Work Package 3: Analytical characterization

Final Report | August 2019

Project: Conservation of Art in Public Spaces

Acronym: CAPuS

Webpage: http://capusproject.eu/

Work package: Work Package 3 Analytical characterization

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Estimated work package start and end date: M6 – M9

Actual work package start and end date: M13 – M20

Report version: 1.0

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This project has received funding from the European Commission, the Erasmus+ Knowledge Alliances Programme, Project N° 588082-EPP-A-2017-1-IT-EPPKA2-KA.

1. Introduction

The following chapter presents the main assumptions of WP3, research groups, a description of the work methodology, comments on the duration of the work package, and conclusions. The following chapters contain the results of all research groups participating in WP3.

1. 1. The main aim of WP3

The purpose of WP3 is to gather knowledge about selected works, in particular in terms of their technique and technology of execution, and the causes of degradation. Therefore, individual research groups took samples from selected objects (according to the list created in WP2) and subjected them to tests according to the WP3 Leader's recommendations. As a result, a database was created on the techniques and technologies of creating various works of art in public space. In addition, selected artworks were observed for damage. The obtained research and observation results will be used in further project activities (WP4 and WP5).

1. 2. Research groups

Seven research groups were created under WP2:

- Research Group 1: University of Turin (Italy) and Conservation and Restoration Centre „La Venaria Reale" (Italy)
- Research Group 2: CESMAR7 (Italy) and An.t.a.res srl (Italy)
- Research Group 3: University of Vigo (Spain)
- Research Group 4: Academy of Fine Arts in Warsaw (Poland)
- Research Group 5: University of Split (Croatia) , Sisak Municipal Museum (Croatia), and Metris (Croatia) / All WP2 activities were performed by the University of Split.
- Research Group 6: Cologne Institute of Conservation Sciences (Germany) and Schmincke (Germany)
- Research Group 7: Montana Colors

1. 3. Description of work methodology

At the inaugural meeting in Split, which took place in early July 2018, partners were asked to perform analytical tests using a scanning electron microscope with an X-ray spectrometer (SEM-EDS) and Fourier-transform infrared spectroscopy (FT-IR) using the attenuated total reflection (ATR) technique. It was agreed that the partners could also use other analytical techniques as needed. In addition to the

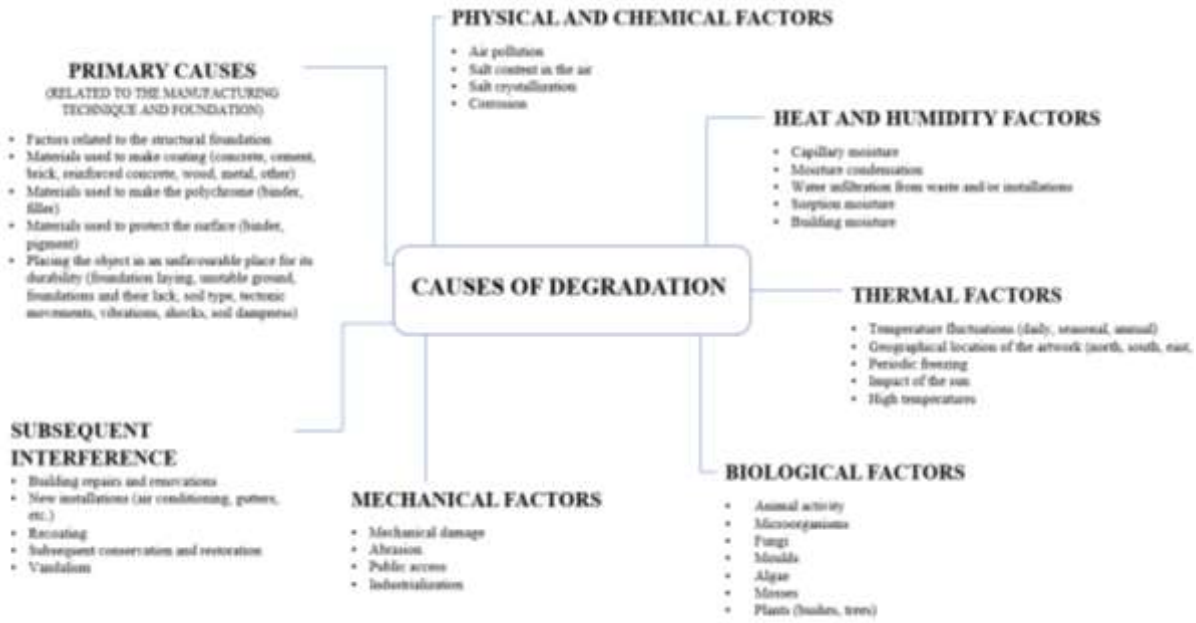
indicated techniques, the most commonly used were: μ-Raman spectroscopy and X-ray diffraction (XRD) and Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS).

The WP3 leader sent the following three templates to all research groups, in which the research results were to be included:

- main written report
- report (table) with analytical results
- report (table) with reasons for degradation

The analytical report contains the results of analyses carried out on various materials and substrates. It focuses on the physico-chemical properties of constituent materials as a painting and sculptural substrate. Each research group contributed to the analytical report through the results of the analysis of samples taken from specific works using the available equipment.

The degradation processes report provides guidelines for identifying and classifying degradation processes for works of art in public space. The WP3 leader classified the main reasons for the degradation of this type of artworks according to the following model:



The materials were collected in June 2019. The number of tested artworks is as follows:

In terms of analytical research:

- Research Group 1: University of Turin (Italy) and Conservation and Restoration Centre „La Venaria Reale" (Italy) – 10 murals, a series of 16 painted wood bench, 1 painted concrete bench and 2 painted metal artworks (a gate and a series of 5 painted metal panel).

- Research Group 2: CESMAR7 (Italy) and An.t.a.res srl (Italy) – 8 murals
- Research Group 3: University of Vigo (Spain) – 6 murals
- Research Group 4: Academy of Fine Arts in Warsaw (Poland) – 7 murals
- Research Group 5: University of Split (Croatia) – Metris (Croatia), Sisak Municipal Museum (Croatia), and University of Split (Croatia) – 36 sculptures
- Research Group 6: Cologne Institute of Conservation Sciences (Germany) and Schmincke (Germany) – 0

In terms of causes of degradation:

- Research Group 1: University of Turin (Italy) and Conservation and Restoration Centre „La Venaria Reale" (Italy) – 10 murals, a series of 16 painted wood bench, 1 painted concrete bench and 2 painted metal artworks (a gate and a series of 5 painted metal panel).
- Research Group 2: CESMAR7 (Italy) and An.t.a.res srl (Italy) – 10 murals
- Research Group 3: University of Vigo (Spain) – 6 murals
- Research Group 4: Academy of Fine Arts in Warsaw (Poland) – 1 mural and team of 25 murals
- Research Group 5: University of Split (Croatia) – 38 sculptures (a more detailed report has been produced on 5 sculptures)
- Research Group 6: Cologne Institute of Conservation Sciences (Germany) and Schmincke (Germany) – 1 sculpture

1.4. Comments on the duration of the work package

The launch of WP3 was delayed due to the late start of the project. Activities related to WP3 began immediately after the end of WP2. Additional delays were caused by numerous suggestions for changes in the tables proposed by particular research groups, the necessity to change artworks by Partner 10. Also, members of the Croatian research team had disagreements regarding work distribution (who would be tasked with sampling).

1.5. WP3 conclusions

As part of WP3, two typologies of street artworks have been analysed: murals and metal sculptures.

MURALS: Paints of various synthetic binders with a predominance of acrylic, alkyd and polyester binders were most often used by artists. Artists often use organic pigments despite their instability. A common type of damage to this type of paint are fading or loss of colour intensity and flaking. Most of

the tested murals were made on old plasters with or without an undercoat layer. In some cases, the paintings were covered with a protective layer.

The most common causes of damage of the murals are as follows:

Primary causes:

- Materials used for coating, plaster: binder, filler
- Materials used for polychrome: pigment, binder
- Factors related to the construction base: reinforced concrete

Thermal-humidity factors: capillary moisture, temperature fluctuations, geographic location of the artwork

Thermal factors: exposure to light, high temperature

Physico-chemical factors: salt dissolution and crystallization, air pollution

Later interferences: repainting, vandalism

Biological factors: plants, microorganisms

Mechanical factors: mechanical injuries, public access

METAL SCULPTURES: The building chosen by the Cologne Institute of Conservation Sciences is in good condition due to fact that the sculpture was made from bronze, which is a hard material. The only problem is finding the right protective coating against vandalism (graffiti, mechanical damage). The collection of outdoor sculptures selected for research by the University of Split (in collaboration with Sisak Municipal Museum and Metris) are in very poor condition. This is mainly due to the materials which are not resistant to external conditions: steel (painted and unpainted) and galvanized steel. In addition to corrosion, Partner 10 has indicated the problem of vandalism in the form of theft of many sculptures.

The most common causes of damage for metal sculptures are as follows:

Factors related to the construction base /sculpture base material

- Metal
- Materials used to make polychrome: pigment, binder
- Material used to protect the surface
- Location of an object in a place negatively affecting its lasting: setting of foundations, soil dampness

Later interferences: vandalism

Thermal-humidity factors: moisture condensation, water infiltration

Thermal factors: seasonal frost penetration, impact of sunlight and high temperatures

Physico-chemical factors: air pollution, corrosion, salt dissolution and crystallization

Biological factors: microorganisms, plants

Mechanical factors: public access

The following is a summary of the results of analytical tests and the main causes of destruction of all research groups:

INFORMATION ON ANALYTICAL TESTS CARRIED OUT ON SELECTED OBJECTS

CESMAR7 ANTARES	• Microscopic observations • μ-Raman / Raman spectroscopy • Fourier transform infrared spectroscopy-attenuated total reflectance (FTIR-ATR) • Colorimetric analyses • Biological analysis
UVIGO	• micromorphological study • micromorphological and compositional analysis (SEM), (FEI), (EDX) • X-ray diffraction (XRD), X-ray generator and Cu-Ka by random powder and incident methods • Fourier transform infrared spectroscopy (FTIR) • content of soluble salts • colour measurements in the CIELAB space
CICS	**Information about all the materials used was obtained through interviews with the artist and documentation**
UNITO, CCR	• microscopic observations • stratigraphy • SEM-EDX • Fourier transform infrared spectroscopy (FTIR) • pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) • X-ray diffraction (XRD)
AFA	• micromorphological and compositional analysis (SEM-EDS), • Fourier transform infrared spectroscopy-attenuated total reflectance (FTIR-ATR) • μ-Raman spectroscopy • X-ray diffraction (XRD)
METRIS (for the Croatian research group)	• Optical microscopy • SEM and SEM/EDS • FT-IR / micro FT-IR • Microbiological analysis • Py-GC/MS

TECHNIQUE (PIGMENTS AND BINDERS)

