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Editorial

Heritage Conservation and Restoration: Surface Characterization, Cleaning and Treatments

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Conservation is not the same thing as restoration. Conservation attempts to preserve an artifact in its current condition. By contrast, the restoration process strives to return an artifact back to its original condition. In other words, conservation lets a viewer see the damage that naturally and inevitably occurs as a result of the aging of the artifact over the course of its life, whereas restoration lets a viewer see what the artifact originally looked like. Why are the conservation and restoration of cultural heritage items relevant or even necessary? Heritage items (historical buildings, artifacts, sculptures, paintings, and books) are symbols of our cultural patrimony, which are subject to aging and degradation processes due to several factors (physical, chemical, biological, and air pollution) [1–4] and, therefore, need to be properly preserved for the benefit of future generations. Generally, decay processes of historical materials related to physical and chemical phenomena, mainly occur in the presence of water, which is one of the most deteriorating factors, especially for porous materials (paper, wood, and stone). Highly porous materials often undergo faster degradation, as water and other decay agents carried by water may easily penetrate below their surface through their wide and highly accessible pores [1,5–7]. For instance, history books and wood artifacts may undergo drastic damage due to this phenomenon. In fact, due to the hydrophilic nature of their components (cellulose and hemicellulose), they can easily adsorb water (both as vapor and liquid), establishing an equilibrium with the air moisture [8]. The presence of water mainly promotes hydrolytic reactions and biodegradation processes (e.g., bacteria, fungi, and xylophages), particularly when the moisture content of those materials exceeds the fiber saturation point [8]. Besides water, environmental agents (e.g., air pollution, solar radiation, and temperature variations) and microorganism colonization are frequently related to the harmful degradation of cultural heritage items [7–10]. For instance, building materials undergo weathering due to different processes (freezing–thawing cycles, salt crystallization, acid rain, and interactions with atmospheric pollutants such as SO_2), when exposed to outdoor conditions, which can produce a variety of types of damage to the original stone substrates, such as surface erosion, exfoliation, loss of material, and, in the worst cases, disaggregation [4,11,12]. Absorption of solar light, particularly of the ultraviolet (UV) component, is responsible for the photodegradation of paper and wood materials owing to different photolytic and/or photo-oxidative reactions [13,14]. As a consequence, these kinds of materials undergo different decay processes when exposed to solar light, ranging from changes in their esthetic appearance to a severe decrease in their mechanical properties [8,15].

Thus, the conservation and restoration of cultural heritage materials have become a necessity in many countries. In addition to their intrinsic value, effective conservation and maintenance not only help in preserving and safeguarding resources, but also in revitalizing local economies and in bringing about a sense of identity, pride, and belonging to residents. Hence, in past decades, scientists have focused their research on discovering appropriate materials and procedures for conservation and restoration purposes.

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The removal of any undesired matter (e.g., dust, aged coatings, deposits of pollutants, graffiti, and dirt) is one of the most important and delicate operations that affects the different ways (potentially invasive, aggressive, and completely irreversible) the original material should be approached, and occurs before any conservation or restoration process begins [5,16–18]. This is an essential approach because it helps to remove foreign matter which could promote the degradation of the heritage materials as well as cause changes to their original appearance.

If the cleaning intervention is not correctly performed, it may irreversibly damage the original substrate of the considered heritage items. Therefore, there are many conditions to control when selecting the appropriate cleaning agent. For instance, when the removal of undesired materials involves a water-sensible substrate, no cleaning procedures involving aqueous solutions can be carried out, making it a more challenging task than when using other substrates [17]. Hence, high-performing cleaning systems, which are able to perform controlled and selective cleaning actions, are highly desired [16]. Traditionally, several organic solvents have been used to dissolve or swell aged polymers, varnishes, and other unwanted materials, whose removal from substrate surfaces can also accomplished through mechanical action [17,19,20]. However, this method has declined in use due to several drawbacks: uncontrolled penetration of the organic solvents into the substrates, the solvents reacting with and damaging the original materials, poor selectivity, residues left behind, and safety problems (for the environment as well as for users) [16,17]. Thus, several other methods have been introduced to this field, but have produced unsatisfactory results. For instance, the cleaning methods based on cellulose pulp poultice and gels (the inclusion of the solvents within a cellulose matrix and a polymer network, respectively) also showed some unsatisfactory results, particularly when the residual gel or cellulose (or other components, e.g., surfactants) were used on the treated surface [16,21,22]. Therefore, there is high demand to develop smart cleaning tools that can overcome all these limitations. In recent decades, conservation scientists have investigated alternative products such as physical and chemical gel materials based on natural (e.g., xanthan gum, gellan gum, agar, chitosan, sodium alginate, and glucomannan-borax) and artificial polymers (e.g., polyacrylamide and p(HEMA)/PVP)), as well as conducted research into modifying them to act as a transporting medium for different aqueous cleaning systems (micro-emulsions, mixed solvent systems, micellar solutions, and nanoemulsions), which could be correctly used to clean heritage items and overcome the above-mentioned limitations [16,23–26].

