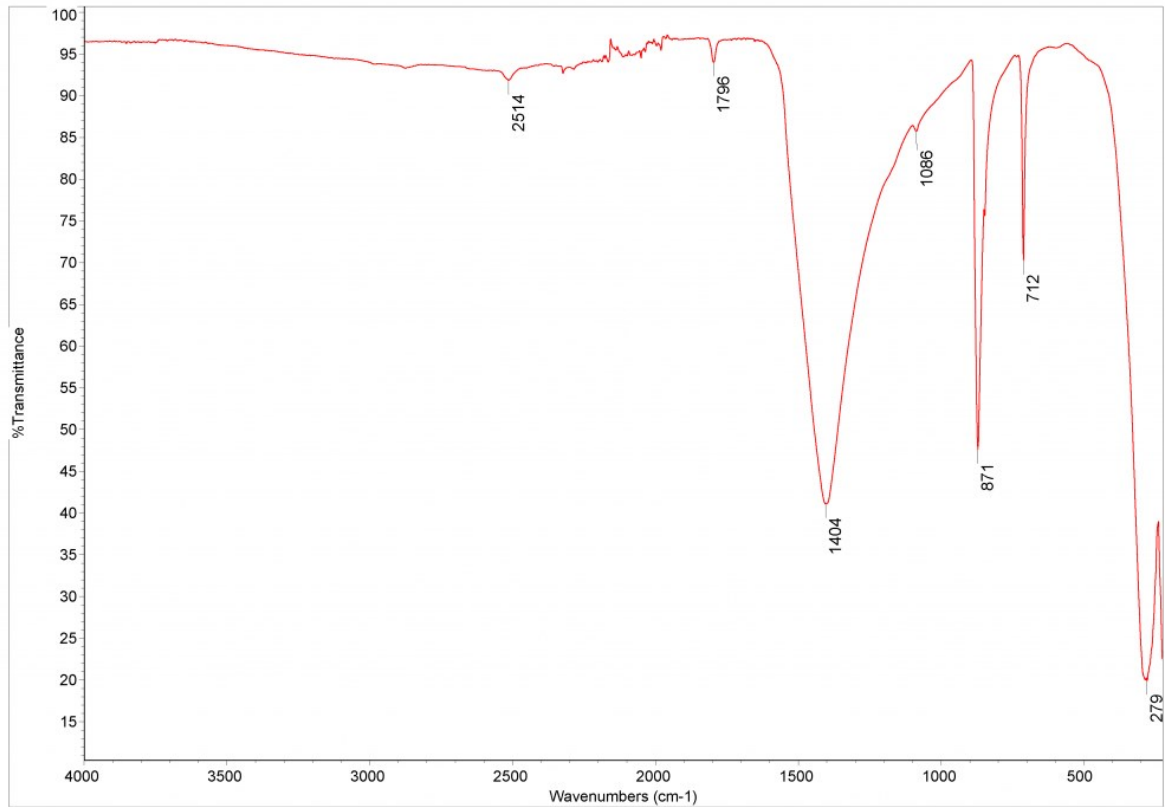


Figure 76. Reference FTIR Spectrum of Calcite (Vahur et al., 2016).

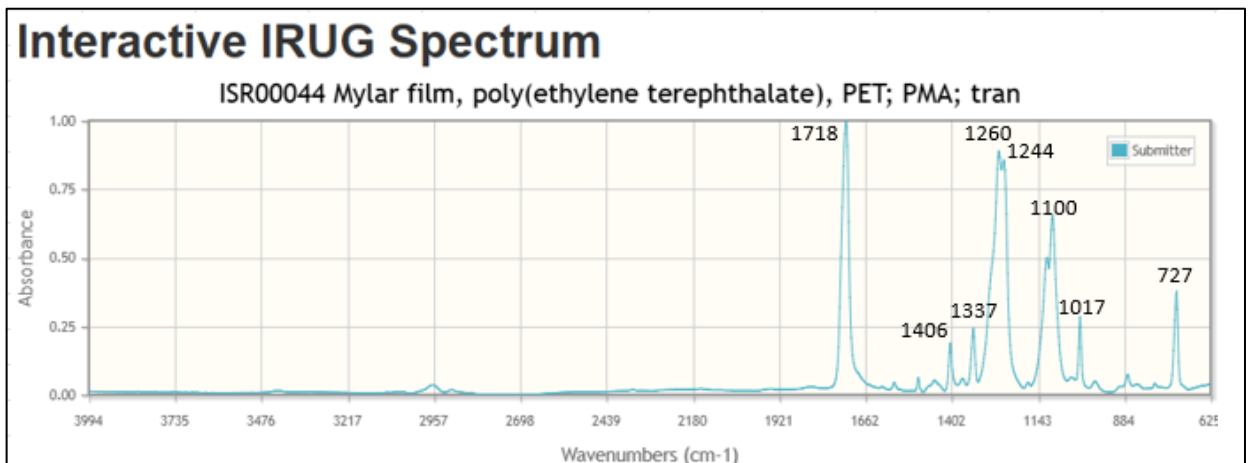


Figure 77. Reference Raman spectrum for PET film. (Price et al., 2014).