CESMAR7 ANTARES	PIGMENTS • PY74, PY83, PO34, PR112, PR22 or PR8 and PR18?, PR254, PR48:1, PV23?, Hostopen Violet, phtalocyanine, Hostasol green, PB15:3?, Calcite, Rutile, Silicates BINDERS • styrene modified polyester, alkyd, acrylic, alkyd-nitro, PVA *the use of a white prime coating about 40 µm thick is very common
UVIGO	PIGMENTS • organic pigments, Ni (?), Ti, Cu, S, organic Cl (?), gypsum, titanium white, iron red, carbon black, organic Cu (?), calcite BINDER • Acrylic resin, Sb stabilizer,
CICS	**Information about all the materials used was obtained through interviews with the artist and documentation**
UNITO, CCR	PIGMENTS: a) INORGANIC • The most frequently present are talc, kaolin and other silicates, calcite, titanium white and quartz. • Sometimes also barite, dolomite, Prussian blue, Zn white and possibly earth pigments (only once). • Gypsum was also found, usually in association with the presence of a concrete support. b) ORGANIC • Pigment Violet 19 (or Cinquasia Violet), Pigment Yellow 151, Pigment Yellow 74, Pigment Red 48 and several orange organic pigments, reasonably identified as Pigment Orange 5, 16, 34 and 36. BINDER a. METAL ARTWORKS: o nitrocellulose, styrene acrylic and alkyd-based products o poly(vinyl acetate) and acrylic paints b. WOOD ARTWORKS: o alkyd paints on a previous green acryl-based paint c. MURALS (by number): o alkyd and alkyd-nitro paint, eventually modified with styrene or in mixture with poly(vinyl acetate)/versatate o acrylic resin, either modified with styrene or nitrocellulose o Poly(vinyl acetate) resin (6 samples, 2 of which came from acts of vandalism) o mixture of styrene acrylic and alkyd resin (3 samples) o mixture with poly(vinyl acetate)/versatate (only in one sample)

AFA	PIGMENTS • barium white, titanium white, calcium carbonate, dolomite, gypsum, black iron oxide, carbon black, organic yellow (monoazo), organic red (monoazo), phtalocyanine blue, ultramarine, raw umbre, burnt sienna and silicates or aluminosilicates as a filler BINDERS • acrylic resin, polyester resin, polyvinyl acetate and a mixture of acrylic and phthalic resin MORTAR • lime-sand mortar, lime mortar, lime and cement mortar with quartz filler; charcoal black
METRIS (for the Croatian research group)	PIGMENTS • whites: barite, titanium white, chalk, silicates • red lead, iron red, chrome red, • chrome yellow • Prussian blue • organic pigments BINDERS • alkyd binders METAL • steel, in some examples zinc plated steel

OTHER STUDIES HAVE BEEN HELPFUL

CESMAR7 ANTARES	Imaging analyses such as digital photography with raking light and ultraviolet fluorescence
UVIGO	We have not found the need to apply other techniques
CICS	An open source offering climate data collected between 1982 and 2012 showed large amounts of rainfall in Cologne during the years since the sculpture was mounted.
UNITO, CCR	In general, the observed degradation phenomena were reasonably produced by a set of causes difficult to interpret. Only in a few cases the careful observation of the artworks, even with portable microscopes, led to the identification of some hypothetical causes of decay, often associated to vandalism, mechanical injuries, biological colonization, animal activity, percolation of water, air pollution or interactions between constituent materials and the outdoor environment (salts dissolution- crystallization, runoff, filming layers, freezing and unfreezing cycles, light-induced ageing/alterations, ...).
AFA	Photography, documentation from previous years, interview with the artist

METRIS (for the Croatian research group)	It was very important to compare and reconcile the results of analytical analysis and the in-situ visual inspection. In some cases we have new discoveries of paint that was preserved only in traces or zinc plating that became almost invisible to the naked eye.

INFORMATION ON THE CAUSES OF DETERIORATION OF SELECTED WORKS OF ART (GENERAL)

CESMAR7 ANTARES	Primary causes: ▪ Materials used for coating, plaster: binder, filler ▪ Materials used to make polychrome: pigment, binder ▪ Factors related to the construction base: reinforced concrete Thermal-humidity factors: capillary moisture, temperature fluctuations, geographic location of the object Thermal factors: exposition on light, high temperature Physico-chemical factors: salt dissolution and crystallization, air pollution Later interferences: repainting, vandalism Biological factors: plants, microorganisms Mechanical factors: mechanical injuries, public access
UVIGO	Factors related to the construction base: concrete, reinforced concrete, wood, metal Thermal-humidity factors: capillary moisture, water infiltration Thermal factors: exposition light, high temperature Physico-chemical factors: salt dissolution and crystallization, Mechanical factors: mechanical injuries, abrasions, public access
CICS	Later interferences: repainting, later conservations and restorations, vandalism Thermal-humidity factors: water infiltration Thermal factors: seasonal frost penetration, impact of sunlight and high temperatures Physico-chemical factors: air pollution, salt in the air Biological factors: animal activities Mechanical factors: mechanical injuries, abrasions, public access
UNITO, CCR	In general, the observed degradation phenomena were reasonably produced by a set of causes difficult to interpret. Only in a few cases the careful observation of the artworks, even with portable microscopes, led to the identification of some hypothetical causes of decay, often associated to vandalism, mechanical injuries, biological colonization, animal activity, percolation of water, air pollution or interactions between constituent materials and the outdoor environment (salts dissolution- crystallization, runoff, filming layers, freezing and unfreezing cycles, light-induced ageing/alterations,...).
AFA	Primary causes: ▪ Materials used to make polychrome: pigment, binder Later interferences: reparations, setting up new installations, repainting, vandalism Thermal-humidity factors: capillary moisture, water infiltration

	Thermal factors: seasonal frost penetration, sunlight influence, high temperature influence Physico-chemical factors: air pollution Biological factors: animal activities, plants
METRIS (for the Croatian research group)	Factors related to the construction base /sculpture base material ▪ Metal ▪ Materials used to make polychrome: pigment, binder ▪ Material used to protect the surface ▪ Location of an object in a place negatively affecting its lasting: setting of foundations, soil damp Later interferences: vandalism Thermal-humidity factors: moisture condensation, water infiltration Thermal factors: thermal factors: seasonal frost penetration, impact of sunlight and high temperatures Physico-chemical factors: air pollution, **corrosion**, salt dissolution and crystallization Biological factors: microorganisms, plants Mechanical factors: public access

THE MOST COMMON CAUSES OF DETERIORATION IN THE ANALYZED OBJECTS FOR EACH PARTNERS

CESMAR7 ANATRES	• product choice (spray paints or unstable pigments like fluorescent paint) • extreme exposure to sunlight, temperature fluctuations • atmospheric agents • technical errors
UVIGO	• the climate of the NW of Spain is an important deterioration factor: all the artworks are more or less affected by biological colonization, which is the cause of the loss of paint and flaking • the poor quality of the support (raw materials of poor quality) and the previous deterioration state of the walls
CICS	• irregularly performed artificial patination and due to an unprofessional cleaning in the lower parts of the sculpture • located in a public park near a sandy footpath dust and soiling in form of earth and sand settled on the sculpture • vandalism • loss of material in form of abrasion, scratches due to sharp objects and marks from opening bottles with crown caps • animal activity (dog urine)
UNITO, CCR	• vandalism • salt dissolution and crystallization • biological colonization • mechanical injuries • animal activities • later conservations

	• poor drainage • air pollution • capillary moisture • mechanical factors
AFA	• technical errors • extreme exposure to sunlight, temperature fluctuations • atmospheric agents • different type of humidity • vandalism • biodeterioration • air pollution
METRIS (for the Croatian research group)	• open space • high moisture • moisture retention • air pollution • vandalism

2. Research Group 1: University of Turin (Italy) and Conservation and Restoration Centre "La Venaria Reale" (Italy) – Report on the Analytical Characterisation of Selected Artworks

NUMBER OF PARTNER:	P1 – University of Turin P2 – Centro Conservazione e Restauro La Venaria Reale (CCR)
COUNTRY:	ITALY
LIST OF OBJECTS:	OBJ1, OBJ2, OBJ3, OBJ4, OBJ6, OBJ7, OBJ8, OBJ9, OBJ10, OBJ11, OBJ12, OBJ13, OBJ14

2.1 Information on analytical tests carried out on selected objects, including details on sample preparation, instruments and experimental conditions used

Scientific analyses aimed at identifying the original painting materials and any protective coatings were carried out on the samples taken from the following artworks: OBJ1, OBJ2, OBJ3, OBJ4, OBJ6, OBJ7, OBJ8, OBJ9, OBJ10, OBJ11, OBJ13, OBJ14. On all the artworks listed above, condition reports have been drawn up (not included in this report) and the main problems of degradation have been identified (see annex "WP3 Causes of damage, agents of deterioration – table"). In particular, the analytical characterisation of OBJ3 and OBJ7, two of the artworks selected for the conservation intervention as part of the activities of WP5 and 6, has been performed by, a more extensive campaign of non-invasive and micro-invasive analyses.

The surfaces of works of art underwent macroscopic and microscopic observations by means of a portable visible microscope (at different magnification 60x -100x). Sampling was made with a lancet, using, when possible, areas of lacuna, flacking or scaling. A tiny fragment from the painting layers was used for stratigraphic analysis. This sample was photographed under a stereoscopic microscope front and back side (OLYMPUS SZ X10 interfaced with a digital camera OLYMPUS Color View) and then was embedded in a synthetic transparent epoxy resin; the face perpendicular to layers is grinded and polished to obtain a flat mirror surface to be observed and studied. The cross section was observed under VIS and UV light with an optical microscope OM (OLYMPUS BX51 with VIS e UV light interfaced with a PC with a digital camera OLYMPUS DP71). The acquisition and the elaboration of the images was done with the analySIS Five software. The same cross section underwent then SEM-EDX analysis with an electron microscope Zeiss EVO60 equipped with a Bruker Quantax200 XFlash®6|10 SDD detector microprobe for semi-quantitative EDX analysis. The sample was metallized with graphite and analysed with high vacuum instrumental mode (HV).

Small fragments of the various colours of the painting layers were also sampled and analysed first by Fourier transform infrared spectroscopy (FTIR) and then by pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS). FTIR spectra were measured by means of a Spectrum 100 instrument (PerkinElemer, USA) in the attenuated total reflectance (ATR) mode with a diamond crystal, using 16 scans at 4 cm^{-1} resolution in the a 4000 – 600 cm^{-1} spectral range. For Py-GC/MS analyses, samples were derivatized with the Thermally Assisted Hydrolysis and Methylation method (THM) using tetramethylammonium hydroxide (TMAH) in aqueous solution at a concentration of 25% by weight (Sigma-Aldrich, Italy). A micro-furnace Multi-Shot Pyrolyzer EGA/Py-3030D (Frontier Lab, Japan) coupled to a GC/MS system was used. Samples were placed into a stainless steel cup, added with 5 µL of TMAH solution and inserted into the micro-furnace. The pyrolysis temperature was set at 650 °C for

0.2 min, the interface temperature was 300 °C and the temperature of the GC injector was kept at 280 °C. The GC was a 6890N Network GC System (Agilent Technologies, USA) gas chromatograph with a methylphenyl-polysiloxane cross-linked 5% phenyl methyl silicone (30 m, 0.25 mm i.d., 0.25 µm film thickness) capillary column. The carrier gas was helium (1.0 mL/min) and split ratio was 1/20 of the total flow. The mass spectrometer coupled to the GC apparatus was a 5973 Network Mass Selective Detector (Agilent Technologies, USA). Mass spectra were recorded under electron impact at 70 eV, scan range 40-600 m/z. The interface was kept at 280 °C, ion source at 230 °C and quadrupole mass analyzer at 150 °C. All instruments were controlled by Enhanced Chem Station (ver. 9.00.00.38) software. The mass spectra assignment was done with the Wiley 138 and NIST1992 libraries and by comparison with literature data.
X-ray diffraction measurements were performed only on selected samples taken from the support of murals. Analyses were performed using the diffractometer PW3040/60 X'Pert PRO MPD from PANalytical, in Bragg-Brentano geometry, equipped with the high power ceramic tube PW3373/10 LFF source with Cu anode.