After successfully cleaning the undesired materials from the heritage items, further steps are required for the conservation/restoration process. As mentioned previously, the process completely depends on the substrate and its porosity. Traditionally, using different kinds of materials for the surface treatment has been the common method of consolidation and protection, especially in the case of wood and stone artifacts [7,27–29]. A variety of protecting and consolidating products, based on both organic and inorganic materials, have been developed in recent decades, but their uses were often limited due to different adverse phenomena. For instance, synthetic polymers generally show poor durability and insufficient compatibility, as well as significantly affect the properties of the original substrate. On the other hand, inorganic consolidants (e.g., $Ca(OH)_2$, $Ba(OH)_2$, and $(NH_4)_2C_2O_4$) show good compatibility and good durability properties, but, at the same time, they are characterized by an insufficient penetration depth and often induce surface whitening and poor strengthening of the substrates [4,30,31]. The use of the well-known consolidant tetraethoxysilane (TEOS) also depends on the substrate and has several limitations when applied to carbonate stones [4]. In recent decades, the use of nanomaterials in all fields has been a successful development, providing new materials, concepts, and advantages to the research areas concerning conservation/restoration. For instance, different inorganic nanomaterials have been studied as active components for the conservation of stone and wood artifacts [32–34]. For instance, Baglioni et al., reported that alcoholic dispersion of calcium hydroxide nanoparticles is highly compatible with carbonate-based materials, such as in wall paintings and calcareous stone [32]. The dispersion was commercialized as Nanorestore Plus®, which is a good alternative to the traditional consolidation products [35]. Moreover, other alkaline hydroxides ($Sr(OH)_2$, $Ba(OH)_2$, and $Mg(OH)_2$), silica nanoparticles, and nano-hydroxyapatite (the in situ reaction of calcium hydroxide nanoparticles with diammonium hydrogen phosphate) have been also tested as consolidation agents for different kind of porous stones [1,4,32,36–39]. Meanwhile, conservation scientists have a great interest in developing multifunctional products that are able to provide surface protection, consolidation, and self-cleaning efficiency when applied to the heritage materials. For example, Crupi et al., reported the self-cleaning efficiency of a TiO_2–SiO_2–PDMS coating [40]; Kapridaki et al., analyzed different types of coatings (a SiO_2-crystalline TiO_2 nanocomposite coating and TEOS-nanocalcium oxalate consolidant) for the same purposes [41,42]; La Russa et al., studied nano-TiO_2 coatings with different binder materials [43]; Ag-TiO_2/PDMS and Gd-doped TiO_2/PDMS nanocomposites were analyzed by Ben Chobba et al. [44–47]; and Weththimuni et al., examined a nanocomposite coating based on ZrO_2-doped-ZnO-PDMS as a self-cleaning, multifunctional, and durable coating [48–50]. Nanomaterials were also used in chemical modification, impregnation, and to improve the properties of natural coatings (e.g., shellac). For instance, Cristea et al., examined the improvement of wood coatings by using zinc oxide (ZnO), silica (SiO_2), and titanium dioxide (TiO_2) nanoparticles [51], whereas Weththimuni et al., studied the enhancement of properties displayed by traditional shellac varnish by introducing inorganic nanoparticles (e.g., ZnO, SiO_2, ZrO_2, and montmorillonite) as well as functionalized nanoparticles [52,53]. The same group also reported the enhancement of wood resistance to decay induced by ZnO nanorod-based treatments [8]. Although numerous new materials and methods have been developed over the past decade, conservation/restoration efficiency still depends on several factors, including the nature of the substrate, porosity, the chemical composition of the original material, decay phenomena happening on the original heritage item, and the location and conservation conditions of original artifacts. Hence, all products and methods must always be used with some precaution and in a controlled way.

Therefore, research scientists are still focusing their research to discover more appropriate new materials and their applications to conserve and restore our heritage items for future generations. With this goal in mind, we are assembling a Special Issue of *Coatings* with the aim of encouraging researchers to publish novel studies this topic by providing them with a platform. Subtopics may include (but are not limited to): surface characterization methods, new tools for characterization purposes, analyses of decay processes, new materials and methods for surface cleaning, new materials and methods (novel treatments) for conservation, novel approaches to restoration, and durability assessments. In this Special Issue, original research articles and reviews are welcome.

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