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Synthetic white pigments (white titanium and white zinc) in different binding media. Influence of environmental agents

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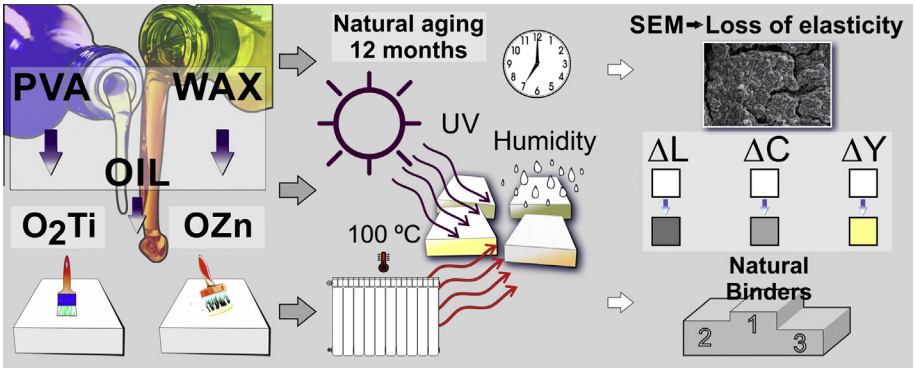
HIGHLIGHTS

- Preparations zinc oxide pigment is more stable than titanium oxide pigment.
- The most important impact of exposure to environmental agents is infrared radiation.
- Non destructive techniques are critical to the study of effects in the pigments.
- The techniques proved more affected with natural binders than with synthetic binders.

GRAPHICAL ABSTRACT



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ABSTRACT

This work concerns the behaviour of white pigments of white titanium and white zinc in different media both of natural and synthetic binders. In addition, a study was made of the impact that time, high-energy UV radiation, heating by infrared radiation, or saturation processes of relative humidity exert on stability and chromaticity of the samples. The composition of pigments and binders as well as the time course of their samples were studied by X-ray diffraction, mass spectrometry, electron microscopy, and instrumental colour measurement. The effect of the aging, UV, and infrared exposure together with moisture saturation were found to result in losses in elasticity and cracking of the film generated by the binder, the latter two factors causing the most severe losses. The greatest variations were detected in the colorimetric study, reflecting the utility of instrumental colour measurements for these types of studies. The chromatic variations detected consist fundamentally of loss in luminosity (ΔL) and chroma (ΔC) as well as a slight yellowing tendency. In general, the samples based on natural binders were more affected that those based on synthetic products.

1. Introduction

The use of pigments in different applications within the field of Materials Engineering, and intervention in architectonic heritage, is necessary in many cases to achieve a certain exterior appearance [1], as well as to undertake actions requiring matching visual and aesthetic characteristics [2], but also to improve, for example

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photovoltaic light-capturing efficiency [3], the hiding power of ceramic enamels in construction [4,5], and acrylic photoprotective coatings [6], while lowering resource consumption [7,8], cost, and environmental impact [4,9,10].

Specifically, the pigments titanium oxide and zinc oxide are frequently used in different materials and media that come from natural or artificial raw materials [11–13] with a broad range of compositions and various proportions of pigments together with different media needed for their application and composition. Many factors during the production of these mixtures affect the quality and the technical features, such as the type of pigment, the binder and the composition (in the process of manufacturing and its applications).

It is fundamental to know the performance of these pigments in different media and guarantee greater suitability and durability of their effectiveness as well as their characteristics and finishes [14,15], as these are determinant in architectonic materials and designs as well as in restoration [16]. Also of special importance is the need to ascertain the effect both the aging as well as of the exposure to environmental agents, UV rays, heating, and humidity.

Technically, many studies and manufacturers have investigated the features of the pigments, the characteristics of organic as well as inorganic pigments, which have focused primarily on the production processes and their formulation, the most suitable application methods that preserve the environment, resource savings, and product finish. However, their performance and effectiveness differ depending on the media and exposure conditions. Therefore these materials need to be studied by aging tests to quantify their technical properties.

In the present work, we focus on one of the applications mentioned, specifically the one related to the field of restoration of cultural heritage and architectonic interventions. In this sense, we examine the intended use for the pigments studied, the suitability of their physical characteristics, and the features of the materials, and we investigate their colorimetric implications.

The function of pigments is fundamental in the preparation of the chromatic palette as well as throughout the execution of artwork. Today, white pigments are used in the field of art, decoration, building, industry, serving as bases, preparation, coatings, and protections on all types of surfaces, this requiring resistance, durability, and stability. In addition to their use in white colour, these pigments are essential in mixtures to achieve specific tones, corrections, glazes, carnation, etc. Thus, these are essential components in any pictorial technique and therefore their nature and performance need to be ascertained not only to broaden knowledge or analyse diverse pictorial media, but also to control possible restoration/conservation techniques. In this respect, it is important to understand their reaction with the passage of time as well as the effect of environmental agents such as the exposure to given levels of ultraviolet radiation, rises in temperature, or variations in relative humidity, as demonstrated elsewhere [17–27]. The general behaviour of pigments has been established in some pictorial media according to the physical–chemical features of the material. Recent works have applied instrumental colour study in the field of monumental heritage, as in monitoring stone restoration [28,29], as well as in analysing the performance of pigments treated with restoration products [30–36].

To determine the main factors that influence the characteristics of the material, we used different experimental techniques. The performance of the pigments O_2Ti and OZn were characterized in various organic and inorganic binders, by X-ray diffraction (XRD), scanning electron microscopy (SEM), and inductively coupled plasma mass spectrometry (ICP-MS), in an effort to recognize the structural changes and development of new mineral phases, while chromatic performance was assessed by diffuse spectral-reflectance measurements.

Table 1
Main properties of the white pigments used in this study, in accordance with [40–43]. The temperature and pressure of the data were 20 °C and 1 atm.

Pigment colour	Colour index name/number	Permanency 1 (excellent) 5(poor)	Transparency/Opacity 1 (less opaque) 8 (most opaque)	Chemical description crystal system	Lightfastness 1(excellent) 5 (poor)	Tint strength %	Gloss average	Refraction index	Density g/cm^3
Titanium white	PW-4/77891	1	6	Anatase synthetic O_2Ti Tetragonal	1	42.25	43.15	2.72	4.06
Zinc white	PW-6/77947	1	3	Zincite synthetic OZn Hexagonal	1	27.20	58.87	2.08	5.61