2.2. What characteristic features in the technique have been found in analytical studies (dominant groups of materials and techniques)?

In general, various inorganic pigments and fillers have been identified in the investigated artworks. The most frequently present are talc, kaolin and other silicates, calcite, Ti white and quartz. Sometimes also barite was found. Dolomite, Prussian blue, Zn white and possibly earth pigments were identified only once. Gypsum was also found, usually in association with the presence of a plaster support. Finally, some degradation products have been identified including oxalates, quite widespread, and iron oxide, in OBJ9 (i.e. the painted metal gate).
The number of organic pigments that have been identified is reasonable, notwithstanding the instrumental limits. The identified organic pigments are: Pigment Violet 19 (or Cinquasia Violet), Pigment Yellow 151, Pigment Yellow 74, Pigment Red 48 and several orange organic pigments, reasonably identified as Pigment Orange 5, 16, 34 and 36.
About the organic binders it is appropriate to consider separately the different types of artwork. In the gate by Halo Halo (OBJ9) nitrocellulose, styrene acrylic and alkyd-based products were used, while in Gianasso's painted panels (OBJ10) poly(vinyl acetate) and acrylic paints were used.
In the wooden benches by Navolio (OBJ11) all the analysed samples were alkyd paints, while the base green paint that was the original colour of the benches is an acryl-based paint. In two of the benches a transparent protective varnish was also found and sampled, and it has been identified as a perfluorinated polyurethane.
Regarding the murals, 39 samples out of 92, all of different colour in different artworks were found to be alkyd and alkyd-nitro based (OBJ 2, 4, 12, 13, 14 and OBJ1, 3 respectively). In 24 samples the organic binder was identified as a styrene acrylic resin (OBJ1, 3, 4, 6, 7, 8, 14) and only in one sample a mixture with poly(vinyl acetate)/versatate (OBJ8). Furthermore, styrene modified alkyd resin and in mixture with poly(vinyl acetate)/versatate have been detected in 9 and 4 samples respectively (OBJ4,12, 13 and OBJ1, 2), whereas acrylic binder was observed in 5 samples (OBJ 1, 4), only one modified with nitrocellulose (OBJ3). Poly(vinyl acetate) resin has been detected in 6 samples, two of which came from an act of vandalism registered on OBJ7 artwork. Only 3 samples have been characterized by a mixture of styrene acrylic and alkyd resin (OBJ14).
In OBJ3 and OBJ6 the protective coating covering the mural surface was identified as a poly(vinyl acetate)/versatate resin.

The variety of binders found in the same mural confirms what has already emerged in the interviews to artists, that is that often the artists used paints, both spray and not, of different brand and line: in OBJ1 and OBJ2 four different binders were identified, two different binders in OBJ4, OBJ6, OBJ8 and OBJ14, and only one binder in OBJ12 and OBJ13.

2.3. What other studies (apart from those indicated by the WP3 leader) have been helpful?

In order to investigate more in detail the chemical stability of the paints and spray colours used by street artists and to better understand the interface phenomena and interactions between the painted/sprayed layers and the support, it was decided to perform an additional study, which is placed between WP3 and WP4, and consists in the preparation and study of a series of mock-ups of murals. Based on the interviews with the artists and the results of the analyses carried out on the artworks, 5 commercial products, i.e. 3 sprays (Montana Gold, Montana 94, Molotow Belton) and 2 paints (Sikkens AlphaAcrilmat and Sikkens Fullfarbe), were selected, and for each 4 different colours (red, military green, black and white). Two primers are also included in the experimentation (Montana and Sikkens). With each of the products, films were prepared on glass slides, bricks, concrete and plaster. In the next months these model samples will be aged naturally and under accelerated outdoor conditions, and their mechanical integrity, chemical, colour and surface (hydrophobicity) changes will be monitored over time.

2.4. Information on the causes of deterioration of selected works of art

The scientific campaign carried out by the joint UNITO and CCR team aimed i) to identify the constituent materials (paints, primers, protective layers,…) present in the selected artworks through scientific analyses and ii) to identify the main degradation processes and their visible effect, through the drafting of internal condition reports. The analyses conducted within WP3 are not sufficient to unambiguously define the causes of degradation, which would have required more detailed investigations and a more extensive experimentation in situ and/or in the laboratory.
During summer internship, two of the selected artworks (OBJ 3 and 7) were further studied in order to deeper understand deterioration phenomena and set up an effective conservative intervention. For the two artworks, a detailed survey has been made after close observation of the surfaces and comparison with the results of the preliminary diagnostic campaign. Results have been collected in an accurate graphic documentation of the two artworks that describes extension and localisation of all the deterioration phenomena observed in the substrate, on the background and on the painting layers. The assessment of decay causes has been based both on the observation of the conservative condition of the artworks and on an extensive analysis of the environment, with a special focus on the exposition to atmospheric agents such as rainfalls, direct sunlight and air pollution. Since structural decay has been detected in the central part of OBJ 3, the backside of the wall was investigated, in order to understand possible connections between previous reconstruction works and the observed phenomena.

2.5. The most common causes of deterioration in the analyzed objects (eg resulting from technical and technological errors in the execution of the object, climatic conditions in a given region, social factors)

In general, the observed degradation phenomena were reasonably produced by a set of causes difficult to interpret. Only in a few cases the careful observation of the artworks, even with portable microscopes, led to the identification of some hypothetical causes of decay, often associated to vandalism, mechanical injuries, biological colonization, animal activity, percolation of water, air pollution or interactions between constituent materials and the outdoor environment (salts dissolution- crystallization, runoff, filming layers, freezing and unfreezing cycles, light-induced ageing/alterations,...).
After summer internship on OBJ 3 and 7, some of the hypothetical causes of decay have been confirmed, leading to the identification of some aspects that might be in common with the other artworks selected in Turin. Considering the constitutive materials, the use of filming paint in relation with the presence of large amount of moisture in the substrate (due both to water infiltration or capillarity absorption) has been found to be one of the most relevant causes for scaling, flacking and, subsequently, lacuna formation. Substrate irregularity, resulting from abrasion, erosion and lacunas, represents a very attractive surface for biological colonisation and growth, as well as for deposit accumulation. Exposition to direct sunlight represents instead a significant factor for chromatic variation such as fading, widely present in dark and red painting layers of the studied artworks; while, atmospheric pollution, found to be a relevant problem in the city centre, would be the main cause for particulate deposit on the surface.
Since in most cases it is very difficult to define the causes of deterioration, we preferred to refer to the effects of deterioration, that have been reported in the second part of the annex entitled “WP3 Causes of damage, agents of deterioration – table” together with a graphic representation showing their position and diffusion on the artwork.
In murals the most frequent effects of degradation were loss of cohesion, such as fracturing, cracking and flacking, loss of materials and lacunae, biological colonisation, graffiti and soiling. Of these, cracking, flacking and lacunae, if present, spread over at least half of the artwork.
In the two artworks on metal, incisions, lacunae, chromatic alterations, yellowing, corrosion, deposits and graffiti were observed.
In the wooden artworks, i.e. the series of 10 benches, the most frequent effects of degradation were incisions, fracturing, cracking and lacunae.

2.6. Added value due to the European dimension of the project

In the context of WP3 the European dimension of the project will be useful to obtain a wide and varied set of scientific data about the constituent materials of different artworks of urban art located in various parts of Europe. This will make it possible to have a general overview of the materials used in urban art, especially for the case of murals, and of their degradation processes. Moreover, it will allow to evaluate in a comparative way the performances of different products over time or of the same product used in different climatic and environmental contexts. This will be very important, in a perspective of preventive conservation, for the development of WP5, where the guidelines for the conservation of urban art will be defined.
The European dimension will facilitate the circulation of the scientific results obtained, also at the level of a non-specialist public, offering to various stakeholders (for example artists or clients) the possibility to acquire greater awareness on the relationship between quality of materials, technical execution and the conservation of the artworks.

2.7. Potential benefits of cooperation / division of competences between partners

The partners University of Turin and CCR worked together on the analytical characterization of the painting materials and on the study of deterioration effects. The scientific expertise and instrumental facilities present in the Department of Chemistry of the University and in the CCR laboratories were completed by the work of conservators who took care of the sampling and drafting of condition reports for each of the artworks. The collaboration between the two partners has stimulated the discussion between experts with different skills and a more critical approach to the various activities of WP3.
The collaboration with the municipality of Turin has in many cases made it possible to simplify the procedures for obtaining the authorizations for sampling and for carrying out scientific analyses. This is an important aspect if we consider that the delays recorded in the implementation of WP3 were caused above all by the difficulty to obtain such authorizations quickly.
The results of the scientific analyses and of the studies conducted in WP3 will constitute a collection of useful data for business partners that deal with the production and sale of painting and restoration materials.

2.8. Derogation from the work plan

Task 1 (Analysis) and Task 2 (Classification of the main degradative processes) have been carried out as planned in the work programme. As for Task 2, due to logistical difficulties and cost issues, it was decided not to carry out a direct control of the environmental parameters, but to analyse the meteorological data (temperature, precipitation, snow, humidity, radiation, wind speed) registered by the automatic stations of ARPA, the regional agency for environmental protection.
Considering that the activities of WP2 were completed late (i.e. at month 11 of the project), the activities of WP3 took place on schedule and are to be considered completed. Moreover, the artworks OBJ3 (mural in honour of the victims of the ThyssenKrupp tragedy, by Monkeys Evolution, 2008) and OBJ7 (mural by Millo, 2014) will be the object of a conservative intervention that has been carried out during the summer internships of the master's degree course in Conservation and Restoration of the University of Turin. In preparation of the summer internships, OBJ3 and OBJ7 has been subjected to a more in-depth diagnostic research campaign that will be organised within WP5 (Implementation of a conservation methodology) and WP6 (Implementation of an innovative formative module).

2.9. Problems encountered and implemented or proposed solutions

Problems were encountered in:

1. getting the authorization of artists and owners to perform sampling and non-invasive in situ analyses of the artworks. In some cases, it was quite complicated and time consuming to get the authorization by signing of specific waiver, mainly due to bureaucratic procedures;
2. complying with the WP3 schedule due to the malfunction of an instrument and its subsequent breakdown. The replacement with a new instrument was quick but still took a couple of months. The deadline for WP3 report was met by limiting the number of analyses and carrying them out only in those cases in which the other performed analyses had not been able to completely clarify the nature of the organic components present in the sample.

1.10. A distinction of the main results (products and results) for artists, structures, sectors or systems that has generated your project so far. Description of receipts for target groups (including participating institutions and stakeholders). Proposal (if possible) of qualitative and quantitative indicators.

Deliverable / results	Target groups / potential beneficiaries	Impact	Quantitative indicators	Qualitative indicators
Analytical report Degradative process report	Researchers Conservators	Increased competences in the conservation of street art and in the materials used in street art	• Number of publications • Number of presentations at conferences • Number of contacts	Degree of satisfaction of the target group (Survey conducted via mailing list)
Analytical report Degradative process report	Museums Municipalities Foundations	• Starting new contacts/ collaborations • Increased visibility • Greater funding possibilities from institutions or companies	• Number of collaborations • Project citation number in social media	Interaction on the social media channels
Analytical report Degradative process report	Students Teachers	• Increased visibility • Lectures and seminars for university students in conservation and restoration, in conservation science and related disciplines • Increased competences in the conservation of street art and in the materials used in street art • Development/use of new teaching methods	Number of seminars	Interaction on the social media channels
Analytical report Degradative process report	Artists	Increased knowledge on materials used in street art	Number of contacts	Interaction on the social media channels
Analytical report	Municipalities Policy makers	Increase technical competences		Introduction of specific

Degradative process report		Greater awareness in relation to specific urban conservation policies		prescription for durability and maintenance in public tenders
Analytical report Degradative process report	General public	Increased interest on urban art and awareness on conservation issues	Number of visualizations of CAPuS Project website and FB page	Interaction on the social media channels

3. Research Group 2: CESMAR7 (Italy) and AN.T.A.RES SRL (Italy) – REPORT ON THE ANALYTICAL CHARACTERISATION OF SELECTED ARTWORKS

NUMBER OF PARTNER:	P3 (CESMAR7) P4 (AN.T.A.RES)
COUNTRY:	Italy
LIST OF OBJECTS:	Murals in Reggio Emilia (Via Selo/Via Candelù: The Big Mother, Big Sacral Bird, Oriental Carpet, Economy subdues you, Mandala-Pigal: Two Dragons-Dalla Chiesa School: Ubuntu) and in Milan (Fabbrica del Vapore: Ubuntu and Homage to Kahled al Asaad- Niguarda Antifascista)

3.1. Information on analytical tests carried out on selected objects, including details on sample preparation, instruments and experimental conditions used

Preliminary observation of the samples taken from the selected mural paintings was performed by using stereomicroscope to describe their superficial appearance and their layered structure. LFZNT stereomicroscope (Opthech) equipped with Digital camera ISDV5003 and led ring light was used.

Analytical examination of the samples was carried out using µ-Raman spectroscopy and Fourier transform infrared spectroscopy-attenuated total reflectance (FTIR-ATR) in order to identify the composition of the paint and ground layers (pigments, classes of synthetic binding media and fillers) such as degradation products and alteration phenomena; for this aim, sampling was mainly focused on chromatically alterated areas.

Sample collecting was performed by scalpels to remove multiple-layer chips.

A chip of the samples was impregnated, under vacuum, with an epoxy resin (Hardrock 554); after curing, it was carefully polished by a lapping machine (LS3V Remet) covered with abrasive papers at various grits (Akasel) to expose the multiple-layer face. The cross-sections obtained were analyzed using both an optical microscope (MP3500 Prior) with reflected visible light than by means of an Olympus BX40 microscope attached to a Jobin-Yvon Horiba LabRam confocal Raman spectrometer equipped with a Peltier-cooled charge-coupled detector (CCD). The spectra were collected exciting with the 473.1 nm line of a doubled Nd:YAG laser and with the 632.8 nm line of a He-Ne laser. The laser beam was focused on the sample with a spot-size of ~2 µm of diameter (objective ULWD 50x) or ~1 µm of diameter (objective 100x). The confocal aperture was set at 150 µm, allowing a spectral resolution of 2-3 cm-1. The Raman spectra were collected in backscattered geometry. The instrument was calibrated using the emission lines of a fluorescent bulb and the silicon Raman peak (520.6 cm-1) before each measurement session.

Another chip of the samples was analyzed employing a FT-IR Spectrum Two-Perkin-Elmer spectrophotometer equipped with a LiTa03 15700–370 cm^{-1} detector and ATR diamond crystal accessory. Infrared spectra were recorded in the 4000–450 cm^{-1} range, resolution 4 cm^{-1} and 4 scans. All spectra were collected and analyzed at least on the upper and lower layer of the samples by using OMNIC software.

Due to the important chromatic alteration observed, a non invasive investigation by using three different portable Raman spectrometers was performed on Reggio Emilia (Via Selo and via Candelù artworks in Reggio Emilia) mural paintings in order to characterize pigments involved in this phenomenon.

The handheld EnSpectr RaPort and the portable *i-Raman®EX* (B&WTek) coupled with a 532 nm and a 1064 nm laser, respectively, together with the handheld dual laser BRAVO Raman spectrometer (Bruker) were employed for the measurements. A mobile scaffold mounted on a truck was used to reach zones of the paintings located at different altitudes (up to 15 meters). The results have been compared to that obtained by means of the Horiba Labram micro-Raman apparatus on few samples.

Microbiological analysis was performed on several samples taken during different periods of the year to confirm the presence of a bio-film on “Two dragons carrying an egg” painting.

In a preliminary survey, the samples (about 20 mg) obtained scraping the dark patina with a sterile scalpel was homogenized in a Potter tissue grinder with sterile mineral water. The liquid samples were observed under an optical microscope (up to 1000 X, Optika).
In subsequent surveys, samples were analysed by cultural techniques. The samples were collected and homogenized as before and then plated directly on Czapek agar (0,2 ml aliquots), a generic media for filamentous fungi but also for yeast and not fastidious bacteria.

Colorimetry analyses were performed only on UBUNTU painting in Reggio Emilia realized in 2018 to start a monitoring campaign regarding the stability of the colours. For this aim, an handheld Konica Minolta CM 2600-d spectrophotometer was used. Data were collected in the 360–740 nm range, 10 nm acquisition step, UV source included, D65 (daylight 6500 K) and SCI_SCE mode.

3.2. What characteristic features in the technique have been found in analytical studies (dominant groups of materials and techniques)?

The optical data from fragments and cross-section samples of different mural paintings have shown that the use of a white prime coating about 40 µm thick is very common; it results mainly composed of Rutile and Calcite and it fills up the roughness of the ground layer allowing a smoother and a more resistant surface to be paint.

The paint layer, regardless of the organic pigments measured, contains the inorganic fillers above mentioned, in particular Rutile.

Many different pigments and dyes, belonging to different paint areas, have been identified.

- Yellow PY74, PY83
- Orange PO34
- Red PR112, PR22 or PR8 and PR18?, PR254, PR48:1
- Violet Hostopen Violet, PV23?
- Blue Phtalocyanine, PB15:3?
- Green Hostasol green

Effects of the photo-degradation have been revealed.

Binding media often contain acrylic or alkyd resin, styrene or not modified. In only two cases PVA and alkyd resin modified with nitrocellulose were found.

Finally, enrichment of Rutile in the very thin whitish patina from faded painting has been measured. This outer layer only contains Rutile and binding media.

In an only one mural painting (Two dragons carrying an egg) we have found an original whitish coating layer based on an acrylic emulsion.

3.3. What other studies (apart from those indicated by the WP3 leader) have been helpful?

Imaging analyses such as digital photography with raking light and ultraviolet fluorescence performed on the "Two dragons carrying an egg" mural painting have been useful in order to observe the state of conservation and the fluorescence response of the coating. Images were taken with different degrees of detail on many areas of the painted surface by a Nikon D800 digital camera with 28 mm, 50 mm and 105 mm micro lens; four incandescent lamps at 800 W (Ianiro) and forty UV fluorescent tubes at 18 W were used for raking and ultraviolet photos, respectively.

3.4. Information on the causes of deterioration of selected works of art.
In Reggio Emilia:

- The **Via Selo-Via Candelù artworks** are mainly affected by heavy chromatic alterations (an orange used in three artworks has turned into greyish purple) and fading (on oranges, purples and yellows), plus an example of total fading of a dark pink used in almost every artwork; this was determined by the instability of some colours (spray colours, MNT94) and by the general total exposure of all the murals to sunlight and to atmospheric factors (no trees except in the case of *The Big Mother* mural). In Zosen, the most exposed of the murals (no trees and south orientation), the general fading is more evident than in other artworks. In two artworks (by Kenor and H101), there are also visible problems of cracking with flaking and losses, deriving hypothetically from the upper layer of plaster (gypsum composition to be confirmed). In this case, the pattern of the cracks follows the bricks underneath. The plaster and the yellowish ground layer are the original ones from the late 50s. As in KENOR, there is no priming (data from photos taken during production) and the damage is slightly more severe than on H101, with pronounced cracks, larger flakes and, in the lower part, also subfluorescence between the yellowish ground layer and the plaster.
- **PIGAL:** in this case, the main cause of deterioration is the lack of priming along with the presence of a coating that, on this very exposed wall (south-west facing, no trees), started flaking together with the colour underneath. In many cases, we can see general fading, blistering (sprays) and darkening of the blue paint. There is also the presence of biological colonization (dark areas).
- **Dalla Chiesa school:** from the comparison of the pictures taken in July 2018 with the conditions as of March 2019, it is evident that the fluorescent sprays used for the flag have faded and, in some cases, almost disappeared (MNT 94); this is due to the general instability of the hues and also to the exposure of the artwork to sunlight and pollution.

In Milan:

- **Fabbrica del Vapore:** in the mural *UBUNTU* (2014), we can see general fading and a strong chromatic alteration to greyish purple of the orange used for Mandela's face. This is mainly due to pigment instability (in this case, the paint is an acrylic, not a spray). The most prominent cause of deterioration is that the wall had not been fixed before painting began (in many cases we see losses with the colour in, so they must have already been present

at the time of production). In *Homage to Kahled al Asaad*, the conditions are generally good because it is a more recent piece and the plaster was completely reapplied by the Municipality of Milan before the execution.

- **Niguarda Antifascista:** In this case, the deterioration is mainly due to the fillers in the concrete brick (glass and pieces of metal) which caused losses and erosion. General fading due to the colours' instability and to exposure to atmospheric agents (rain washout on the upper part, pollution) is visible.

3.5. The most common causes of deterioration in the analyzed objects (e.g. resulting from technical and technological errors in the execution of the object, climatic conditions in a given region, social factors)

In general, the selected artworks are affected by chromatic alteration, darkening and fading caused by a number of factors, including product's choice (spray paints or unstable pigments like fluorescent paint), extreme exposure to sunlight, temperature fluctuations (in Milan and in Reggio Emilia the climate can be very cold in winter and extremely hot and humid in summer) and atmospheric agents (polluted areas with traffic). In some cases, we can also see technical errors (e.g. deteriorated walls, not fixed before painting or/and not primed as in Kenor in Reggio Emilia). In one case, the wall itself was not suitable for painting because of inerts in the concrete, causing diffused blistering and losses (*Niguarda Antifascista*). Except for Pigal, no coatings were applied to artworks. However, in the case of the *Two Dragons*, the coating itself was the first cause of damage, along with the paint having been applied directly onto not primed concrete.

3.6. Added value due to the European dimension of the project

In this phase, the European dimension of the project offers the opportunity to compare the different types of degradation closely related to the climate conditions of the location, as well as to the modus operandi of the local artists and how this influences the artworks' conservation (product's choice, intervention on the wall – e.g. priming or preparation/fixing the wall before painting). Throughout the project, it was also possible to involve scientific personalities from other institutions, who wished to contribute to it (because of the European value and the prestige of the initiative): University of Parma, University of Ghent, Ca' Foscari University of Venice, with analysis or MA thesis, and IVBC- Istituto Veneto per i Beni Culturali for a BA thesis. This opportunity will allow us to investigate many more aspects regarding materials and their alterations, as well as to discuss analytical protocols. The experience of the professionals will also be key to the teaching module's design. The involvement of European institutions outside the partnership also promotes the project and it is functional to the highly desired leverage effect that contributes to the long-term sustainability of the project. The project is having great resonance even outside the conservation sphere: we were contacted by a journalist who has been writing about street art for years (Clara Amodeo of *Another Scratch in the Wall*) in order to study other writing artworks by the Milan Old School.

3.7. Potential benefits of cooperation / division of competences between partners

The cooperation between partners and colleagues has enabled us to carry out analysis, exchanging on the protocols used (for analytical techniques and sample preparation). The opportunity to share equipment (py-GC/MS and colorimeter from UNITO) enabled us to further investigate the materials' degradation processes and their characterization. The exchange of the final results will be essential to the design of the subsequent phases of the project, especially the products' choice and the best

application methods. The involvement of the companies was very important for defining an analytical protocol that could be useful not only from the researcher's or conservator's point of view, but also to understand the materials and their stability as commercial formulations.

3.8. Derogation from the work plan

To better characterize the constituent materials of the selected mural painting, some samples already analyzed has been addressed to Pyrolysis/Gas Chromatography–Mass Spectrometry (Py/GC–MS); this technique will provide additional information on polymers, dyes, pigments and additives on respect to Raman and FTIR analyses.
Moreover, we add further investigation dealing with a MA thesis at Ca' Foscari University of Venice: together with the candidate, we have prepared samples simulating real cases (plaster support+paint colours) focusing on the most unstable paint among those used in the selected artworks. After artificial aging, monitoring the colour change with colorimetry and other analytical techniques is planned. The selected coating products will be tested on these samples (see Wp4).
During WP3, an additional interview was added to those already carried out, in order to better understand the execution of the UBUNTU work (Reggio Emilia) and the products used. Another thesis that is underway is the one by an IVBC student focusing on the analysis of a work by a Venetian artist (Zentequerente). The student, who conducted an interview with the artist, will take and analyse samples through cross section. The paper will end with an intervention hypothesis. Within next summer, a second campaign of colorimetric measurements will be carried out in order to monitor UBUNTU (Dalla Chiesa middle school, Reggio Emilia).

3.9. Problems encountered and implemented or proposed solutions

- Difficulties in involving local institutions to collaborate in the promotion and dissemination of the project. **PROPOSED SOLUTION:** organise a seminar or a one-day conference to promote the project in partnership with Municipalities
- Difficulties in coordinating with other partners, when it came to timing and communicating with everyone on how to carry out the activities (current channels of communication are not very effective and the active ones are not used by partners). **PROPOSED SOLUTION:** improve the communication channels (e.g. other platforms like *Slack* collaboration software) and promote the social media activity.

- FOR CESMAR7: difficulties as NGOs in carrying out activities independently; the WP3 activities have always been carried out in partnership with ANTARES and developing alliances with other European and Italian institutions or relying on other Italian partners for analytical devices. **PROPOSED SOLUTION**: develop other alliances or express the need to do so with other partners (carefully planning next WPs activities with a more precise schedule, in order to have time for finding solutions and seeking help from partners).

3.10. A distinction of the main results (products and results) for artists, structures, sectors or systems that has generated your project so far. Description of receipts for target groups (including participating institutions and stakeholders). Proposal (if possible) of qualitative and quantitative indicators.

Deliverable / results	Target groups / potential beneficiaries	Impact	Quantitative indicators	Qualitative indicators
Analytical characterization of the materials used	Partners	✓ Exchange of analytical protocols and methods used ✓ Improved knowledge of other analytical techniques ✓ Exchange of useful results to further the project (WP4)	✓ Number of scientific papers in collaboration with consortium partners	Internal survey on **collaborative publication**
	Researchers	✓ Increase knowledge on materials used by artist and methods ✓ Increased knowledge on analytical methods and protocols	✓ Number of scientific papers on urban art topic ✓ Number of researchers accessing the website (publication session) ✓ Number (increase) of followers (researchers) on post on analytical details	• Survey via project website, FB page and mailing list (targeting access) • Statistics on accesses to other urban art conservation channels (social media, blogs, websites)
	Conservators -Restorers	✓ Increased knowledge on materials used by artists and methods (and how to link them to degradative patterns)	✓ Number of papers (on line, journals) on conservative treatment of urban artworks ✓ Number of on line news (specialized website) on conservative treatment of urban art	• Survey via project mailing list, FB page and website • Statistics on accesses to other

			✓ Number of conservators accessing the website (publication session)	urban art conservation channels (social media, blogs, websites)
	Students	✓ Increased knowledge on materials used by artists and methods (and how to link them to degradative patterns) ✓ Increased knowledge on analytical methods and protocols	✓ Number of students involved in theses on the topic ✓ Number of students accessing website (publication session), FB page (post on analytical characterization) and subscribing to mailing list	• Survey via project website, FB page and other social media, mailing list • Statistics on accesses to other urban art conservation channels (social media, blogs, websites)
	Teachers	✓ Increased knowledge on materials used by artists and methods (and how to link them to degradative patterns) ✓ Increased knowledge on analytical methods and protocols	✓ Number of teachers (outside the consortium) involved in theses or researches on the topic ✓ Number of teachers accessing website (publication session), FB page (post on analytical characterization) and subscribing to mailing list	• Survey via project website, FB page and other social media, mailing list • Statistics on accesses to other urban art conservation channels (social media, blogs, websites)
	Product companies	✓ Increased knowledge on materials used by artists and methods (and how to link them	✓ Number of companies involved in publication or researches on the topic (urban art conservation and	• Survey via project website, FB page and other social media, mailing list

		to degradative patterns) ✓ Increased knowledge on analytical methods and protocols ✓ Increased knowledge on instability of commercial products (organic pigments in spray or paints); ineffectiveness of some coatings	materials' stability)	• Statistics on accesses to other urban art conservation channels (social media, blogs, websites)
Degradation processes report	Partners	✓ Increase in knowledge on degradative processes as a result of the exchange of information with other partners ✓ Increased knowledge on degradative processes connected with other climate/atmospheric conditions ✓ Increase in knowledge of degradative processed on other supports (different from the one considered by the team)	✓ Number of collaborative papers on degradation patterns	• Internal survey
	Researchers	✓ Increase in knowledge on degradative patterns and common factors for urban art (on wall and on metal) ✓ Increased knowledge of	✓ Number of scientific papers on the topic ✓ Number of researches on the topic	• Survey via project website, FB page and other social media, mailing list • Statistics on accesses to other

		products' instability ✓ Increased knowledge on degradative processes connected with specific climate/atmospheric conditions		urban art conservation channels (social media, blogs, websites)
	Conservators-Restorers	✓ Increase in knowledge on degradative patterns and common factors for urban art (on wall and on metal) ✓ Increased knowledge of products' instability ✓ Increased knowledge on degradative processes connected with specific climate/atmospheric conditions ✓ Improvement of knowledge on materials' behaviour for other supports or artworks, including such products (e.g. coatings for architecture or spray also used on canvas) /further researches	✓ Number of published papers on conservation of urban art (especially on materials' stability and degradative factors) ✓ Number of papers on conservation of other types of artworks referring/mentioning the project's publications	• Survey via project website, FB page and other social media, mailing list • Statistics on accesses to other urban art conservation channels (social media, blogs, websites) • Statistics on access to conservation channels (not directly connected with urban art)
	Students	✓ Increase in knowledge on degradative patterns and common factors for urban art (on	✓ Number of theses on the topic ✓ Number of students involved in researches on urban art	• Survey via project website, FB page and other social media, mailing list

		wall and on metal) ✓ Increased knowledge of products' instability ✓ Increased knowledge on degradative processes connected with specific climate/atmospheric conditions ✓ Improvement of knowledge on materials' behaviour for other supports or artworks including such products (e.g. coatings for architecture or spray also used on canvas) /further researches	✓ Number of theses on conservation of other types of artworks referring/mentioning the project's publications (results useful also for other types of supports)	• Statistics on accesses to other urban art conservation channels (social media, blogs, websites) • Statistics on other European universities' websites
	Teachers	✓ Increase in knowledge on degradative patterns and common factors for urban art (on wall and on metal) ✓ Increased knowledge of products instability ✓ Increased knowledge on degradative processes connected with specific climate/atmospheric conditions ✓ Improvement of knowledge on materials'	✓ Number of theses on the topic ✓ Number of teachers involved in researches on urban art ✓ Number of papers or theses on conservation of other types of artworks referring/mentioning the project's publications (results useful also for other types of supports)	• Survey via project website, FB page and other social media, mailing list • Statistics on accesses to other urban art conservation channels (social media, blogs, websites) • Statistics on other European universities' websites

		behaviour for other supports or artworks including such products (e.g. coatings for architecture or spray also used on canvas) / or for further researches		
	Municipalities	✓ Increased awareness of general instability of urban art (and materials used) and the need to protect/perform conservation treatments on such artworks	✓ Number of requests for conservative treatments on urban artworks ✓ Number of contacts with other municipalities (not involved in the consortium) to plan an urban art intervention	✓ Survey via project website, FB page and other social media, mailing list ✓ Statistics on accesses to other urban art conservation channels (social media, blogs, websites)
	Companies	✓ Increase in knowledge on degradative patterns and common factors for urban art (on wall and on metal) ✓ Increased knowledge of products' instability ✓ Increased knowledge on degradative processes connected with specific climate/atmospheric conditions ✓ Improvement of knowledge on materials'	✓ Number of companies involved in publication or researches on the topic (urban art conservation and materials' stability) ✓ Number of researches or publications on new products ✓ Number of changes in products' catalogues (products added/remove) after the	

		behaviour for other supports or artworks including such products (e.g. coatings for architecture or spray also used on canvas) /further researches ✓ Improved awareness of the need for more stable products or specific formulations for artworks in extreme conditions	publication of project results	
	Citizens and general public	✓ Increased awareness of general instability of urban art (and materials used) and the need to protect/perform conservation treatments on such artworks	✓ Number of requests for conservative treatments ✓ Number of contacts from the general public (emails, phone calls) for interventions or for dissemination activities	✓ Survey via project website, FB page and other social media, mailing list ✓ Statistics on accesses to other urban art conservation channels (social media, blogs, websites)
New alliances with other institutions (European universities)	Partners	✓ Exchange of knowledge on analytical protocols and methods ✓ Exchange of degradative processes directly associated with	✓ Number of collaborative papers with other universities	✓ Internal survey ✓ Statistics on involved European universities' websites

		local climate conditions ✓ New approaches to include in the learning module		
	Universities (not included into the consortium)	✓ Exchange of knowledge on analytical protocols and methods ✓ Exchange of degrative processes directly associated with local climate conditions ✓ New approaches to include in the learning module ✓ Possibility to publish articles on the topic or develop further researches	✓ Number of collaborative papers on urban art conservation ✓ Number of researches on urban art conservation ✓ Number of theses on the topic ✓ Number of modules activated on the topic	✓ Survey via project website, FB page and other social media, mailing list ✓ Statistics on accesses to other urban art conservation channels (social media, blogs, websites) ✓ Statistics on other European universities' websites
	Students	✓ Improved knowledge on analytical protocols and methods ✓ Improve knowledge on degrative processes directly associated with local climate conditions ✓ Possibility to be included in researches for MA theses	✓ Number of theses on urban art ✓ Number of researches on urban art involving student from partner universities	✓ Survey via project website, FB page and other social media, mailing list ✓ Statistics on accesses to other urban art conservation channels (social media, blogs, websites)

				✓ Statistics on involved European universities' websites
	Municipalities	✓ Possibility to get in touch and exchange good practices with other European institutions through university researches	✓ Number of events (on urban art) in collaboration with other European institutions	✓ Survey via project website, FB page and other social media, mailing list ✓ Statistics on accesses to other urban art conservation channels (social media, blogs, websites)

4. Research Group 3: University of Vigo (Spain)

NUMBER OF PARTNER:	15
COUNTRY:	SPAIN
LIST OF OBJECTS:	1, 4, 7, 8, 14, 15, 16, 18, 20, 25, 26

4.1. Information on analytical tests carried out on selected objects, including details on sample preparation, instruments and experimental conditions used

In deteriorated works, we carry out samplings of alteration forms and supports. In these samples the following analyses were applied:

• A micromorphological study of the samples using the Nikon SMZ1500 stereomicroscope, observing both the surfaces of the samples and cross sections made after embedding the samples in resin and polishing them in cloth with 3 µm diamond paste.

• A micromorphological and compositional analysis was performed using two scanning electron microscopes (SEM): QUANTA 2000 (FEI) and Phillips XL 30 equipped with a coupled energy dispersion probe (EDX).

• Mineralogy was obtained by x-ray diffraction (XRD) using a Siemens D5000 equipped with an X-ray generator and Cu-Ka by random powder and incident methods.

• Chemical analysis using infrared spectroscopy by Fourier transforms (FTIR) specially indicated to characterize the organic phase of paints. Thermo Nicolet 6700 equipment has been used (mainly in ATR mode and occasionally by reflection) in the spectral region of the average IR (between 400 and 4000 cm-1).

• Content of soluble salts. To perform this analysis, 0.5 g of the sample is stirred in 25 mL of deionized water for 1 hour after which the extract is filtered and the chloride, sulphate, nitrate and carbonate anions are analysed by high performance liquid chromatography. This analysis was done only on samples of supports

In the new works, a sampling of the main colouring palettes was carried out and colour measurements were made in the CIELAB space, repeating the measurements every 30 days. After one year, the repetition of the sampling will be performed in order to compare initial and altered paint samples in a natural environment.

4.2. What characteristic features in the technique have been found in analytical studies (dominant groups of materials and techniques)?

Basically the bad quality of the supports and the complete absence of preparation of the supports to house the mural work. With respect to the composition of paintings, we can not provide much information yet.

4.3. What other studies (apart from those indicated by the WP3 leader) have been helpful?

We have not found the need to apply other techniques

4.4. Information on the causes of deterioration of selected works of art.

With respect to the deterioration works, the following are the most important deterioration forms:

1. flaking, peeling and loss of painting : the results of analyses confirmed that the most likely cause of deterioration is associated with the poor quality of the support, either because its quality as a constructive material was already initially poor (cement mortars made with raw materials of low quality) or because the support was already deteriorated before painting. In these last cases, soluble salts crystallization processes (mostly gypsum) and biological colonization are the mechanisms / factors involved in the deterioration of the supports. It should be noted that this fact confirmed that independent artists did not previously prepare the support before painting it. This is the case of the objects 1 and 7 (Entaraña and EScarabajo Pelotero).

2) In the loss of paint and peeling also influences biological colonization, specifically in those murals facing north. The humid and temperate Galician climate favours the colonization by mosses, vascular plants and, above all, biofilms formed by cyanobacteria (the Nostoc, Scytonema, Gleocapsa genus) and lichens such as Lepraria sp, Collema sp and Candellriella sp. This is the case of objects 7 and 14.

3) The other alteration form is fading. With respect to this form of alteration, we do not yet have clear what is the cause since the research is based on laboratory analysis after submitting samples to aging tests and also on the analysis of samples of recent works that are monitored over time (which are the case of the objects 26, 20, 18, 16 and 15).

4.5. The most common causes of deterioration in the analyzed objects (eg resulting from technical and technological errors in the execution of the object, climatic conditions in a given region, social factors)

As indicated in the previous section, the poor quality of the support (raw materials of poor quality) and the previous deterioration state of the walls chosen by the artists chose to paint their artworks (in these cases, the artists are independent) are the key aspects unrelated to the characteristics of the paintings, which affect the conservation of the works. In addition, we found that the climate of the NW of Spain is an important deterioration factor: all the objects are more or less affected by biological colonization, which is the cause of the loss of paint and flaking.

4.6. Added value due to the European dimension of the project

As we expressed in the wp2 report, the main contribution of the Spanish team is the study of works that are subject to a climate environment that favours the rapid biological colonization, which is the climate that characterizes Galicia, where it rains about 2000 mm at year and, in addition, with a great marine influence. In this sense, the analytical study of the durability of the paintings used in modern works in this environment will suppose a contribution of unique character to the project.

4.7. Potential benefits of cooperation / division of competences between partners

The exchange of ideas, information and analytical practices during this work package was null.

4.8. Derogation from the work plan

There has been no deviation from the proposed work plan.

4.9. Problems encountered and implemented or proposed solutions

No problem has arisen

4.10. A distinction of the main results (products and results) for artists, structures, sectors or systems that has generated your project so far. Description of receipts for target groups (including participating institutions and stakeholders). Proposal (if possible) of qualitative and quantitative indicators.

Deliverable / results	Target groups / potential beneficiaries	Impact	Quantitative indicators	Qualitative indicators
WP3 results on deteriorated works	group of restorers	High	-	Invitation to urban art conservation debate (1/3/2019) https://www.museoreinasofia.es/actividades/20a-jornada-conservacion-arte-contemporaneo
WP3 results on deteriorated works	group of restorers	High	-	Invitation to write dissemination publication about urban art deterioration to be include as a contribution to the annual monograph of the IIC Spanish Group about Urban Art (tobe published at the end of 2019) https://www.ge-iic.com/category/grupos-de-trabajo/arte-urbano/
WP3 results	Researchers on the conservation of cultural heritage field	Medium	-	Presentation of results during international congress (27/4/2019) https://drive.google.com/file/d/1adhAszvl1bhSAq3n2GIYrw0_K6ZPDwH7/view

5. Research Group 4: Academy of Fine Arts in Warsaw (Poland)

NUMBER OF PARTNER:	Academy of Fine Arts in Warsaw
COUNTRY:	Poland
LIST OF OBJECTS:	

5.1. Information on analytical tests carried out on selected objects

The analysis of materials taken from murals included the identification of mortar, pigments and binders. Numerous instrumental methods and basic classical microchemical methods were used.

Mortar identification

Mortar identification was carried out using the X-ray Diffraction method. Measurements were taken in Bragg-Brentano geometry, using the SmartLab diffractometer from Rigaku, equipped with a Cu anode and a D/tex Ultra 250 detector.

Visual examination and additional microchemical tests of mortar samples were carried out using the Nikon SMZ1000 stereomicroscope, and a flexible fiber optic illuminator.

Organic binder identification

Fourier Transform Infrared Spectroscopy is an instrumental technique used for organic binder analysis. As it identifies only different types of chemical bonds (functional groups), it allows to determine the class of the analysed organic compound. The FTIR analysis of samples was performed with a Thermo Fisher Scientific Nicolet iS 10 camera using the reflective technique of multiple weakened reflection (ATR - Attenuated Total Reflectance). To conduct a precise analysis of the obtained spectra, a series of FTIR - ATR analyses of reference substances were carried out.

To confirm the results, reaction to an alkaline solution (4M NaOH) and reaction to Lugol's solution (aqueous solution of iodine with potassium iodide) was analysed.

Pigment identification

To identify the pigments, fillers and dyes contained in the mural paints, the following analyses were carried out:

I. Microchemical analysis including: reflected light observation with the use of a Nikon SMZ1000 stereomicroscope; observation of water and/or DMF smears in transmitted light, Nikon Eclipse E200; sensitivity to acid (98% HNO_3 and 3M HCl) and alkali (4M NaOH); specific cation microchemical reaction tests.

II. Instrumental analysis:

- Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDS) for an elemental analysis of samples.

Electron images and elemental composition analysis were obtained using a scanning electron microscope (JEOL IT500 LA) with an integrated EDS X-ray spectrometer.

- X-Ray Fluorescence Spectrometry (XRF) for in situ elemental analysis.

Elemental analysis was carried out using a portable XRF analyzer Tracer 5i, Bruker. XRF analysis provided the qualitative result – a list of elements from the coloured outer layer and also from the layers underneath.

- Raman spectroscopy for pigments and organic dye identification.

***Raman spectroscopy* is a** non-destructive, reliable and sensitive method, based on inelastic light scattering at the chemical bonds of a sample. It **allows to quickly identify materials** and their molecular composition.
Pigments and organic dyes were identified using an inVia Qontor confocal Raman microscope (Renishaw) **equipped with two lasers: 532 nm and 785 nm.**

Stratigraphic cross-sections
Samples were obtained from the polychromed wall decoration by scraping minute pieces containing all paint layers with a clean and dry scalpel. They were taken from different significant parts of the decoration. Then they were embedded with a particular orientation in a transparent acrylic resin (Meliodent Rapid Repair, Heraus Kulzer), ground and polished with sand paper up to a grit size of 2000 parallel to painting layers. Highly polished layers are required for good-quality microphotographs and proper layer recognition. Such samples were used for analysis using a stereomicroscope.
Microscopic photographs were taken using a Nikon ECLIPSE Ci-L biological microscope and a Nikon D5300 digital camera connected to it.

5.2. What characteristic features in the technique have been found in analytical studies (dominant groups of materials and techniques)?

Based on the conducted tests, the substrate for the used murals (mortar) and paints (pigments and binders) was identified for 8 out of 24 murals.
The same lime mortar with quartz filler was used for all murals, and then whitened with a layer of acrylic paint containing calcium carbonate and titanium white.
Among the tested paints were mainly blacks, reds and blues. The most commonly identified pigments in the used paints were: titanium white, calcium carbonate, fillers based on silicon and aluminium compounds, less often barite white. Iron black and soot was most common in black, ultramarine and organic dye in the form of phthalocyanine blue were in blue, while synthetic red dyes mainly in the form of azo compounds were present in reds.
The majority of the used paints had an organic binder in the form of acrylic resin. In some cases, paints based on polyester resin, polyvinyl acetate or a mixture of acrylic and phthalic resins were used.

5.3. What other research (apart from those indicated by the WP3 leader) have been helpful?
On one of the murals by Mikołaj Chylak, a piece of fabric was used as part of the composition. The condition of the submitted sample (presence and type of layers) prevented fiber identification in accordance with the recommended methodology. To identify the type of fibers, the sample was subjected to pre-treatment to allow fiber preparation. Then a preparation was made – a longitudinal view in glycerin, on the basis of which the material used was determined.

5.4. Information on the causes of deterioration of selected works of art.
Cracks and other plaster damage caused by the subsiding of wall foundations were noticed in all the murals.
The main factor damaging the murals are atmospheric factors, especially variable temperature and humidity (annual, daily and seasonal). Atmospheric precipitation is particularly important. Paint layers were washed out in many areas, thus affecting the aesthetics of the work. Moisture caused the development of mould and hence dark discolouration on the surface of many murals. In addition, moisture combined with heating from the sun (periodic humidification and drying of the object) is probably the cause of the white colour peeling off on many objects.

The paintings' resistance to external factors also results from technical and technological errors of their execution – the use of too much paint binder or the use of old (expired) paints in which the binder has precipitated and the use of organic pigments which change colour when exposed to light. These are the main causes of the peeling and powdering of the paint layer, numerous washes and colour changes. Important factors degrading the murals also include all subsequent interventions, for example resulting from the renovation of the building, such as the installation of a air conditioning or the replacement of gutters, the reconstruction of the street, the modernization of the space around the building (construction of new buildings). In addition, murals are very often covered by graffiti and stickers.
Poor conservation and restoration can greatly accelerate the degradation of murals. An example is the conservation of the Utz mural, where poor fixation of the paint layer has completely changed its character. Additionally, poor under-plaster injections and fillers were used. In addition, the entire mural has been repainted.
All murals are heavily covered with dirt due to air pollution. The murals are located near traffic routes and birds and other animals.

5.5. The most common causes of damage in the analysed objects (e.g. resulting from technical and technological errors, climatic conditions in the region, social factors).

- Poor technique and technology of execution
- Weather conditions:
    - Humidity factors (capillary moisture, water infiltration, rainwater)
    - Thermal factors (temperature fluctuations: annual, seasonal and daily)
    - Physico-chemical factors (air pollution)
- Biological factors (mould growth, birds)
- Subsequent interference
- Vandalism

5.6. Added value due to the European dimension of the project.

The project at this stage of its implementation allows to determine what techniques contemporary artists use to make murals and how they affect the durability of their works. Thanks to this, it will be possible to distinguish which binders and pigments are the most resistant to atmospheric factors, and thus to offer artists the most durable techniques of painting on facades. These studies resulted in closer cooperation between various specialists at the Faculty of Conservation and Restoration of Fine Arts at the Academy of Fine Arts in Warsaw – conservators from the NOVUM Laboratory for the Protection and Conservation of Modern and Contemporary Art, conservators and technologists from the Department of Conservation and Restoration of Wall Painting, and chemists from the Department of Specialist Research and Documentation Techniques. Activities carried out under the CAPUS program can to some extent contribute to the preservation of at least some murals in Warsaw.

5.7. Potential benefits of cooperation / division of competences between partners.

Comparison of the results of analytical tests and causes of damage sent by partners from different countries allows conclusions to be drawn about the durability of street art works. This database will also be a very important element in the implementation of the next stages of the project, e.g. WP4 and WP5, because it will be helpful in determining the appropriate methods and materials for the conservation of contemporary artworks exposed to external factors.

5.8. Derogation from the work plan.

None

5.9. Problems encountered and implemented or proposed solutions.

None

5.10. Specification of the main results (products and results) for artists, structures, sectors or systems that has generated your project so far. Description of impact on target groups (including participating institutions and interested parties). Suggestion (if possible) of qualitative and quantitative indicators.

Deliverable / results	Target groups / potential beneficiaries	Impact	Quantitative indicators	Qualitative indicators
Analytical characterization of the materials used and Degradation processes report	Partners	• Exchange of analytical protocols and methods used • Improved knowledge of other analytical techniques • Increase in knowledge on degradative processes as a result of the exchange of information with other partners	• Number of scientific papers in collaboration with consortium partners • Number of collaborative papers on degradation parterns	Internal survey on **collaborative publication**
Analytical characterization of the materials used and Degradation processes report	Researchers	• Increase knowledge on materials used by artist and methods • Increased knowledge on analytical methods and protocols • Increase in knowledge on degradative patterns and	• Number of scientific papers on urban art topic •	Interaction on the social media channels

		common factors for urban art		

6. Research Group 5: University of Split (Croatia) , Sisak Municipal Museum (Croatia), and Metris (Croatia)

NUMBER OF PARTNER:	P11, P13, P10
COUNTRY:	Croatia
LIST OF OBJECTS:	1. Milena Lah, *Galebovo krilo*, 1973 2. Sašo Stević, *Proces rada*, 1975 3. Milivoje Babović, *Skulptura V*, 1981 4. Josip Diminić, *Objekt I*, 1979 5. Milena Lah, *Forma*, 1973 6. Theo Amrein Kujundžić, *Naš život*, 1977 7. Jure Žaja, U *spomen Jurju Dalmatincu*, 1979 8. Josip Diminić, *Objekt II*, 1979 9. Peruško Bogdanić, *Bez jahača*, 1983 10. Josip Zeman, *Crne vizije I*, 1983 12. Dušan Subotić, *Reljef u prostoru*, 1981 13. Josip Zeman, *Crne vizije II*, 1983 14. Ivan Kožarić, *Antipodi*, 1972 15. Unknown artist, title and date uknown 16. Erik Lovko, *Stup-puzzle*, 1978 17. Petar Barišić, *Muškarac i žena*, 1979 18. Dubravka Sambolec, *Ritam II*, 1978 19. Zlatko Zlatić, *Proizvoljan oblik s tezom*, 1978 20. Slobodanka Stupar, *Molitvenik*, 1987 21. Dora Kovačević, *Zid*, 1985 22. Ante Kuduz, *Grad '85*, 1985 23. Branko Ružić, *Vrata*, 1984 24. Hamo Čavrk, *Forma I*, 1982 25. Ante Rašić, *Govornik*, 1984 26. Belizar Bahorić, *Visoki napo*n, 1982 27. Zlatko Zlatić, *Zgurić i obitelj*, 1978 28. Boško Atanacković, *Kompozicija I and II*, 1982 29. Zvonimir Kamenar, *Leptir*, 1982 30. Zvonimir Kamenar, *Imaginarni stroj*, 1982

	31. Ratko Petrić, *Čovjek-stroj*, 1975 32. Jure Žaja, *Glava bika*, 1979 33. Vera Fischer, *Cvijet*, 1980 34. Mila Kumbatović, *Fontana*, 1975 35. Ratko Petrić, *Užareni planet*, 1975 36. Andre Mohorovičić, *Ornament*, 1984 37. Branislav Milašinović, *Krajputaš*, 1984

6.1. Information on analytical tests carried out on selected objects, including details on sample preparation, instruments and experimental conditions used

Of the 38 sculptures that form the Sisak Steelworks Sculpture Park, samples of coatings and corrosion products were taken from 36 artworks.

The following methods were used to analysed the samples (their descriptions are provided by METRIS /items a – d / and UNITO /item e/):

a) Optical microscopy – analysis performed on sample or cross section using visible (VIS), ultraviolet (UV), polarized (POL) or infrared (IR) light depending on the characteristic of the observed sample. Observation and images taken from 50x to 1000x magnification. Equipment used: Optical microscopy Olympus BX51 and optical microscopy Carl Zeiss Image m2M.

b) SEM and SEM/EDS – analysis performed operating under low vacuum conditions for non-conductive samples (80 Pa) and under high vacuum for conductive samples. Images were recorded with Backscattered electrons detector (BSED) with spot from 3 to 5, working distance 10 mm, acceleration voltage from 20 to 30 kV. Equipment used: FEG Quanta 250 FEI. EDS microanalysis were performed on observed samples at acceleration voltage of 30 kV and working distance10 mm. Equipment used: Penta FET X-act detector Oxford Instruments. NOTE: The EDS microanalysis of the chemical composition by SEM is performed by analysing the chemical composition in a small sample segment and under a certain magnification, whereby the results are not quantitatively comparable, i.e. the measurements vary considerably from one point to another due to inhomogeneity of the tested samples, surface contamination, segregation of the elements and sensitivity of the method. The results of EDS analysis do not represent the chemical composition of the whole sample but the chemical composition of the examined point/field on the sample's surface.

c) FT-IR / micro FT-IR – FTIR: analysis performed using KBr pellets preparation (2 mg sample + 120 mg Kbr). Each spectrum is a result of 64 scans taken at resolution of 4 cm^{-1} in the range from 4000 to 400 cm^{-1}. Collected spectra were baseline corrected and when necessary smoothed according to Savitzky/Golay algorithm. Equipment used: FTIR spectrometer Tensor 27 Bruker. µFTIR: analysis performed on prepared cross section using Attenuated Total reflection objective (ATR) suitable of analysis on area of approximately 50 x 50 µm. The spectra are the results of 32 scans taken at resolution of 4 cm^{-1} in the range from 4000 to 600 cm^{-1}. Equipment used: FTIR microscope Hyperion 1000 Bruker and as source FTIR spectrometer Tensor 27 Bruker.

d) Microbiological analysis – Sterile scrapings and swab of taken samples were inoculated on two different growth media: Malt Extract Agar - MEA (Liofilchem S.r.l., Italy) and Czapek Dox Agar -

CzA (Liofilchem S.r.l., Italy) with addition of 0,005% chloramphenicol (Acros Organics, Thermo Fisher Scientific, Belgium) for bacterial growth inhibition. After 7-day incubation at 28 °C, mixed cultures formed and the single cell cultures were then isolated on separate growth media to form pure cultures. After 3 weeks, when pure cultures started to show their morphological features, microscopy analyses were performed in order to determine the genus of the fungi. In samples were algae or lichens were detected, optical microscopy was used (VIS light).

e) **Py-GC/MS** – For Py-GC/MS analyses, samples were derivatized with the Thermally Assisted Hydrolysis and Methylation method (THM) using tetramethylammonium hydroxide (TMAH) in aqueous solution at a concentration of 25% by weight (Sigma-Aldrich, Italy). A micro-furnace Multi-Shot Pyrolyzer EGA/Py-3030D (Frontier Lab, Japan) coupled to a GC/MS system was used. Samples were placed into a stainless steel cup, added with 5 µL of TMAH solution and inserted into the micro-furnace. The pyrolysis temperature was set at 500 °C for 0.2 min, the interface temperature was 300 °C and the temperature of the GC injector was kept at 280 °C. The GC was a 6890N Network GC System (Agilent Technologies, USA) gas chromatograph with a methylphenyl-polysiloxane cross-linked 5% phenyl methyl silicone (30 m, 0.25 mm i.d., 0.25 µm film thickness) capillary column. The carrier gas was helium (1.0 mL/min) and split ratio was 1/20 of the total flow. The mass spectrometer coupled to the GC apparatus was a 5973 Network Mass Selective Detector (Agilent Technologies, USA). Mass spectra were recorded under electron impact at 70 eV, scan range 40-600 m/z. The interface was kept at 280 °C, ion source at 230 °C and quadrupole mass analyzer at 150 °C. All instruments were controlled by Enhanced Chem Station (ver. 9.00.00.38) software. The mass spectra assignment was done with the Wiley 138 and NIST1992 libraries and by comparison with literature data.

6.2. What characteristic features in the technique have been found in analytical studies (dominant groups of materials and techniques)?

The results of analytical research indicate that the main material of which the sculptures are made is steel, in some cases zinc plated steel, and that most of the sculptures are painted with alkyd-based paints. In several sculptures other materials have been identified such as copper (or it's alloys), and polymer materials (plastics).

6.3. What other studies (apart from those indicated by the WP3 leader) have been helpful?

It was very important to compare and reconcile the results of analytical analysis with the results of *in situ* visual inspection. Analytical research has in some cases led to a discovery of traces of paint or zinc plating, which had became almost invisible to the naked eye.

6.4. Information on the causes of deterioration of selected works of art

The two main causes of deterioration of the sculptures are: (1) environmental (outdoor environment, high moisture, moisture retention, pollution etc.), and (2) lack of maintenance from the time sculptures were created (1970s and 1980s) until present, and vandalism.

6.5. The most common causes of deterioration in the analyzed objects (ex. resulting from technical and technological errors in the execution of the object, climatic conditions in a given region, social factors)

It can generally be said that the main cause of deterioration is lack of maintenance. The paints that were applied to the sculptures were never intended to last 30 to 40 years, so it is logical that with time, and because of exposure to a harsh outdoor environment, they would deteriorate to the point where they no longer provide adequate protection to the metal below, nor the intended visual effects. Once the coating was damaged, corrosive processes started damaging the construction of sculptures. This negligence could be related (this isn just a speculation) to the socio-economic and political changes that the town of Sisak and this part of Europe went trough in the 1990s.

As for the environmental conditions, it can be said that Sisak has moist climate (the city is surrounded with three rivers). Also, pollution levels were high in the past, even extreme during the time when the industry was active (oil refinery, steelworks etc.).

6.6. Added value due to the European dimension of the project

Without the EU funding it would not have been possible to carry out such an extensive analytical research, which resulted in a better understanding of the material build-up of the 36 sculptures from the Sisak Steelworks Sculpture Park and of the causes of their deterioration. The knowledge acquired will ensure that these artworks are preserved for future generations.
Being a part of a European project team enabled us to hear opinions of different experts on production technologies and techniques, and the state of preservation of public art, and to compare experiences, expertise and equipment (UNITO students participated in the sampling of the sculptures, and some analysis were conducted at UNITO).

6.7. Potential benefits of cooperation / division of competences between partners

Sisak Municipal Museum conducted the sampling, with some help from UNITO students who participated in the 8th Conservation-Restoration Workshop in the Sisak Steelworks Sculpture Park. Sisak Municipal Museum also produced a catalogue of the samples taken from the sculptures (*Catalogue of Samples Taken from the Sculptures from Sculpture Park of Sisak Ironworks, Sisak, Croatia*). Based on that document, the University of Split produced an extensive report about the samples (*Sisak Steelworks Sculpture Park, Croatia: Description of the samples delivered to METRIS for analysis*).
Metris was in charge of the analytical work. 125 samples in total were analysed, with 1 – 3 analytical techniques used on each sample. Metris produced an elaborate report for each of the 36 sculptures from which samples were taken. These reports are extremely important as they provide foundation for the future conservation-restoration of the sculptures. University of Split provided guidelines for the production of these reports, as well as a detailed feedback on the results of the analyses. Finally, Sisak Municipal Museum carried out in situ stratigraphic analysis on several artworks to confirm the results of the analysis (there were discrepancies between the results of the analyses and the result of visual inspection of the artworks).
Sisak Municipal Museum filled out the forms for the reporting of the results of analytical research in WP3, and the forms related to the degradation of the 38 sculptures that form the Sisak Steelworks Sculpture Park. University of Split provided more detailed reports on the degradation of five sculptures from the collection, and also amended the text of the final report.
Benefits of the cooperation are clearly visible from the results – none of the partners involved could have compiled the data on their own. The cooperation and the division of competences enabled us to gather a great amount of information on each sculpture, but also on the collection as a whole.

6.8. Derogation from the work plan

Because of organisational and legal issues, the start and the completion of WP3 were late, but given the number of the artworks included, and the amount and the quality of data produced, it can be concluded that the benefits outweighed the problems.

6.9. Problems encountered and implemented or proposed solutions

For the Croatian research team the biggest delay in WP3 was caused by the inability of the partners to agree on three issues: (1) who will draw up a sampling strategy, (2) who will obtain the permission from the Ministry of Culture of the Republic of Croatia to perform the sampling, and (3) who will perform sampling.
University of Split produced a Sampling Plan Template, mediated the dispute between partners through emails, organized a meeting for the partners involved, and complied the minutes of the said meeting (a 10-page document, which had to be translated to English). Finally, the project coordinator was asked to help define the roles and responsibilities of Croatian partners, and to propose allotment of their assignments within WP3. This was formalized through a legal document prepared by the UNITO. Sisak Municipal Museum was tasked with the sampling, and the funds for this work were transferred to them from University of Split and Metris.
The increased workload of Sisak Municipal Museum resulted in a significant delay in the completion of the WP3. In addition to that, Metris needed time to carry out complex analysis of a vast number of samples (125 samples, with 1 – 3 analytical techniques per sample), and to produce an elaborate report for each of the 36 sculptures, which was requested by the University of Split. The University of Split needed time to go through each report and to provide feedback.

6.10. A distinction of the main results (products and results) for artists, structures, sectors or systems that has generated your project so far. Description of receipts for target groups (including participating institutions and stakeholders). Proposal (if possible) of qualitative and quantitative indicators.

Deliverable / results	Target groups / potential beneficiaries	Impact	Quantitative indicators	Qualitative indicators
Analytical report Degradative process report	Researchers/Conservators-restorers	- better understanding of the deterioration outdoor metal sculptures - in-depth knowledge on the materials of the Sisak sculptures, and on their production technology		

		and techniques; excellent foundation for future conservation-restoration treatments		
Analytical report Degradative process report	Students	- learning tool for conservation-restoration students - UNITO students acquired practical knowledge in sampling		
Analytical report Degradative process report	Stakeholders (Municipalities, Ministry of Culture of the Republic of Croatia or its Monuments Care Offices etc.) and organisations/institutions who take care of outdoor sculptures	- better understanding of the problems posed by the lack of regular maintenance - better understanding of the complexity of conservation-restoration issues - raised awareness of public artworks - possibilities of funding projects related to this topic		
Analytical report Degradative process report	Wider public	- increased visibility of the artworks -better understanding of the conservation-		

		restoration issues - better understanding of the funding needed to preserve public artworks		

7. Research Group 6: Cologne Institute of Conservation Sciences (Germany) and Schmincke (Germany)

NUMBER OF PARTNER:	CICS, Schmincke
COUNTRY:	Germany
LIST OF OBJECTS:	1 (Uralte Form)

7.1. Information on analytical tests carried out on selected objects

Due to the previous documentation of the artist's techniques and the measures performed at a later point in time we already had information about all the materials used. To avoid an intervention in the substance of the object we decided to not carry out irreversible physical sampling, but to work with the data gained macroscopically, as well as with the documented data.

7.2. What characteristic features in the technique have been found in analytical studies (dominant groups of materials and techniques)?

The object was casted in bronze. The Bronze is physically intact. It was artificially patinated and waxed. At a later point in time scratches in the patination were filled with Parisian oxide and the entire sculpture was rubbed with Tecero wax 30222 and 30410 at a ratio of 1 to 1. Currently the patination and the wax coating are damaged.

7.3. What other research (apart from those indicated by the WP3 leader) have been helpful?

An open source offering climate data collected between 1982 and 2012 showed large amounts of rainfall in Cologne during the years since the sculpture was mounted.
www.climate-data.org

7.4. Information on the causes of deterioration of selected works of art.

A common cause of damage is vandalism because of the free public access. Mostly graffitis, adhesive labels, scratches with sharp objects and marks from opening bottles with crown caps.
The Climate in Cologne, especially the rainfall, is a problem for the protective wax coatings. In average the amount of rainfall per year is 774 mm. This is the reason why the protective coating wax on outdoor sculptures in Cologne is not as resistant as it is meant to be.

7.5. The most common causes of damage in the analysed objects (e.g. resulting from technical and technological errors, climatic conditions in the region, social factors).

At first sight you can see an optical alteration which is expressed in the form of chromatic alteration and the change of colour in some areas due to an irregularly performed artificial patination and due to an unprofessional cleaning in the lower parts of the sculpture. In this process patina in the lower parts of the object was removed.

Since the sculpture is located in a public park near a sandy footpath dust and soiling in form of earth and sand settled on the sculpture.
Vandalism in form of graffitis are other additions of substances found on the sculpture.
Besides there is a loss of material in form of abrasion, scratches due to sharp objects and marks from opening bottles with crown caps.
Since the object is located in a public park dog's urine is also one cause of the damages.

7.6. Added value due to the European dimension of the project.

Since we know that wax as a protective coating must be maintained and renewed yearly and it's no prevention or protection against graffiti or soiling, the testing of long-lasting surface coatings with more resistance is an important step for the preventive conservation of waxed outdoor sculptures.

7.7. Potential benefits of cooperation / division of competences between partners.

The aim to find a coating which is more protective and long lasting than wax benefits the city of Cologne. The cooperation with companies operating in the field of varnishes benefits of mutual experiences and creates a connection between theory and practice.

7.8. Derogation from the work plan.

Specifications on the main results concerning tests of a wax replacement are performed with the students in the summer term 2019.

7.9. Problems encountered and implemented or proposed solutions.

Since we didn't have the means to control the environmental parameters around the object, we rely on an open access webpage with climate data.

7.10. Specification of the main results (products and results) for artists, structures, sectors or systems that has generated your project so far. Description of impact on target groups (including participating institutions and interested parties). Suggestion (if possible) of qualitative and quantitative indicators.

The main result was that wax coatings are not practical when it comes to a long-term protection of outdoor sculptures. Since there are less free funds to maintain those sculptures at least twice a year and to clean and refresh those wax coating the research interest applies to how those waxes could be replaced. Results will be compiled by the students joining the seminar in the summer term 2019.

Deliverable / results	Target groups / potential beneficiaries	Impact	Quantitative indicators	Qualitative indicators
Degradation processes report	conservators	better understanding of the problems in conservation of		

		the outdoor metal sculpture		